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A Meaningful U.S. Cap-and-Trade System to Address Climate Change

Robert N. Stavins
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CCMP – Climate Change Modelling and Policy

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A Meaningful U.S. Cap-and-Trade System to Address Climate Change

Summary

There is growing impetus for a domestic U.S. climate policy that can provide meaningful reductions in emissions of CO₂ and other greenhouse gases. In this article, I propose and analyze a scientifically sound, economically rational, and politically feasible approach for the United States to reduce its contributions to the increase in atmospheric concentrations of greenhouse gases. The proposal features an up-stream, economy-wide CO₂ cap-and-trade system which implements a gradual trajectory of emissions reductions over time, and includes mechanisms to reduce cost uncertainty. I compare the proposed system with frequently discussed alternatives. In addition, I describe common objections to a cap-and-trade approach to the problem, and provide responses to these objections.

Keywords: Cap-and-Trade System, Carbon Dioxide, Greenhouse Gas Emissions, Global Climate Change, Carbon Taxes

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A MEANINGFUL U.S. CAP-AND-TRADE SYSTEM TO ADDRESS CLIMATE CHANGE

Robert N. Stavins*

1. INTRODUCTION

It is increasingly clear that anthropogenic emissions of greenhouse gases are likely to change the earth's climate in ways that many people will regret. Two trace constituents of the atmosphere, carbon dioxide (CO₂) and water vapor, create a thermal blanket for the planet much the way glass on a greenhouse traps the sun's energy within. It is a good thing, too: without greenhouse warming, the planet would be far too cold to be livable. But the balance between too much and too little greenhouse effect is remarkably delicate. Massive quantities of CO₂ are produced from the combustion of fossil fuels — coal, petroleum, and natural gas — and deforestation. Meanwhile, the direct warming effects of CO₂ and other greenhouse gases — methane, nitrous oxide, and halocarbons — are indirectly amplified because the warming increases the evaporation of water, which thereby increases atmospheric water vapor concentrations (Intergovernmental Panel on Climate Change 2007a).

Global-average surface temperatures have risen by about 1.25 degrees Fahrenheit over the past 150 years, with most of the increase occurring since 1970, but the most important consequences of greenhouse gas concentrations are likely to be changes in patterns of precipitation and runoff, the melting of glaciers and sea ice, increases in sea level, and changes in storm frequency and intensity (Intergovernmental Panel on Climate Change 2007b). This is why it is important to view the problem as global climate change, rather than global warming.

Greenhouse gases uniformly mix in the atmosphere, and hence emissions in one country affect the climate in every other. Hence, the fundamental logic of a global pact on emissions, such as the one hammered out in Kyoto, Japan, in December, 1997. Many analysts — particularly economists — have been highly critical of the Kyoto Protocol, noting that because of specific deficiencies it will be ineffective for the problem and relatively costly for the little it accomplishes (Aldy, Barrett, and Stavins 2003). Others have been more supportive by noting that it is essentially the “only game in town.” But both sides agree that whether that first step was good or bad, a second step is required. Indeed, as some nations prepare for the Kyoto Protocol's first commitment period

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(2008-2012), the international policy community as a whole has begun to search for a better global policy architecture for the second commitment period (Aldy and Stavins 2007).

In the meantime, the impetus for a meaningful U.S. climate policy is growing. Scientific evidence has increased (Intergovernmental Panel on Climate Change 2007a, b), public concern has been magnified, and many people perceive what they believe to be evidence of climate change in progress. Such concern is reinforced by the aggressive positions of key advocacy groups, reflected in greatly heightened attention by the news media. The overall result is that a large and growing share of the U.S. population now believes that government action is warranted (Bannon *et al.* 2007).

In the absence of Federal policy, regions, states, and even cities have moved forward with their own proposals for policies intended to reduce the emissions of CO₂ and other greenhouse gases.¹ Partly in response to fears of a fractured set of regional policies, an increasing number of large corporations, sometimes acting individually, and at other times in coalitions — together with environmental advocacy groups — have announced their support for serious national action.² Building upon this is the April 2007 U.S. Supreme Court decision that the Administration has the legislative authority to regulate CO₂ emissions,³ as well as ongoing pressure from our European allies and other nations that the United States re-establish its international credibility in this realm by enacting a meaningful domestic climate policy.

Thus, momentum is clearly building toward the enactment of a domestic climate change policy. But there should be no mistake about it — meaningful action to address global climate change will be costly. This is a key “inconvenient truth” that must be recognized when policymakers construct and evaluate proposals, because a policy’s specific design will greatly affect its ability to achieve its environmental goals, its costs, and the distribution of those costs. Even a well-designed policy will ultimately impose annual costs on the order of tens (and perhaps hundreds) of billions of dollars.⁴ That does not mean that action should not be taken, but it does suggest that the costs should be recognized if effective and sensible policies are to be designed and implemented.

¹ Ten northeast states have developed a cap-and-trade program under their Regional Greenhouse Gas Initiative, and California’s Assembly Bill 32 may do likewise for the nation’s largest state. See section 1.3.2 and the Appendix.

² The U.S. Climate Action Partnership issued “a call for action” in January, 2007, recommending “the prompt enactment of national legislation in the United States to slow, stop, and reverse the growth of greenhouse gas (GHG) emissions over the shortest time reasonably achievable” (2007, p. 2). The partnership consists of some of the largest U.S. companies with a stake in climate policy from a diverse set of sectors: electricity (Duke Energy, Exelon, FPL Group, NRG Energy, PG&E Corporation, and PNM Resources); oil and gas (BP, ConocoPhillips, and Shell); motor vehicles (Caterpillar, Daimler-Chrysler, Ford, GM, and John Deere); aluminum (Alcan and Alcoa); chemicals (DuPont and Dow); insurance (AIG and Marsh); mining (Rio Tinto); and manufacturing (Boston Scientific, General Electric, Johnson & Johnson, Pepsico, Siemens, and Xerox). The coalition is rounded out by six environmental organizations: Environmental Defense, National Wildlife Federation, Natural Resources Defense Council, Nature Conservancy, Pew Center on Global Climate Change, and World Resources Institute.

³ Massachusetts *et al.* v. Environmental Protection Agency *et al.*, No. 05-1120, argued November 29, 2006, decided April 2, 2007.

⁴ By comparison, the cost (in 2001 dollars) of all U.S. Environmental Protection Agency regulations enacted from 1996 to 2006 was estimated at \$25 to \$28 billion annually (U.S. Office of Management and Budget 2007), and a number of historical studies have estimated the annual cost of all environmental regulation in the United States to be on the order of 1 to 2 percent GDP (Jaffe, Portney, Peterson, and Stavins 1995; Morgenstern, Pizer, and Shih 2001).

It is important to identify an appropriate policy instrument at the outset in order to avoid creating constituencies that will later resist change (Repetto 2007). Once a policy architecture is put in place, it can be exceptionally difficult to make a change. Thus, the stakes associated with policy design are significant. A poorly designed policy could impose unnecessarily high costs or unintended distributional consequences while providing little public benefit, and could potentially detract from the development of and commitment to a more effective, long-run policy.

1.1 Alternative Policy Instruments to Achieve Greenhouse Gas Emission Reductions

There is general consensus among economists and policy analysts that a market-based policy instrument targeting CO₂ emissions — and potentially some non-CO₂ greenhouse gas (GHG) emissions — should be a central element of any domestic climate policy.⁵ While there are tradeoffs between two alternative market-based instruments — a cap-and-trade system and a carbon tax — the best approach for the short to medium term in the United States is a cap-and-trade system.

The environmental integrity of a domestic cap-and-trade system for climate change can be maximized and its costs and risks minimized by: targeting all fossil-fuel-related CO₂ emissions through an upstream, economy-wide cap; setting a trajectory of caps over time that begin modestly and gradually become more stringent, establishing a long-run price signal to encourage investment; adopting mechanisms to protect against cost uncertainty; and including linkages with the climate policy actions of other countries. Importantly, by providing the option to mitigate economic impacts through the distribution of emission allowances, this approach can establish consensus for a policy that achieves meaningful emission reductions. It is for these reasons and others that cap-and-trade systems have been used increasingly in the United States to address an array of environmental problems.⁶

Cap-and-trade should not be confused with emission reduction credit or credit-based programs, in which those reporting emission reductions generate credits that others are required to buy or may buy to offset obligations under some other policy. Credit-based programs have often been considered as a means of encouraging emission reductions from activities outside the scope of a cap-and-trade system, emissions tax, or standards-based policy. But an important limitation of credit-based programs is that they typically require measurement — or, more likely, estimation — of emission *reductions*, which, unlike emissions themselves, cannot be directly observed. Hence, these programs generally face difficulties establishing that reported reductions would not have occurred absent the credit-based program. This is the so-called baseline or “additionality” problem: making a comparison with an unobserved and fundamentally unobservable hypothetical (what would have happened had the credit *not* been generated). This problem reduces environmental effectiveness if credits generated by activities that would have occurred even without the credit program are used to offset real emission reduction obligations. Despite these obstacles, cost savings still may be achieved through *selective* use of credit-based programs targeting certain activities, as I later discuss, such as various types of carbon-saving land-management that otherwise would be too costly or infeasible to integrate into a cap-and-trade system.

⁵ This is reflected in international assessments of national policy instruments, as well (Intergovernmental Panel on Climate Change 2007c).

⁶ Domestic cap-and-trade systems have been used to phase out the use of lead in gasoline, limit SO₂ and NO_x emissions, and phase out CFCs (Stavins 2003). See section 1.3.1 and the Appendix.

The alternative to a cap-and-trade system most frequently considered by policymakers is the use of command-and-control standards, such as energy efficiency or emission performance standards, which require firms and consumers to take particular actions that directly or indirectly reduce emissions. The costs of standards are often largely invisible except to those directly affected by them, but standards would impose significantly greater economic impacts than market-based policies, because standards offer firms and consumers far less flexibility regarding how emission reductions are achieved, and they could not target many low-cost emission reduction opportunities. Moreover, the effectiveness of standards in achieving nationwide emission targets is highly uncertain, in part because they could only cover a fraction of nationwide emissions, leaving many sources of emissions unregulated. In contrast, market-based policies can cover all sources of fossil-fuel-related CO₂ emissions, and unlike other alternatives, a cap-and-trade system can essentially guarantee achievement of emission targets for sources under the cap.

1.2 *The Focus on Cap-and-Trade*

A cap-and-trade system caps the aggregate emissions of a group of regulated sources by creating a limited number of tradable emission allowances and requiring firms to surrender a quantity of allowances equal to their emissions.⁷ The government may initially distribute allowances for free or sell them through an auction. Regardless of how allowances are initially distributed, the need to surrender valuable allowances to cover any emissions and the opportunity to trade those allowances creates a price signal for emissions. In turn, this price signal provides firms with an incentive to reduce their emissions that influences all of their production and investment decisions. Because allowances are tradable, the ultimate distribution of emission reduction efforts necessary to meet the overall emissions cap is determined by market forces. Thus, the cap is placed only on aggregate emissions, and imposes no particular limits on emissions from any given firm or source. A firm can emit as much as it chooses to, as long as it obtains sufficient allowances to cover its emissions. Overall, however, a cap-and-trade system provides certainty regarding emissions from regulated sources, because *aggregate* emissions from all regulated entities cannot exceed the total number of allowances.

A well-designed cap-and-trade system will minimize the costs of achieving any given emissions target.⁸ While firms have flexibility regarding precisely how much they emit, because they have to surrender an allowance for each ton of their emissions they will undertake all emission reductions that are less costly than the market price of an allowance. Through trading, this allowance price adjusts until emissions are brought down to the level of the cap. Firms' ability to trade emission allowances creates a market in which allowances migrate toward their highest-valued use, covering those emissions that are the most costly to reduce. Conversely, as a result of trading,

⁷ This introductory description of cap-and-trade is in terms of what is called a “downstream” system in the CO₂ context, where CO₂ emissions sources are regulated. Alternatively, in an “upstream” cap-and-trade system for CO₂, tradable permits regulate the carbon content of fossil fuels at the point of fuel extraction, import, processing, or distribution. The cap-and-trade program proposed in this article is an upstream system, because of its economy-wide coverage. The basic workings of cap-and-trade are explained above with a downstream (emissions) trading example, because many people find it more intuitive.

⁸ In practice, while cap-and-trade systems may not be able to fully *minimize* emission reduction costs in the absence of idealized market conditions, experience has demonstrated the ability of cap-and-trade systems to achieve significant cost savings relative to conventional regulatory approaches (Stavins 2003).

the emission reductions undertaken to meet the cap are those that are least costly to achieve.

The cost of achieving significant emission reductions in future years will depend critically on the availability and cost of low- or non-emitting technologies. A cap-and-trade system that establishes caps extending decades into the future provides important price signals and hence incentives for firms to invest in the development and deployment of such technologies, thereby lowering the future costs of achieving emission reductions.

A cap-and-trade system must provide credible commitments to long-run emission targets in order to create these investment incentives. If a lack of credibility makes the payoff from investments highly uncertain, these investments will lag (Montgomery and Smith 2007). On the other hand, it is also important to maintain flexibility to adjust long-term targets as new information is obtained regarding the benefits and costs of mitigating climate change. Managing the tradeoff between credibility of long-run targets and flexibility is an important issue for the success of any climate policy.

Even a credible long-run cap-and-trade system may provide insufficient incentives for investment in technology development because it would not address certain well-known factors (market failures) that discourage such investment, such as those associated with the public good nature of the knowledge that comes from research and development efforts (Jaffe *et al.* 2005, Newell 2007). Thus, a cap-and-trade system alone will not encourage the socially desirable level of investment in research, development, and deployment of new technologies that could reduce future emission reduction costs. To achieve this desired level of investment, additional policies may be necessary to provide additional government funding or to increase incentives for private funding of such research activities.⁹

1.3 Applications of Cap-and-Trade Mechanisms

Over the past two decades tradable permit systems have been adopted for pollution control with increasing frequency in the United States (Tietenberg 1997), as well as other parts of the world. As explained above, tradable permit programs are of two basic types, credit programs and cap-and-trade systems. The focus of this brief review of other applications — in keeping with the proposed policy — is on applications of the cap-and-trade approach.¹⁰ The programs described below are examined in more detail in the Appendix.

1.3.1 Previous Use of Cap-and-Trade Systems for Local and Regional Air Pollution

The first important example of a trading program in the United States was the leaded gasoline phasedown that occurred in the 1980's. Although not strictly a cap-and-trade system, the phasedown included features, such as trading and banking of environmental credits, that brought it closer than other credit programs to the cap-and-trade model and resulted in significant cost-savings. The lead program was successful in meeting its environmental targets, and the system was cost-effective, with estimated cost savings of about \$250 million per year (U.S. Environmental Protection

⁹ See, for example: National Commission on Energy Policy (2007b). Such complementary policies are examined in section 2.8.

¹⁰ This section of the article draws, in part, on Stavins (2003).

Agency, Office of Policy Analysis 1985). Also, the program provided measurable incentives for cost-saving technology diffusion (Kerr and Newell 2000).

A cap-and-trade system was also used in the United States to help comply with the Montreal Protocol, an international agreement aimed at slowing the rate of stratospheric ozone depletion. The Protocol called for reductions in the use of CFCs and halons, the primary chemical groups thought to lead to depletion. The timetable for the phaseout of CFCs was accelerated, and the system appears to have been relatively cost-effective.

The most important application made in the United States of a market-based instrument for environmental protection is arguably the cap-and-trade system that regulates SO₂ emissions, the primary precursor of acid rain, established under the U.S. Clean Air Act Amendments of 1990. The program is intended to reduce sulfur dioxide and nitrogen oxide emissions by 10 million tons and 2 million tons, respectively, from 1980 levels. A robust market of SO₂ allowance trading emerged from the program, resulting in cost savings on the order of \$1 billion annually, compared with the costs under some command-and-control regulatory alternatives (Carlson, Burtraw, Cropper, and Palmer 2000). The program has also had a significant environment impact: SO₂ emissions from the power sector decreased from 15.7 million tons in 1990 to 10.2 million tons in 2005 (U.S. Environmental Protection Agency 2005).

In 1994, California's South Coast Air Quality Management District launched a cap-and-trade program to reduce nitrogen oxide and sulfur dioxide emissions in the Los Angeles area. This Regional Clean Air Incentives Market (RECLAIM) program set an aggregate cap on NO_x and SO₂ emissions for all significant sources, with an ambitious goal of reducing aggregate emissions by 70 percent by 2003. Trading under the RECLAIM program was restricted in several ways, with positive and negative consequences. But despite problems, RECLAIM has generated environmental benefits, with NO_x emissions in the regulated area falling by 60 percent and SO_x emissions by 50 percent. Furthermore, the program has reduced compliance costs for regulated facilities, with the best available analysis suggesting 42 percent cost savings, amounting to \$58 million annually (Anderson 1997).

Finally, in 1999, under U.S. Environmental Protection Agency guidance, twelve northeastern states and the District of Columbia implemented a regional NO_x cap-and-trade system to reduce compliance costs associated with the Ozone Transport Commission (OTC) regulations of the 1990 Amendments to the Clean Air Act. Emissions caps for two zones from 1999-2003 were 35 percent and 45 percent of 1990 emissions, respectively. Compliance cost savings of 40 to 47 percent have been estimated for the period 1999-2003, compared to a base case of continued command-and-control regulation without trading or banking (Farrell *et al.* 1999).

1.3.2 CO₂ and Greenhouse Gas Cap-and-Trade Systems

Although cap-and-trade has proven to be a cost-effective means to control conventional air pollutants, cap-and-trade has a very limited history as a method of reducing CO₂ emissions. Several ambitious programs are in the planning stages or have been launched.

First, the Kyoto Protocol, the international agreement that was signed in Japan in 1997, includes a provision for an international cap-and-trade system among countries, as well as two systems of project-level offsets. The Protocol's provisions have set the stage for the member states

of the European Union to address their commitments using a regional cap-and-trade system.

By far the largest existing active cap-and-trade program in the world is the European Union Emissions Trading Scheme for CO₂ allowances, which has operated for the past two years with considerable success, despite some initial — and predictable — problems. The 11,500 emitters regulated by the downstream program include large sources such as oil refineries, combustion installations, coke ovens, cement factories, ferrous metal production, glass and ceramics production, and pulp and paper production, but the program does not cover sources in the transportation, commercial, or residential sectors. Although the first phase, a pilot program from 2005 to 2007, allowed trading only in carbon dioxide, the second phase, 2008-2012, potentially broadens the program to include other GHGs. In its first two years of operation, the EU ETS produced a functioning CO₂ market, with weekly trading volumes ranging between 5 million and 15 million tons, with spikes in trading activity occurring along with major price changes. Apart from some problems with the program's design and early implementation (discussed in the Appendix), it is much too soon to provide a definitive assessment of the system's performance.

A frequently-discussed U.S. CO₂ cap-and-trade system that has not yet been implemented is the Regional Greenhouse Gas Initiative (RGGI), a program among 10 northeastern states that will be implemented in 2009 and begin to cut emissions in 2015. RGGI is a downstream cap-and-trade program intended to limit CO₂ emissions from power sector sources. Beginning in 2015, the emissions cap will decrease by 2.5 percent each year until it reaches an ultimate level 10 percent below current emissions in 2019. This goal will require a reduction that is approximately 35 percent below business-as-usual, or equivalently, 13 percent below 1990 emissions levels. RGGI only limits emissions from the power sector, and so incremental monitoring costs are low, because U.S. power plants are already required to report their hourly CO₂ emissions to the Federal government (under provisions for continuous emissions monitoring as part of the SO₂ allowance trading program). The program requires participating states to auction at least 25 percent of their allowances; the remaining 75 percent of allowances may be auctioned or distributed freely. Given that the system will not come into effect until 2009, at the earliest, it is obviously not possible to assess its performance. Several problems with its design are examined in the Appendix.

Finally, California's Greenhouse Gas Solutions Act (Assembly Bill 32) was signed into law in 2006, is intended to begin in 2012 to reduce emissions to their 1990 levels by 2020, and may employ a cap-and-trade approach. Although the Global Warming Solutions Act does not require the use of market-based instruments, it does allow for their use, albeit with restrictions that they must not result in increased emissions of criteria air pollutants or toxics, that they must maximize environmental and economic benefits in California, and that they must account for localized economic and environmental justice concerns. This mixed set of objectives potentially interferes with the development of a sound policy mechanism. The Governor's Market Advisory Committee has recommended the implementation of a cap-and-trade program, with a gradual phase-in of caps covering most sectors of the economy, and an allowance distribution system that uses both free distribution and auctions of allowances, with a shift toward more auctions in later years.

1.4 *Criteria for Policy Assessment*

Three criteria stand out as particularly important for the assessment of a domestic climate change policy: environmental effectiveness; cost effectiveness; and distributional equity.¹¹

First of all, environmental effectiveness addresses whether it is feasible to achieve given targets with a specific policy instrument. This will include, for example, the technical ability of policymakers to design and the administrative ability of governments to implement technology standards that are sufficiently diverse and numerous to address all of the sources of CO₂ emissions in a modern economy, and the ability of political systems to put in place taxes that are sufficiently severe to achieve meaningful emissions reductions (or limits on global greenhouse gas concentrations, or limits on temperature changes).

In addition, the environmental-effectiveness criterion considers the certainty with which a policy will achieve emission or other targets. Although alternative policy designs may aim to achieve identical targets, design choices affect the certainty with which those targets are achieved. For example, a cap-and-trade system can achieve emission targets with high certainty because emission guarantees are built into the policy. On the other hand, with policies such as carbon taxes or technology standards, actual emissions are difficult to predict because of current and future uncertainties.¹² Consequently, while such policies can aim to achieve particular emission targets, actual emissions may exceed or fall below those targets depending on factors beyond policymakers' control.

Moreover, the tendency with taxes and standards to grant exemptions to address distributional issues weakens the environmental effectiveness of these instruments (Ellerman 2007). By contrast, distributional battles over the allowance allocation in a cap-and-trade system do not raise the overall cost of the program nor affect its climate impacts.

It is essential to keep in mind that to be effective globally, any domestic U.S. program needs to be accompanied by meaningful policies by other countries. For some other industrialized countries, notably the member states of the European Union, constraints are already in place under the Kyoto Protocol, and are likely to be more severe in the second commitment period, after 2012. Negotiations with key developing countries — including China and India — are more likely to succeed if the United States is perceived to be prepared to adopt a meaningful domestic program.

¹¹ Efficiency is ordinarily a key criterion for assessing public policies, but is less useful when comparing alternative domestic policy instruments to address climate change. This is because the efficiency criterion requires a comparison of benefits and costs. Given the global commons nature of climate change, a strict accounting of the direct benefits of any U.S. policy to the United States will produce results that are small relative to costs. Clearly, the benefits of a U.S. policy can only be considered in the context of a global system. Later, in section 3.3, the marginal cost (allowance price) of the proposed policy is compared with previous estimates of the marginal benefits of globally efficient policies. In the short term, the cap-and-trade system — like any meaningful domestic climate policy — may best be viewed as a step toward establishing U.S. credibility for negotiations on post-Kyoto international climate agreements. At the same time, another argument in favor of a cap-and-trade (or carbon tax) policy is that the political likelihood of a national climate policy is increasing in the United States, and it is preferable that such a policy be implemented cost-effectively rather than through more costly, conventional regulatory approaches.

¹² Relevant uncertainties may include uncertainty over future energy prices or how quickly new technologies will be adopted.

The cost-effectiveness criterion considers a policy's relative cost of achieving emission targets compared with alternative policy designs.¹³ One policy is considered more cost-effective than another if it achieves a given target at lower cost. Many categories of economic costs are relevant to the evaluation of alternative policy designs.¹⁴

Economic impacts of any climate policy will be broadly felt, but impacts will vary across regions, industries, and households. The ultimate distribution of economic impacts will depend not only on the costs imposed by the policy, but also on resulting shifts in the supply of and demand for affected goods and services, and associated changes in market prices. Firms directly regulated by a climate policy typically experience two impacts: (1) direct regulatory costs that reduce their profit margins; and (2) changes in demand for their products. A policy's initial burdens on directly regulated firms may be partially offset as the introduction of direct regulatory costs lead to increases in those firms' product prices and/or reductions in prices of some inputs. As a result of these changing prices, other firms not directly regulated by climate policy will also experience changes in profits and demand. The extent to which firms facing the direct or indirect costs of a climate policy pass those costs on to their consumers (or back to their suppliers) depends on the characteristics of the markets in which they compete, including the industry's cost structure and consumers' price responsiveness.

While a climate policy will adversely affect many firms, some may experience increased, or so-called "windfall" profits. For example, less carbon-intensive firms may enjoy windfall profits if a climate policy increases market prices for their products more than it increases their own costs. Thus, evaluation of a climate policy's distributional implications requires identifying its ultimate burdens, reflecting all adjustments in market prices, rather than just its initial impacts on costs.

While discussion often focuses on the impact of climate policies on firms, all economic impacts are ultimately borne by households in their roles as consumers, investors, and/or workers. As producers pass through increased costs, *consumers* experience increased prices of energy and non-energy goods, as well as reduced consumption. As a policy positively or negatively affects the profitability of firms, *investors* experience changes in the value of investments in those firms. Finally, *workers* experience changes in employment and wages.

2. PROPOSAL FOR A MEANINGFUL CAP-AND-TRADE SYSTEM

The United States can launch a scientifically sound, economically rational, and politically feasible approach to reducing its contributions to the increase in atmospheric concentrations of greenhouse gases by adopting an up-stream, economy-wide CO₂ cap-and-trade system which implements a gradual trajectory of emissions reductions over time, and includes mechanisms to reduce cost uncertainty, such as multi-year compliance periods, provisions for banking and borrowing, and possibly a cost containment mechanism to protect against any extreme price

¹³ Comparisons of the cost of alternative policies should be made on an equal footing, where each policy achieves a common emissions target. Of course, less cost-effective policies may limit the extent of emission reductions that are politically tolerable. On the other hand, transparent policies which exhibit their costs in obvious ways, such as (cost-effective) pollution taxes, may be less politically tolerable than less transparent policies (Keohane, Revesz, and Stavins 1998).

¹⁴ For a taxonomy of the costs of environmental regulation, see: Stavins (1997).

volatility.

The permits in the system should be allocated through a combination of free distribution and open auction, in order to balance, on the one hand, legitimate concerns by some sectors and individuals who will be particularly burdened by this (or any) climate policy, with, on the other hand, the opportunity to achieve important public purposes with generated funds. The share of allowances freely allocated should decrease over time, as the private sector is able to adjust to the carbon constraints, with all allowances being auctioned after 25 years.

In addition, it is important that offsets be made available both for underground and biological carbon sequestration, to provide for both short-term cost-effectiveness and long-term incentives for appropriate technological change. The Federal cap-and-trade system can provide for supremacy over U.S. regional, state, and local systems, to avoid duplication, double counting, and conflicting requirements. At the same time, it is also important to provide for harmonization over time with selective emission reduction credit and cap-and-trade systems in other nations, as well as related international systems.

2.1 Major Though Not Exclusive Focus on CO₂

This proposal focuses on reductions of fossil-fuel-related CO₂ emissions, which accounted for nearly 85 percent of the 7,147 million metric tons of U.S. GHG emissions in 2005, where tons are measured in CO₂-equivalent.¹⁵ Carbon dioxide emissions arise from a broad range of activities involving the use of different fuels in many different economic sectors. In addition, biological sequestration and reductions in non-CO₂ GHG emissions can contribute substantially to minimizing the cost of limiting GHG concentrations (Reilly, Jacoby, and Prinn 2003; Stavins and Richards 2005). Some non-CO₂ GHG emissions might be addressed under the same framework as CO₂ in a multi-gas cap-and-trade system.¹⁶ But challenges associated with measuring and monitoring other non-CO₂ emissions and biological sequestration may necessitate separate programs tailored to their specific characteristics, as I describe later.

2.2 A Gradually Increasing Trajectory of Emissions Reductions Over Time

The long-term nature of the climate problem offers significant flexibility regarding when emission reductions actually occur. Policies taking advantage of this “when flexibility” by setting annual emission targets that gradually increase in stringency can avoid many costs associated with taking stringent action too quickly, *without sacrificing environmental benefits* (Wigley, Richels, and Edmonds 1996). Premature retirement of existing capital stock and production and siting bottlenecks that can arise in the context of rapid capital stock transitions can be avoided. In addition, gradually phased-in targets provide time to incorporate advanced technologies into long-lived investments (Goulder 2004; Jaffe, Newell, and Stavins 1999).¹⁷ Thus, for any given

¹⁵ Measuring greenhouse gases in CO₂-equivalent terms means standardizing their quantities in regard to their radiative forcing potential over their average duration in the atmosphere, relative to CO₂.

¹⁶ Because landfill methane emissions are already monitored, and monitoring of industrial (as opposed to agricultural) non-CO₂ GHGs would not be difficult, regulation of these sources of non-CO₂ GHGs might be integrated with CO₂ policies (Reilly, Jacoby, and Prinn 2003).

¹⁷ In addition, due to the time value of money (the opportunity cost of capital), environmentally-neutral delays in the

cumulative emission target or associated atmospheric GHG concentration objective, a climate policy's cost can be reduced by gradually phasing in efforts to reduce emissions.

Because of the long-term nature of the climate problem and because of the need for technological change to bring about lower-cost emissions reductions, it is essential that the caps constitute a long-term trajectory. The development and eventual adoption of new low-carbon and other relevant technologies will depend on the predictability of future carbon prices, themselves brought about by the cap's constraints. Therefore, the cap-and-trade policy should incorporate medium-term to long-term targets, not just short-term targets.

While cost savings can be achieved by setting targets that gradually become more stringent, it is a mistake to conclude that "when flexibility" is a reason to delay enacting a mandatory policy. On the contrary, the *earlier* a mandatory policy is established, the more flexibility there is to set emission targets that gradually depart from business-as-usual emission levels while still achieving a long-run atmospheric GHG concentration objective. The longer it takes to establish a mandatory policy, the more stringent near-term emission targets will need to be to achieve a given long-run GHG concentration objective.

Gradually phasing in the stringency of emission targets also may reduce the near-term burdens of a climate policy, and therefore reduce both the costs and significant challenges associated with gaining consensus. On the other hand, a policy that shifts reduction efforts too far into the future may not be credible, thus reducing incentives for investments in advanced technologies.

Several alternative types of policy-target trajectories are possible, including: emission caps, emission reduction targets, global concentration targets, and allowance price trajectories. Given the long-term nature of the climate problem described above, the best measure of policy stringency may be the sum of national emissions permitted over some extended period of time. As I explain later, if banking and borrowing of allowances is allowed, then only the sum is consequential, not the specific trajectory of legislated caps, because market activity will generate the cost-minimizing trajectory.¹⁸

How should the sum of capped national emissions be identified? The classic economic approach would be to choose targets that would maximize the difference between expected benefits and expected costs. Such an approach is simply not feasible in the current context. First of all, reliable information about anticipated damages — even in bio-physical, let alone economic terms — is insufficient. And such a calculation could be made only at the global — not the national — level due to the global-commons nature of the problem. Furthermore, it is increasingly clear that it is insufficient to carry out such an analysis with expected benefits and expected costs, since it is the small risks of catastrophic damages that are at the heart of the problem (Weitzman 2007).

For illustrative purposes in my later cost assessment, I adopt and assess a pair of trajectories for the period 2012 to 2050 to establish a reasonable range of possibilities. The less ambitious trajectory involves *stabilizing* CO₂ emissions at their 2008 level¹⁹ over the period from 2012 to

timing of emission reduction investments can be socially advantageous.

¹⁸ The timing of emissions reductions can affect total damages, even if cumulative emissions are the same.

¹⁹ In the cost analysis presented later in the article, this is the business-as-usual level predicted for 2008 by Paltsev *et al.* 2007a, 2007b.

2050. This trajectory, in terms of its cumulative cap, lies within the range defined by the 2004 and 2007 recommendations of the National Commission on Energy Policy (2004, 2007b). The more ambitious trajectory — again defined over the years 2012-2050 — involves reducing CO₂ emissions from their 2008 level to *50 percent below their 1990 level by 2050*. This trajectory — defined by its cumulative cap — is consistent with the lower end of the range proposed by the U.S. Climate Action Partnership (2007).

This illustrative pair of cap-trajectories over the period 2012-2050 has several significant attributes. First, this range of trajectories is consistent with the frequently cited global goal of stabilizing atmospheric concentrations of CO₂ at between 450 ppm and 550 ppm *if* all nations were to take commensurate action.²⁰ Second, the caps gradually become more stringent over an extended period of time, thus reducing costs by avoiding the necessity of premature retirement of existing capital stock, reducing vulnerability to siting bottlenecks and other risks that arise with rapid capital stock transitions, and by ensuring that long-lived capital investments incorporate appropriate advanced technology.

These two trajectories are provided for illustrative purposes only, and are included so that the costs and other impacts of the cap-and-trade proposal can later be examined in quantitative terms. Importantly, the key design elements that are described in the remainder of this section should be employed with any cap-and-trade system, regardless of the specific trajectory of quantitative caps it is intended to implement.

2.3 Upstream Point of Regulation and Economy-Wide Scope of Coverage

Two important aspects in the design of a cap-and-trade system for CO₂ are the set of emission sources that are capped (the scope of coverage) and the point in the fossil fuel supply chain at which that cap is enforced (the point of regulation). In order to create *economy-wide coverage*, an *upstream point of regulation* should be employed, whereby allowances are surrendered based on the carbon content of fuels at the point of fossil fuel extraction, import, processing, or distribution.²¹ This can be thought of as a system where regulation is at the mine-mouth, well-head, and point of import. First sellers of fossil fuels could be required to hold allowances: for coal, at the mine shipping terminus; for petroleum, at the refinery gate; and for natural gas, at the first distribution point; and for imports, at the point of importation. Such a cap will effectively cover all sources of CO₂ emissions throughout the economy (Table 1).²²

²⁰ “Commensurate action” is defined in the analysis as other countries taking action that is globally cost-effective, for example by employing cap-and-trade systems with the same allowance price or equivalent carbon taxes (Paltsev *et al.* 2007a, including Table 12, page 57).

²¹ Regulating at the point of transportation or distribution is sometimes referred to as mid-stream. A downstream program imposes allowance requirements at the point of emissions, such as an electricity generator or factory. An upstream point of regulation has been used in prior policies where ultimate emissions are directly related to upstream production activity. For example, an upstream point of regulation was used to phase out automobile lead emissions by limiting the quantity of lead that refineries could use in gasoline. Similarly, emissions of ozone depleting substances have been phased out through limits on production of those substances, rather than through direct limits on their use. It should be noted that an upstream approach is not fully comprehensive unless provisions are made to address “process emissions” from natural gas and crude oil extraction.

²² The electricity and transportation sectors account for over 70 percent of total emissions; when the industrial sector is included, these three sectors account for nearly 90 percent of emissions. But it is important to recognize that electricity sector emissions result from electricity use by the other economic sectors. The last column of Table 1 includes indirect

The upstream program should include a credit mechanism to address the small portion of fossil fuels that are not combusted and to address the use of post-combustion emission reduction technologies, such as carbon capture and sequestration (CCS).²³ Emission reductions from CCS technologies can be readily measured, and, unlike some credit-based programs, a program for CCS does not introduce a risk of granting credits for fictitious emission reductions. Because there is no incentive to install CCS equipment absent a climate policy, emission reductions achieved by CCS are clearly “additional”. As CCS technologies are expected to play a significant role in achieving long-run emission reduction goals, such a credit mechanism is an essential component of an upstream cap.

Although the point of regulation determines which entities are ultimately required to hold allowances, this decision can be made independently of decisions regarding how allowances are initially allocated. The point of regulation does not dictate or in any way limit who could receive allowances if allowances are freely distributed. Furthermore, the point of regulation decision also has no direct effect on either the magnitude of emission reduction costs or the distribution of resulting economic burdens.²⁴ A cap has the same impact on the effective cost of fuel for downstream firms regardless of the point of regulation. With upstream regulation, the allowance cost is included in the fuel price. Since all suppliers face the same additional allowance cost, they all include it in the prices they set for downstream customers. With downstream regulation, the downstream customer pays for the allowances and fuel separately. In either case, the downstream customer ultimately faces the same additional cost associated with emissions from its fuel use.

This has two important implications. First, the distribution of costs between upstream and downstream firms is unaffected by the point of regulation decision. Second, firms and consumers will undertake the same emission reduction efforts — and thereby incur the same emission reduction costs — in either case because they face the same carbon price signal.

Confusion has emerged regarding these points, with some observers suggesting that an upstream program will dilute the carbon price signal, because allowance costs will be only partially passed through to downstream emitters. In particular, higher fuel prices will reduce demand. This, in turn, will lead producers to moderate their price increases, thereby absorbing some of the allowance costs themselves. This argument is valid, but is not unique to upstream systems. With a downstream point of regulation, fossil fuel would — in effect — become more expensive, because emitters would be required to surrender allowances. This would reduce their demand, and lead to the same offsetting effect on fuel prices. In a similar way, some people find an upstream point of regulation counterintuitive, since it does not control emissions *per se*. However, an upstream approach gets at the problem *more* directly: it caps the amount of carbon coming into the system.

emissions from electricity use in reporting each of the other sectors’ emissions.

²³ In addition, upstream regulation should include a credit-based program for fossil fuel exports so that they are not at a competitive disadvantage relative to supply from other countries that do not face any allowance requirements.

²⁴ This point was established decades ago in the context of tax policy (Musgrave and Musgrave 1980). However, there are a few exceptions. For example, the point of regulation will affect the distribution of administrative costs between upstream and downstream entities, although these costs would be small relative to the overall cost of a well-designed cap-and-trade system.

2.3.1 Environmental-Effectiveness of the Upstream Point of Regulation

An economy-wide cap provides the greatest certainty that national emission targets will be achieved. Limiting the scope of coverage to a subset of emission sources leads to emissions uncertainty through two channels. First, changes in emissions from unregulated sources can cause national emissions to deviate from expected levels.²⁵ Second, a limited scope of coverage can cause “leakage,” in which market adjustments resulting from a regulation lead to increased emissions from unregulated sources outside the cap that partially offset reductions under the cap. For example, a cap that includes electricity-sector emissions (and thereby affects electricity prices) but excludes emissions from natural gas or heating oil use in commercial and residential buildings may encourage increased use of unregulated natural gas or oil heating (instead of electric heating) in new buildings.

As a result, increased emissions from greater natural gas and oil heating will offset some of the reductions achieved in the electricity sector. More generally, any cap-and-trade system that is not economy-wide in scope will encourage entities that are potentially covered by the cap to exploit this incomplete coverage by seeking ways to avoid regulation.

Some stakeholders have argued for downstream point of regulation for at least some emission sources.²⁶ If a broad scope of coverage is to be achieved, downstream regulation of some facilities will require a “hybrid” point-of-regulation approach, in which some sources are regulated upstream and others downstream. The commonly proposed means of implementing such a hybrid approach would involve upstream producers surrendering allowances for some, but not all of the fuel they sell, depending on whether or not the fuel is sold to sources subject instead to downstream regulation. There are two significant problems with this approach. First, such a hybrid point of regulation may not provide complete coverage of fossil-fuel related CO₂ emissions. Some emission sources may fall through the cracks, and not be covered by either downstream or upstream regulation. Second, there would need to be two classes of fuel in the market, one for which allowances have been surrendered, and one intended for use by facilities subject to downstream regulation. This increases administrative complexity and the potential for noncompliance.

2.3.2 Cost-Effectiveness of the Upstream Point of Regulation

An upstream point of regulation makes economy-wide scope of coverage feasible, and the aggregate cost of emission reductions undertaken to meet a cap is directly affected by the scope of coverage, with costs declining more than proportionately with increases in the program’s scope. While the point of regulation decision does not directly affect emission reduction costs, it does affect a cap’s administrative cost.

An emission cap with broad coverage of emission sources reduces the cost of achieving a particular national emissions target. Three factors contribute to lower costs. First, a broader cap expands the pool of low-cost emission reduction opportunities that can contribute to meeting a national target. Even if a sector may contribute only a small portion of reductions, including that

²⁵ For example, the European Union’s (EU) Emissions Trading Scheme (ETS) covers CO₂ emissions from facilities accounting for about 45 percent of the EU’s GHG emissions. As a result, the EU’s ability to meet its Kyoto Protocol target is threatened by significant growth in transportation sector emissions, which are not covered by the ETS (European Environment Agency 2006). See the Appendix.

²⁶ See, for example, the debates surrounding the development of a cap-and-trade program to implement California’s AB 32 (Market Advisory Committee 2007; Stavins 2007).

sector under the cap can yield significant cost savings by displacing the highest-cost reductions that would otherwise be necessary in other sectors. For example, the cost of achieving a five percent reduction in U.S. CO₂ emissions could be cut in half under an economy-wide cap compared with a cap limited to the electricity sector (Pizer *et al.* 2006).

Second, an economy-wide cap provides important flexibility to achieve emission targets given uncertainties in emission reduction costs across sectors. By drawing from a broader, more diverse set of emission reduction opportunities, an economy-wide cap reduces the risk of unexpectedly high emission reduction costs much like a mutual fund reduces investment risk through diversification.

Third, an economy-wide cap creates incentives for innovation in all sectors of the economy. Such innovation increases each sector's potential to contribute cost-effective emission reductions in future years, and the resulting long-run cost savings from starting with a broad scope of coverage may far exceed any short-term gains. In theory, broad incentives for innovation might be introduced by a policy that proposes to eventually expand an initially narrow scope of coverage. But achieving such subsequent expansion would be difficult in practice, given that the adjustments that sectors will face upon joining the cap will only become more significant over time as the cap's stringency increases. Thus, political obstacles to expanding the cap may only grow over time as the cap becomes more stringent.

The point of regulation decision is a primary determinant of a cap-and-trade system's administrative costs through its effect on the number of sources that must be regulated. As the number of regulated sources increases, the administrative costs to regulators and firms rise. The point of regulation should be chosen to facilitate and minimize the administrative costs of a desired scope of coverage.²⁷

The upstream point of regulation makes an economy-wide cap-and-trade system administratively feasible, making it possible to cap nearly all U.S. CO₂ emissions through regulation of just 2,000 upstream entities (Bluestein 2005). A key advantage of an upstream program is that it eliminates the regulatory need for facility-level GHG emissions inventories, which would be essential for monitoring and enforcing a cap-and-trade system that is implemented downstream at the point of emissions.²⁸ The fossil fuel sales of the 2,000 entities to be regulated under the upstream cap-and-trade system are already monitored and reported to the government for tax and other purposes (Table 2). Monitoring is of little use without enforcement, and hence meaningful and credible penalties are important, such as fees set at up to ten times marginal abatement costs, plus the requirement for firms to make up the difference. Such a scheme has resulted in virtually 100 percent compliance in the case of the SO₂ allowance trading program (Stavins 1988).

2.3.3 *Distributional Consequences of Upstream Point of Regulation*

²⁷ The size of regulated sources also affects aggregate administrative costs. In the downstream European Union Emissions Trading Scheme, there are approximately 11,000 sources, 90 percent of which account for less than 10 percent of total emissions (Ellerman, Buchner, and Carraro 2007). The questionable "fix" apparently being devised in that case is a set of less demanding monitoring and verification requirements for smaller sources.

²⁸ In contrast, it would be administratively infeasible to implement an economy-wide cap-and-trade system through downstream regulation, as this would require regulation of hundreds of millions of commercial establishments, homes, and vehicles (Nordhaus 2005).

An economy-wide emissions cap spreads the cost burden of emission reductions across all sectors of the economy. In contrast, limiting the scope of coverage both increases the overall cost (as discussed above) and shifts burdens across sectors, regions, and income groups. Sectors remaining under the cap experience a greater economic burden as the cost of achieving emission reductions is both increased and spread over fewer sources.

Limiting the scope of coverage also may have unintended consequences. For example, limiting a cap's coverage to the electricity sector would lead to greater electricity rate impacts, and more regional variation in those impacts than would be anticipated under an economy-wide cap. In addition, excluding direct emissions from residential and commercial buildings will alter regional variation in household impacts because of regional differences in household use of electricity, heating oil, and natural gas.

2.4 Elements of the Cap-and-Trade System that Reduce Cost Uncertainty

While a cap-and-trade system can minimize the cost of meeting an emissions target, a poorly designed system can lead to emission reduction costs that are greater than anticipated. This risk arises because, barring mechanisms described below that control costs, regulated sources will meet an emissions cap regardless of the cost. This cost uncertainty is one reason offered in favor of a carbon tax, which largely eliminates cost uncertainty (but introduces emissions reduction uncertainty) by setting the carbon price at a pre-determined level. But policymakers can protect against cost uncertainty under a cap-and-trade system through the adoption of a few key design elements: provision for banking and borrowing of allowances, and possible inclusion of a cost containment mechanism. These cap-and-trade provisions can reduce cost uncertainty while largely maintaining certainty over emissions.

2.4.1 The Nature of Cost Uncertainty

Cost uncertainties arise from numerous factors: many advanced technologies expected to contribute significantly to achieving emission reductions have highly uncertain costs and/or have not yet been commercially demonstrated; people's willingness to adopt less emissions-intensive and energy-intensive technologies is not well understood; and unanticipated events could significantly affect the cost of meeting particular emission targets, including future exogenous changes in energy prices, GDP growth, as well as future political decisions.

Concern about cost uncertainty in the context of cap-and-trade systems derives from the possibility of unexpected, significant cost increases. The experience with the southern California RECLAIM cap-and-trade system for nitrogen oxide (NO_x) emissions is the frequently cited example.

RECLAIM had *no* automatic mechanism to relax emission caps in the face of unexpectedly high costs, and, in 2000, allowance prices spiked to more than 20 times their historical levels (Pizer 2005).²⁹ Cost uncertainty may increase the long-run cost of emission caps, because uncertainty

²⁹ Because electricity generators were part of this cap-and-trade system, these price spikes worsened the developing West Coast electricity market crisis (Joskow 2001). Such unexpectedly high costs, even if only temporary, may jeopardize commitments to long-run policy goals. The RECLAIM program, for example, returned electricity generators to standards-based regulation in response to the economic disruptions created by including them under the cap (Harrison 2003). See the Appendix.

about future allowance prices may deter firms from undertaking socially desirable, capital-intensive emission reduction investments,³⁰ forcing greater reliance on less capital-intensive, but more costly measures. Furthermore, although price spikes in allowance markets may be of interest to relatively limited populations, such price spikes pass through to affect the prices of goods and services that are more broadly consumed, such as electricity prices in the case of RECLAIM or gasoline prices in the case of an economy-wide cap on CO₂ emissions.

2.4.2 *Include Provision for Allowance Banking and Borrowing*

Allowance banking and borrowing can mitigate some of the undesirable consequences of cost uncertainty by giving firms the flexibility to shift the timing of emission reductions in the face of unexpectedly high or low costs.³¹ If the cost of achieving targets is unexpectedly and temporarily high, firms can use banked or borrowed allowances instead of undertaking costly reductions. Thus, banking and borrowing mitigate undesirable year-to-year variation in costs. Banking of allowances — undertaking extra emission reductions earlier, so that more allowances are available for use later — has added greatly to the cost effectiveness of previous cap-and-trade systems (Stavins 2003), but banking provides little protection when costs remain high over extended periods, which could eventually lead to exhaustion of banked allowances. This problem may be particularly acute in a cap's early years, when relatively few allowances have been banked. Therefore, borrowing of allowances from future years' allocations can be a particularly useful form of cost protection in these early years.

Banking offers cost protection while guaranteeing achievement of long-run cumulative emission targets. While banking may shift some emissions from earlier to later years (from when allowances are banked to when they are used), cumulative emissions at any point during the cap's implementation can never exceed the number of allowances issued up to that point in time. Credible mechanisms need to be established to ensure that the use of borrowed allowances is offset through future emission reductions. One possible mechanism would be a provision that firms can borrow from their own future supplies, while entering into a contractual — possibly bonded — agreement with the government that the borrowed emissions will be repaid at a subsequent date. Another possible mechanism would be for the government to allocate a future year's vintage permits that can be used in the current year, thereby decreasing a firm's future allocation by the same amount.

2.4.3 *Include Provision for a Sensible Cost-Containment Mechanism*

Ultimately the most robust cost-control feature of a cap-and-trade program is a broad and fluid market. In this sense, offsets — discussed elsewhere — can play a very important role in keeping costs down. Another issue is cost *uncertainty* linked with short-term allowance price volatility. Banking and borrowing can be exceptionally important in reducing long-term cost uncertainty, but the possibility of dramatic short-term allowance-price volatility may call for the inclusion of a sensible cost-containment mechanism. Such a mechanism could allow capped sources

³⁰ Firms facing investments in irreversible or sunk costs require greater returns as uncertainty in costs or revenues increase (Dixit and Pindyck 1994).

³¹ All cap-and-trade programs have implicit provision for banking and borrowing within the length of their compliance periods, one year in the case of the SO₂ allowance trading program, and five years in the case of the Kyoto Protocol's "commitment periods."

to purchase additional allowances at a predetermined price, set sufficiently *high* that it be unlikely to have any effect unless allowance prices exhibited truly drastic spikes,³² *and* the revenues from the fee dedicated *exclusively* to finance emissions reductions by uncapped sources, such as of non-CO₂ greenhouse gases, or to buy back allowances in future years. This is very different from standard proposals for a “safety-valve,” both because environmental integrity (the cap) is maintained by using the fees exclusively to finance additional emissions reductions or buy back allowances in future years, and because the pre-determined price is set at a high level so that it has no effect unless there are drastic price spikes.

The pre-determined fee places a ceiling on allowance prices and hence on abatement costs, because no firms would undertake emission reductions more costly than the trigger price (Jacoby and Ellerman 2002).³³ To be used as an insurance mechanism, the fee should be set at the maximum incremental emission reduction cost that society is willing to bear. At this level, the mechanism would be triggered only when costs are unexpectedly and unacceptably high. Of course, a cost containment mechanism that were set too high would provide no insurance against excessive costs.

Importantly, because revenues from the fee would be used to finance emissions reductions by uncapped sources or to buy back allowances in future years, the cost containment mechanism would reduce cost uncertainty, increase cost effectiveness, *and* could simultaneously maintain environmental effectiveness.

2.5 Allocation of Allowances

The cap-and-trade system will create a new commodity, a CO₂ allowance, which has value because of its scarcity (fostered by the cap on allowable emissions). The government can freely distribute allowances or auction them. This proposal recommends an allowance allocation mechanism that combines auctions with free distribution, with auctions becoming more important over time.

The aggregate value of allowances will be substantial. Indeed, if all allowances are auctioned, annual auction revenues would be significant even compared with annual Federal tax receipts.³⁴ From the perspective of firms that would need to buy auctioned allowances, total allowance costs would significantly exceed the cost of emission reductions that would be undertaken to meet a modest cap. This is because under an economy-wide emissions cap that reduces nationwide emissions by 5 percent, for example, while regulated firms would incur costs associated with reducing those emissions, they would have to purchase allowances for the remaining 95 percent of their emissions.

³² Thus, for example, the “trigger price” of the cost containment mechanism ought *not* be set at 10 or 20 percent above the expected level of allowance prices, but twice to ten times the expected level.

³³ An alternative to maintain and possibly exceed long-run emission targets is a complementary allowance price floor, facilitated by a government promise to *purchase* allowances at a specified price. A price floor ensures achievement of all emission reduction opportunities below a particular cost, which may exceed the amount of reductions necessary to meet the cap. The need for a price floor may decrease, however, with banking.

³⁴ For example, with the economy-wide programs proposed here, annual auction revenues (if all allowances were auctioned) would exceed \$100 billion, compared with fiscal year 2006 Federal net tax revenues of \$351 billion (corporation income tax), \$994 billion (individual income tax), and \$810 billion (employment taxes). Source: U.S. Energy Information Administration 2006b.

The fact that allowance requirements can contribute substantially to firm-level costs indicates that there are important distributional implications associated with the choice of allocation method (auctioning *versus* free distribution) and with decisions about *how* to distribute free allowances or *how* to use auction revenues. By contrast, the allocation choice does not affect achievement of emission targets, and — as emphasized above — the allocation issue is independent of the point of regulation. Indeed, since alternative points of regulation lead to the same ultimate distribution of economic burdens, there is no economic rationale for tying allocation choices to the point of regulation. For example, under an upstream cap, it is possible to freely distribute allowances to downstream energy-intensive industries that are affected by the cap even though they are not directly regulated by it. This is one approach to compensating those entities for the impact of a climate policy, since they can then sell the allowances to those firms that are directly regulated under the cap.

2.5.1 *The Choice Between Auction and Free Distribution: Overall Cost Concerns*

While all allocation decisions have significant distributional consequences, whether allowances are auctioned or freely distributed can affect the program's overall cost. Generally speaking, the choice between auctioning and freely allocating allowances does not influence firms' production and emission reduction decisions.³⁵ Firms face the same emissions cost regardless of the allocation method. Even when using an allowance that was received for free, a firm loses the opportunity to sell that allowance, and thereby recognizes this "opportunity cost" in deciding whether to use an allowance. Consequently, in many respects, this allocation choice will not influence a cap's overall costs. But there are two ways that the choice to freely distribute allowances can affect a cap's cost.

First, auction revenue may be used in ways that reduce the costs of the existing tax system or fund other socially beneficial policies. Free allocations forego such opportunities. Second, free allocations may affect electricity prices in regulated cost-of-service electricity markets, and thereby affect the extent to which reduced electricity demand contributes to limiting emissions cost-effectively.³⁶

³⁵ Two exceptions where free allocations may affect pricing and production decisions (relative to auctions) are allocations to regulated utilities (discussed below) and "updating allocations." If permits are freely allocated, the allocation should be on the basis of some historical measures, not on the basis of measures which firms can affect. Updating allocations, which involve periodically adjusting allocations over time to reflect changes in firms' operations, contrast with this. For example, an output-based updating allocation ties the quantity of allowances that a firm receives to its output. This distorts firms' pricing and production decisions in ways that can introduce unintended consequences and can significantly increase the cost of meeting an emissions target. While updating therefore has the potential to create perverse, undesirable incentives, selective use of updating allocations has been recommended by some to preserve competitiveness and reduce emissions leakage in sectors with high CO₂ emissions intensity and unusual sensitivity to international competition. In this proposal, I recommend an alternative approach for this purpose, namely a requirement that imports of a small set of specific commodities carry with them CO₂ allowances (see below). A closely related issue, which must be addressed even under historical allocations, is whether to freely allocate allowances to new facilities and whether to strip closing facilities of their allocations. As with updating, rewarding new investments with free allowances or penalizing closures by stripping firms of their free allocations can encourage excessive entry and undesirable, continued operation of old facilities, leading to significant inefficiencies (Ellerman 2006), as has apparently happened with the European Union's Emissions Trading Scheme.

³⁶ In addition, auctions eliminate the need for government to develop and implement a method of allocating allowances to individual firms, thereby reducing overall costs of program implementation; and auctions ensure that allowances will

In discussions about whether to auction or freely distribute allowances, much attention has been given to the opportunity to use auction revenue to reduce existing “distortionary” taxes. Taxes on personal and corporate income discourage desirable economic activity by reducing after-tax income from and therefore the incentive for work and investment. Use of auction revenue to reduce these taxes in a fiscally neutral fashion can stimulate additional economic activity, offsetting some of a cap’s costs. The magnitude of potential auction revenue, compared with existing tax receipts, suggests that auction revenue could allow for significant tax reductions. Studies indicate that “recycling” auction revenue by reducing personal income tax rates could offset 40 to 50 percent of the economy-wide social costs that a cap would impose if allowances were freely distributed (Bovenberg and Goulder 2003).

Achieving such gains may be difficult in practice, because climate policy would need to be tied to particular types of tax reform. The estimated cost-reductions in these studies are for policies in which auction revenue is used to reduce marginal tax rates that diminish incentives to work and invest. If, instead, auction revenue funded deductions or fixed tax credits, such tax reform would have a lesser effect (and perhaps no effect) on incentives to work and invest.³⁷ On the other hand, auction revenue could yield economic gains without tax reform by reducing fiscal imbalances, and thereby reducing the need for future tax increases.

In general, auctioning generates revenue that can be put toward innumerable uses. While all uses have distributional implications, some uses create greater economic gains than others. Use of auction revenue to reduce tax rates is just one example of a use that can create larger overall economic gains than would result from free distribution of allowances. Other socially valuable uses of revenue could include reduction of the federal debt (including offsetting a cap’s potentially adverse fiscal impacts), or funding desirable spending programs (for example, research and development). On the other hand, some government uses of auction revenue may generate less economic value than could be realized by private sector use of those funds. Thus, the opportunity to reduce the aggregate cost of a climate policy through auctioning, rather than freely distributing allowances, depends fundamentally on the use to which auction revenues are ultimately put.

2.5.2 The Choice Between Auction and Free Distribution: Distributional Concerns

While auctioning has the potential to reduce a climate policy’s economy-wide costs, depending on how auction revenues are used, free distribution of allowances provides an opportunity to address the distribution of a climate policy’s economic impacts.³⁸ Free distribution of allowances can be used to redistribute a cap’s economic burdens in ways that mitigate impacts on the most affected entities, and a sensible principle for allocation would be to try to compensate the most burdened sectors and individuals. Such redistribution of impacts may help establish consensus on a climate policy that achieves meaningful emission reductions. Thus, the choice between auctioning

be available to all participants in markets. Also, in the presence of particularly perverse types of transaction costs that reduce the cost-effectiveness of trading, auctions can be particularly attractive (Stavins 1995).

³⁷ Unless they indirectly alter the marginal tax rates that individuals face, credits and deductions often do not affect incremental after-tax income from additional work and investment, and thereby do not affect incentives for such activity.

³⁸ In principle, auction revenues could be redistributed in a manner equivalent to any free distribution of allowances, but such a proposal would likely encounter greater political challenges.

and free allocations introduces a potential tradeoff between a cap's aggregate cost and achievement of distributional objectives.

While there are some important exceptions, in competitive markets the benefits of free allowances generally accrue only to their recipients. While free allocations will increase recipients' profitability or wealth, free allocations generally will not benefit consumers, suppliers, or employees of those recipients. Hence, while the cost of allowance requirements can be expected to ripple through the economy, the benefits of free allocations will not do so. Therefore, in competitive markets (including deregulated electricity markets), when used for purposes of compensation, free distribution of allowances should be directly targeted at those industries, consumers, and other entities that policymakers wish to benefit.³⁹ Having said this, it is important to keep in mind that firms *per se* are not the final recipients of these benefits. After a portion of increased profits are turned over to the government through tax payments, the remainder accrues to shareholders, a subset of the general population.

Because free allocations may increase a cap's overall cost, it is important to consider what share of allowances need to be freely distributed to meet specific compensation objectives. A permanent allocation of all allowances to affected firms would, in aggregate,⁴⁰ significantly overcompensate them for their financial losses (Goulder 2000; Bovenberg and Goulder 2003; Smith, Ross, and Montgomery 2002).⁴¹ This is the case because much of the cost that a cap-and-trade system initially imposes on firms will be passed on to consumers in the form of higher prices. In effect, before any free allocation, firms are already partially compensated by changes in prices that result from the cap. Thus, freely allocating *all* allowances in perpetuity to affected firms would both overcompensate them in aggregate, and use up resources that could otherwise be put toward other uses, including compensating consumers that bear much of the ultimate burden.

2.5.3 *Proposal for a Mixed System of Auction and Free Distribution*

Faced with important differences in the implications of free allocation and an auction, the best alternative is to *begin* with a hybrid approach wherein half of the allowances are *initially* auctioned and half are freely distributed to entities that are burdened by the policy, including suppliers of primary fuels, electric power producers, energy-intensive manufacturers, and particularly trade-sensitive sectors. The share of allowances that are freely distributed should decline over time, until there is no free allocation 25 years into the program. This is because over time the private sector will have an opportunity to adjust to the carbon constraints, including industries with long-lived capital assets. Thus, the justification for free distribution diminishes over

³⁹ If allowance allocations are updated in future years or if they are allocated to firms in regulated markets, however, some (if not all) of the economic benefit of free allowances will flow to consumers, suppliers, and employees.

⁴⁰ Even if all firms, in aggregate, are over-compensated, some individual firms may still experience losses, because of unequal cost incidence at the firm level.

⁴¹ According to these studies, the coal, natural gas, and petroleum industries would be fully compensated if less than 25 percent of the allowances in an economy-wide program were freely allocated to them in perpetuity. Each industry would experience no aggregate burden, although some individual firms might suffer losses. If free allocations are phased out over time, a greater share of allowances would need to be freely allocated before the phase-out to achieve the same ultimate compensation as a smaller, but permanent allocation. For analyses of allocations to the electricity sector, see: Burtraw *et al.* (2002) and Burtraw and Palmer (2006).

time. In the short term, however, free distribution provides flexibility to address distributional concerns that might otherwise impede initial agreement on a policy. The half that are initially auctioned will generate revenue that can be used for public purposes, including compensation for program impacts on low-income consumers, public spending for related research and development, reduction of the Federal deficit, and reduction of distortionary taxes.

Why this particular pattern of beginning with a 50-50 auction-free allocation, moving to 100% auction over 25 years? This time-path of the numerical division between the share of allowances that is freely allocated and the share that is auctioned is consistent with analyses which have been carried out of the share of allowances that would need to be distributed freely to compensate firms for equity losses. In a series of analyses that considered the share of allowances that would be required *in perpetuity* for full compensation, Bovenberg and Goulder (2003) found that 13 percent would be sufficient for compensation of the fossil fuel extraction sectors, and in a scenario consistent with the Bovenberg and Goulder study, Smith, Ross, and Montgomery (2002) found that 21 percent would be needed to compensate primary energy producers and electricity generators.⁴²

The time-path recommended here for an economy-wide program — 50 percent of allowances initially distributed freely, with this share declining steadily (linearly) to zero after 25 years — is equivalent in terms of present discounted value to perpetual allocations (as those previously analyzed) of 15 percent, 19 percent, and 22 percent, at real interest rates of 3, 4, and 5 percent, respectively. Hence, the recommended allocation is consistent with the principal of targeting free allocations to burdened sectors in proportion to their relative burdens. It is also pragmatic to be more generous with the allocation in the early years of the program.

2.6 Credits (Offsets) for Specified Activities

For specific activities, it is important to include provision for offsets or credits by which those who report specific activities or emission reductions generate credits that covered firms may buy to offset their obligations under the cap. This is a potentially advantageous means of encouraging emission reductions from activities outside the scope of the cap-and-trade system, and lowering costs. An important concern, however, is the additionality problem, the challenge of identifying whether a credit is really warranted, which requires making a comparison with an unobserved and unobservable hypothetical (what would have happened had the credit *not* been generated). Despite this problem, significant cost savings can be achieved through *selective* use of credit-based programs targeting certain activities that otherwise would be too costly or infeasible to integrate into the cap-and-trade system.

The proposed upstream program should include selective use of the credit mechanism to address the small portion of fossil fuels that are not combusted and to address the use of downstream emission-reduction technologies, such as carbon capture and sequestration (CCS). First, credits should be issued for major non-combustion uses of fossil fuels, such as in some petrochemical feedstocks, as well as fuel exports.

Second, credits should be issued for carbon capture and storage (CCS). Emission reductions

⁴² Analyses by Burtraw and Palmer (2006), and Burtraw *et al.* (2002) appear to corroborate these findings.

from CCS technologies can be readily measured, and because there is no incentive to install CCS equipment absent a climate policy, emission reductions achieved by CCS are clearly additional. As CCS technologies may play a significant role in achieving long-run emission reduction goals (U.S. Energy Information Administration 2007; Deutch and Moniz 2007), this credit mechanism is an essential component of the upstream cap. Indeed, it might even be desirable to intentionally over-compensate CCS activities with credits to provide a stronger incentive for research and development.

Third, a program of credits for selected cases of biological sequestration through land use changes should be included. A cost-effective portfolio of climate technologies in the United States would include a substantial amount of biological carbon sequestration through afforestation and retarded deforestation (Stavins 1999; Stavins and Richards 2005; Lubowski, Plantinga, and Stavins 2006).⁴³ Translating this into practical policy will be a considerable challenge, however, because of concerns about monitoring and enforcement, additionality, and permanence. In principle, monitoring and enforcement is technologically feasible via third-party verification through remote-sensing, but its cost may be high. Additionality is an even greater challenge, although it is likely to be less of a problem with afforestation than with avoided deforestation. The issue of permanence can — in principle — be addressed through renewal of contracts to keep carbon stored (Plantinga 2007), but someone must bear the risk of default. Despite these challenges, it would be important to begin to develop at least a limited system of credits for biological sequestration, partly because otherwise there may be significant leakage due to policies that affect biofuel production (Paltsev *et al.* 2007).

Fourth, provision should be made to provide coverage over time of non-CO₂ greenhouse gases. Although CO₂ is by far the most important anthropogenic greenhouse gas (84 percent of radiative forcing linked with emissions in 2005), it is by no means the only greenhouse gas of concern. Carbon dioxide, methane (CH₄), nitrous oxide (N₂O), and three groups of fluorinated gases — sulfur hexafluoride (SF₆), HFCs, and PFCs — are the major greenhouse gases and the focus of the Kyoto Protocol.⁴⁴ The non-CO₂ GHGs are significant in terms of their cumulative impact on climate change, representing about 16 percent of radiative forcing in 2005. And because some emission reductions could be achieved at relatively low cost, their inclusion in a program would be attractive in principle (Paltsev *et al.* 2007).

The sources of some of these gases are large in number and highly dispersed, making their inclusion in a cap-and-trade program problematic. The answer may be to phase in regulation selectively over time with credit (offset) mechanisms, being careful to grant credits in CO₂-equivalent terms only for well-documented reductions. Over time, such approaches could be developed for industrial⁴⁵ emissions of methane and NO₂ and for the manufacture of key industrial gases in the case of refrigerants (HFCs), circuits (PFCs), and transformers (SF₆). Thus, cap-and-trade of non-CO₂ GHGs would likely combine upstream and downstream points of regulation.

⁴³ For example, Stavins and Richards (2005) estimated that more than one billion metric tons of CO₂ could be sequestered annually at a cost ranging from about \$8 to \$23 per ton of CO₂.

⁴⁴ CFCs, although greenhouse gases, are regulated by the Montreal Protocol, which was motivated by the impacts of CFCs on stratospheric ozone depletion, rather than by their contribution to global climate change.

⁴⁵ Agricultural emissions are probably too dispersed to be subject to a sound credit program.

More broadly, because of concerns about additionality and related perverse incentives, the role of project-based offsets should be defined carefully.⁴⁶ In particular, it is important that offsets be real, additional, verifiable, and permanent. Constraints should not be created in quantitative or geographic terms, however. Allowing even a small number of bad offsets does not make sense, nor does it make sense to deny high-quality offsets. Instead, strict criteria should be developed for allowing the generation of approved offsets, but without reference to quantity or location.

2.7 Linkage with Other Cap-and-Trade Systems and Other Nations' Policies

Three distinct linkage issues are important. These are: the relationship of the proposed national cap-and-trade system with any existing state or regional systems in the United States; the linkage of the proposed cap-and-trade system with other such systems in other parts of the world; and — more broadly — the relationship between the proposed cap-and-trade system and other nations' climate policies.

2.7.1 Linkage with Other Domestic Cap-and-Trade Systems

In the absence of a national climate policy, ten northeast states have planned a downstream cap-and-trade program among electricity generators in their Regional Greenhouse Gas Initiative, and California is considering implementing a cap-and-trade program at the state level. The proposed economy-wide, national, upstream cap-and-trade system could take the place of any regional, state, and local systems to avoid duplication, double counting, and conflicting requirements (Stavins 2007a). It is likely that a decision will be reached on a national cap-and-trade system before any of the regional or state programs have actually been implemented.

2.7.2 Linkage with Cap-and-Trade and Emission Reduction Credit Systems Outside of the United States

In the long run, linking of the U.S. cap-and-trade system with cap-and-trade (CAT) systems in other countries or regions, such as the European Union Emissions Trading Scheme, will clearly be desirable to reduce the overall cost of reducing GHG emissions and achieving any global GHG concentration targets (Jaffe and Stavins 2007). But there is a question of what level and type of linkage is desirable in the early years of the development of a U.S. cap-and-trade system. In the short term, it may be best for the United States to focus on linkage with emission reduction credit (ERC) programs, such as the Kyoto Protocol's Clean Development Mechanism (CDM).

First, by tapping low-cost emission reduction opportunities in developing countries, linkage of the U.S. system with CDM has a greater potential to achieve significant cost savings for the United States than does linkage with CATs in other industrialized countries (where abatement costs are more similar to those in the United States).⁴⁷

Second, linkage with an ERC system such as CDM can only have the effect of decreasing domestic allowance prices, since transactions are uni-directional, i.e., U.S. purchases of (low-cost) CDM credits. In contrast, (bi-directional) linkage of the U.S. system with another CAT system can

⁴⁶ For an optimistic assessment of the role of offsets, see: Natsource 2007.

⁴⁷ This raises concerns about additionality associated with CDM credits; these are addressed later in this section.

either decrease *or* increase the domestic allowance price, depending upon whether marginal abatement costs (and hence allowance prices) are lower or higher in the other CAT system. Similarly, other countries contemplating linking their CAT systems with a U.S. system may object to buying allowances from the U.S. system if the U.S. cap is less stringent (and hence has a lower allowance price).

Third, the U.S. may have to choose between adopting a cost containment mechanism and linking with cap-and-trade systems in other countries. It appears unlikely that the European Union would agree to linking its Emissions Trading Scheme with a U.S. system that employed a safety-valve or other such cost-containment measure. On the other hand, the U.S. could link with ERC systems, such as the CDM, even with a cost-containment measure in place. In summary, compared with linking with other CAT systems, linking with CDM would give the United States greater autonomy over the allowance price that emerges from its system and over efforts to control cost uncertainty.

Fourth, given that other CATs, such as the European Union's system, will likely be linked with CDM, linking the U.S. system with CDM will have the effect of indirectly linking the U.S. system with those other CATs, but in ways that avoid the short-term problems identified above. For example, to the extent that the U.S. system bids CDM credits away from Europe, the offsetting emission reductions associated with resulting increased emissions in the United States would come from Europe, not from the countries that originally supply the CDM credits.

Fifth, this indirect linkage should reduce concerns about additionality normally associated with linking with CDM. If another country or region (for example, the European Union) has already linked with CDM, the effect of U.S. linkage with CDM will differ significantly from what it would be if the United States were the only country linking with CDM. While there may indeed be significant additionality concerns associated with CDM credits, many of the credits that the U.S. system would ultimately purchase would be used by other linked CATs if the United States did not link with CDM. Hence, for these credits, there is no incremental additionality concern regarding the U.S. decision to link with CDM. Any U.S. use of these credits would result in emission reductions in the other linked CATs that would otherwise have used the credits.

Sixth and finally, the indirect linkage created by a U.S. link with CDM can achieve some and perhaps much of the cost savings that would arise from direct linkage with other CATs. This is because CDM credits can be sold on the secondary market, and so will ultimately go to the linked CAT with the highest allowance price, pushing the allowance prices of the various CATs toward the convergence that would be achieved by direct linkage among CATs. If there is a sufficient supply of low-cost CDM credits, direct linkage between the various CATs and CDM would achieve the same outcome as direct linkage among the CATs. Therefore, at least in the short term, bilateral linkage between the various national and regional cap-and-trade systems and CDM will reduce opportunities for additional significant cost savings from direct linkage among those cap-and-trade systems.

For these reasons, linkage of the U.S. cap-and-trade system with CDM may be a sensible first step as cap-and-trade systems begin to develop around the world, with the expectation that the United States will explore direct linkage with these other systems over time.

2.7.3 Linkage with Other Countries' Climate Policies

The fact that climate change is a global-commons phenomenon means that it can be sensible to condition the goals and operations of the proposed U.S. cap-and-trade program on the GHG emissions reductions efforts that other countries are employing. One approach is to include a provision for the overall U.S. emissions cap to be tightened when and if the President or the Congress determine that other major CO₂-emitting nations have taken specific climate policy actions. Such “issue linkage” — making the cap contingent upon the actions of other key countries — can make sense, particularly absent U.S. participation in a binding international agreement. This links the *goals* of the U.S. system with other countries’ actions.

In addition, the *operation* of the cap-and-trade system should be linked with the actions of other key nations. As part of the cap-and-trade program, imports of specific highly carbon-intensive goods (in terms of their emissions generated during manufacture) from countries which have not taken climate policy actions comparable to those in the United States should be required to hold appropriate quantities of allowances (mirroring the allowance requirements on U.S. sources). These allowances can be purchased from any participants in the domestic cap-and-trade system. This mechanism, if properly designed and implemented, can help establish a level playing-field in the market for domestically produced and imported products, and thereby can serve to reduce emissions leakage and induce key developing countries to join an international agreement (Morris and Hill 2007).

There are some understandable concerns with such a mechanism. First of all, there is the economist's natural resistance to tampering with free international trade in order to achieve other ends. Second, there is the difficulty of making the needed calculations of appropriate quantities of allowances on imports of manufactured goods. Third, there is the inescapable irony that the United States might adopt a mechanism for use with other countries, which had recently been proposed by Europeans for use against the United States (although with a border tax) because of U.S. non-ratification of the Kyoto Protocol. More broadly, there is the risk that this mechanism would be abused and inappropriately applied as a protectionist measure.

These concerns can be addressed by properly constraining the mechanism to apply only to primary highly energy-intensive commodities — such as iron and steel, aluminum, cement, bulk glass, and paper — and possibly a very limited set of other particularly energy-intensive (CO₂ emissions-intensive) goods. The requirement would not apply to countries that are taking comparable actions to reduce their GHG emissions, and exemptions could be provided for countries with very low levels of GHG emissions and the lowest levels of economic development.

In order to be compatible with World Trade Organization rules, it is key that the burden imposed on imported and domestic goods be roughly comparable, and that there not be discrimination among nations with similar conditions (Pauwelyn 2007).⁴⁸ Also, this requirement should become binding only after ten years, to allow time for an international climate agreement to be negotiated that includes all key countries in meaningful ways and thereby obviates the need for the mechanism.⁴⁹ If properly designed and constrained, this mechanism can be a useful intermediate

⁴⁸ For further discussion of the relationship between WTO rules and such mechanisms, including the use of border taxes, see: Frankel (2005).

⁴⁹ For a variety of potential post-Kyoto international policy architectures, see Aldy and Stavins (2007); and for an example of a specific proposal that would include all key countries in a meaningful international agreement, see Olmstead and Stavins (2006).

step of international linkage on the way to U.S. participation in a sound international agreement.

2.8 *Associated Climate Policies*

From an economic perspective, the price signals generated by a well-functioning upstream cap-and-trade system will be insufficient for their purpose if there are remaining market failures that render those price signals ineffective. For example, there may be market failures other than the environmental externality of global climate change associated with energy-efficiency investments. If the magnitude of these non-environmental market failures is large enough and the cost of correcting them small enough to warrant policy intervention, then an argument can be made to attack these other market failures directly (Newell, Jaffe, and Stavins 1999).

Examples of such relevant market failures include information problems that lead consumers to under-value expected energy cost savings when purchasing energy-consuming durable goods, ranging from room air conditioners to motor vehicles. Likewise, there is — in theory — the principal-agent problem of landlords who may under-invest in energy-efficient appliances, because electricity costs are paid by tenants. Perhaps most important is the example of the public good nature of research and development, which leads to under-investment in R&D because knowledge generated may not be exclusive and so economic returns cannot be fully captured. To achieve the desired levels of investment, additional public policies — of various kinds, beyond the price signals generated by the cap-and-trade system — may be necessary. A variety of such policies have been recommended by the National Commission on Energy Policy (2004, 2007b).⁵⁰

3. ECONOMIC ASSESSMENT OF THE PROPOSAL

This section of the article begins with a qualitative examination of implications of the proposed cap-and-trade system for both short-term cost-effectiveness and long-term dynamic incentives for cost-saving technological change. Empirical estimates of costs, price impacts, and other aggregate economic measures are provided for the two illustrative trajectories of CO₂ emissions caps. In addition, we consider the challenge of estimating the benefits of a U.S. program addressing a global-commons problem, and provide numerical benefit estimates from previous sources to place the cost estimates in context. The section closes with an extensive consideration of distributional impacts of the proposed system, including illustrative numerical estimates of sectoral cost impacts.

3.1 *A General Cost Assessment of the Cap-and-Trade Approach*

The opportunity for cost savings through the use of a cap-and-trade approach to CO₂ emissions reductions stems largely from the natural scientific characteristics of global climate change. First, climate impacts depend on the stock of GHGs that accumulate in the atmosphere, not on the flow at any point in time. Given the long lag-time of GHGs in the atmosphere, it is cumulative emissions over decades that are the appropriate focus of policy actions. Second, any particular emissions have the same effect on the atmospheric stock no matter where in the country (or the world, for that matter) they are generated. Thus, GHG emission reductions have the same

⁵⁰ A conceptually distinct issue is that there are other policy problems — an example is “energy security” — which may call for public policies which also have climate impacts. For example, see: Sandalow 2007.

beneficial effects no matter how, where, and, to a large extent, when they are achieved. As a result, compliance flexibility can be used to lower costs *without* compromising environmental integrity. A cap-and-trade system (and likewise a carbon tax) offers this flexibility, and takes advantage of what have been termed “what, where, and when” flexibility.

The cap-and-trade system minimizes compliance costs through “what flexibility” by exploiting the fact that many types of actions offer low-cost CO₂ emission reduction opportunities, including adopting more efficient or lower-emitting technologies, adjusting use of equipment that generates emissions, and accelerating the replacement of existing equipment. The cap-and-trade system allows — indeed encourages — emission reductions through whatever measures are least costly.

The cap-and-trade system also minimizes compliance costs through “where flexibility” by allowing for the fact that control costs vary widely across industries and across sources within any industry. Costs can vary significantly even across households or firms that use the same exact equipment. The cap-and-trade system exploits this variation by achieving reductions wherever they are least costly. Emission reduction costs will change over time, as new technologies are developed. So what may be a cost-effective distribution of emission reduction efforts across sectors, technologies, and regulated entities today, will not be ten years from now. The cap-and-trade system adjusts automatically as control costs change over time.⁵¹

As emphasized earlier in our discussion of emission trajectories, the cap-and-trade system also minimizes costs through “when flexibility.” Climate change results from cumulative GHG emissions over decades to centuries, and it is therefore cost-effective to allow for flexibility in the timing of emission reductions. The cap-and-trade system can provide temporal flexibility through the design elements proposed above: allowing the banking of allowances for use in future years; allowing the borrowing of allowances from future allocations for use now; and multi-year compliance periods, where firms have flexibility about how they distribute their emissions within the compliance period. By thereby allowing firms to minimize their costs of complying with the long-term trajectory of caps, the cap-and-trade system avoids requiring premature retirement of existing capital stock or locking-in existing emission reduction technologies in long-lived capital investments when better technologies may be available later. Likewise, the system avoids putting complying firms in the position of undertaking unnecessarily costly emission reductions in one year that may be caused by unusual circumstances, when less costly offsetting reductions can be achieved in other years.⁵² By incorporating “when flexibility,” cost effectiveness is achieved without compromising the achievement of cumulative emissions targets.

Given the long-term nature of climate change, it is exceptionally important that the cap-and-trade approach provides incentives for long-term technological change. New technologies will have the potential to significantly reduce the long-run cost of achieving climate policy objectives (Jaffe, Newell, and Stavins 2003). It is critical that climate policies encourage innovations in technologies

⁵¹ Furthermore, lower-cost opportunities to reduce emissions may exist in other countries, and the cap-and-trade system creates a common currency — emissions allowances — that makes it possible to link with efforts to reduce GHGs in other regions.

⁵² For example, annual variations in weather may affect the availability of renewable energy resources, such as hydroelectric power.

and in how fossil fuels are used. By rewarding any means of reducing emissions, the cap-and-trade system provides broad incentives for any innovations that lower the cost of achieving emissions targets.

3.2 *Empirical Cost Assessment of the Cap-and-Trade Proposal*

A considerable number of analytical models have been employed over the past several years to estimate the aggregate costs (and in some cases, the distributional impacts) of a cost-effective set of emissions-reduction actions to achieve various national CO₂ and GHG targets. Such analyses can be and, in fact, have been used to provide estimates of the costs associated with a domestic cap-and-trade system (and, for that matter, a carbon tax). These include three modeling groups who carried out analyses under the U.S. government's Climate Change Science Program,⁵³ and a much larger set of modeling teams who worked together under Stanford University's Energy Modeling Forum project, "EMF-21" (Chesnaye and Weyant 2006).

Two models have had a distinctly U.S. focus, and have been used to give particular attention to the costs associated with domestic cap-and-trade systems: the National Energy Modeling System (NEMS) of the U.S. Department of Energy (U.S. Energy Information Administration 2007),⁵⁴ and the Emissions Prediction and Policy Analysis (EPPA) model of the Massachusetts Institute of Technology's Joint Program on the Science and Policy of Global Change (Paltsev *et al.* 2007a, 2007b).⁵⁵

None of the models or their results are strictly or simply comparable. The cost estimates they produce depend upon the structure of the models, as well as key assumptions regarding the magnitude of a wide variety of current and future parameters and variables. The factors that stand out as having the greatest effects on respective cost estimates are: the forecasted business-as-usual (BAU) emissions path;⁵⁶ policy stringency and the trajectory of stringency; the scope of policy coverage across the economy; assumed opportunities for fuel switching and energy-efficiency improvements; availability of offsets; and uses of revenues (from auctioned allowances).

To provide illustrative empirical cost estimates, this proposal draws on recent results from MIT's EPPA model, both because of the recent vintage of the analysis and because the model was applied by its authors (Paltsev *et al.* 2007a, 2007b) to examining an upstream cap-and-trade system that is — in its stylized form — close to what is proposed here. As with any analytical model, there are particular aspects of the model and analysis which affect the cost estimates.

⁵³ The three models are: the Integrated Global Systems Model (IGSM) of the Massachusetts Institute of Technology's Joint Program on the Science and Policy of Global Change; the MiniCAM Model of the Joint Global Change Research Institute, itself a partnership of the Pacific Northwest National Laboratory and the University of Maryland; and the Model for Evaluating the Regional and Global Effects (MERGE) of greenhouse gas emission-reduction policies, a joint effort of Stanford University and the Electric Power Research Institute (Newell and Hall 2007). Results are summarized in various documents, including Clarke, *et al.* 2006.

⁵⁴ In addition to the Energy Information Administration's own use of the NEMS model (2007), the National Commission on Energy Policy has used the NEMS model to estimate the costs of its proposals (2004, 2007b).

⁵⁵ Note that EPPA is a component of the IGSM. For a summary of findings from the models, see: Aldy 2007.

⁵⁶ The BAU emissions path is the model's prediction of what emissions will be in the absence of public policy.

Some of the EPPA model's characteristics and assumptions may lead to underestimates of the costs of the proposed cap-and-trade system. First, the model is a stylized computable general equilibrium (CGE) model which assumes perfect frictionless markets (marginal costs equated among emissions sources), with full employment of resources and no costs of transition (important for the short term). In essence, emission reductions but not policies are modeled, which is the case with virtually all such analytical models. Likewise, the costs of monitoring emissions are ignored, as are the transaction costs of firms engaging in allowance trades. Second, EPPA is a deterministic model, that is, uncertainty is not explicitly included. If uncertainty and risk aversion increase costs, then the model's assumption of perfect information tends to understate costs. On the other hand, the cost-saving properties of specific design elements that reduce cost uncertainty cannot really be captured. Third, it is assumed that other regions of the world undertake commensurate climate policies, which is significant because of effects on international fuel and other prices.⁵⁷

Other characteristics and assumptions of the model are likely to lead to overestimates of the costs of the proposed system. First, the EPPA model analyzes an all-GHG program, in which each gas is reduced cost-effectively and in the proper proportion. Compared with a CO₂-only program, this is not a problem for the estimated CO₂ allowance prices, but does result in overestimates of impacts on gross domestic product (GDP) as reported in this article, because the reported GDP impacts are for more ambitious programs that include both the indicated CO₂ emissions reductions and additional reductions in non-CO₂ GHGs.⁵⁸ Second, the model does not allow for biological carbon sequestration either directly in the cap-and-trade system or through credits. Third, it is assumed that there is no linkage and no international trade of allowances or credits for project-level activities. Fourth, nuclear power is assumed to be limited by concerns for safety and siting of new plants, and so nuclear capacity is not allowed to expand despite economic signals.

With various model characteristics and assumptions operating in opposite directions, on balance the EPPA analysis can be employed simply to offer some illustrative cost estimates.⁵⁹

3.2.1 *Anticipated Emissions Under Two Illustrative Cap Trajectories*

The first illustrative trajectory involves stabilizing CO₂ emissions at their 2008 level over the

⁵⁷ In particular, Europe, Canada, Australia, and New Zealand are modeled as complying with the Kyoto Protocol in 2012, with their emissions falling gradually to 50 percent below 1990 levels by 2050. Developing countries are treated as adopting a policy in 2025 that returns and holds them at their year 2015 emissions through 2034, and then returns and holds them at their year 2000 emissions for 2035 through 2050. The *cost* of a U.S. cap-and-trade program is affected by these policies in the rest of the world through international fuel and other prices. Likewise, if a carbon tax were employed, the *effectiveness* of a U.S. policy would depend on policies in the rest of the world.

⁵⁸ On the other hand, any given set of climate targets (such as expressed in terms of CO₂-equivalent) can be achieved at lower cost with a multi-gas program than with a CO₂-only program. However, the EPPA model's treatment of non-CO₂ GHGs, in which measurement (policy implementation) problems are assumed away, likely has the effect of understating to some degree the aggregate costs of control.

⁵⁹ Also, the EPPA model does not take into account the existence of state and regional programs, such as the Regional Greenhouse Gas Initiative in the Northeast, and AB 32 in California. Ignoring such programs in place could tend to overstate the costs of achieving some national cap, but the presence of such programs can also lead to inefficiencies via path dependence, leading to a sub-optimal national program, driving up costs. However, the major impacts of state or regional programs — assuming they are binding — will primarily be distributional, driving up costs (requiring more abatement) by states with such policies in place and reducing the costs of the national program for other states (Stavins 2007).

period from 2012 to 2050 (Table 3). This trajectory, in terms of its cumulative cap, lies within the range defined by the 2004 and 2007 recommendations of the National Commission on Energy Policy (2004, 2007b). The second illustrative trajectory — also defined over the years 2012-2050 — involves reducing CO₂ emissions from their 2008 level to 50 percent below their 1990 level by 2050 (Table 3).⁶⁰ This trajectory — defined by its cumulative cap — is consistent with the lower end of the range proposed by the U.S. Climate Action Partnership (2007). The anticipated emissions paths under the two illustrative caps differ from the cap trajectories themselves, because of the use of emissions banking (Table 4). A comparison of Tables 3 and 4 makes clear that that it is cost-effective for sources to reduce CO₂ emissions well below the cap in early years, generating a bank of allowances which can then be used in later years.

Relative to respective forecasted business-as-usual (BAU) CO₂ emissions, both implementations of a cap-and-trade system would achieve dramatic emissions reductions (Table 5). In the “Stabilization” case, emissions will be 10 percent below BAU in 2015, three years after the program commences in 2012, and fall to 38% below BAU by 2050. In the more aggressive “50% below 1990 Level by 2050” case, emissions are predicted to be 18% below BAU in 2015, and fully 75% below BAU in 2050.

3.2.2 CO₂ Allowance and Fossil Fuel Prices

The tradable CO₂ allowances have value because of their scarcity, and it is their market-determined price that provides incentives for cost-effective emissions reductions and investments that bring down abatement costs over time. As the required emissions reductions (relative to BAU) increase over time under both cap trajectories (Table 5), the market prices of the allowances also increase, rising from \$18/ton of CO₂ in 2015 to \$70/ton of CO₂ in 2050 for the less aggressive policy, and rising from \$41/ton of CO₂ in 2015 to \$161/ton of CO₂ in 2050 for the more aggressive policy (Table 6). Actual current allowance prices for the Kyoto Protocol phase of the European Union’s Emissions Trading Scheme — about \$20 per ton of CO₂ — are consistent with these predictions.

Fossil fuel prices are also predicted to change as a result of the cap-and-trade system, because of effects on the supply and demand for those fuels in various markets. As Table 6 indicates, the net effect of both caps on coal and petroleum prices is to depress those prices *relative* to what they would be in the absence of climate policy, because of reduced fuel demand. It is important to note, however, that although these prices include the effects of allowance prices on fossil fuel supply and demand, they do not include the cost of allowances *per se*.⁶¹

3.2.3 Impacts on Electricity Production

One of the ways in which the cap-and-trade system cost-effectively de-carbonizes the

⁶⁰ Tables 3 and 4 provide the caps and anticipated emissions, respectively for CO₂ and other greenhouse gases. Although the focus of the proposed cap-and-trade system is initially on CO₂, it can be expanded over time — as explained above — to include some of the other GHGs. The EPPA model, which is the source of the cost estimates reported here, was applied by Paltsev *et al.* (2007a) to an analysis of a cap-and-trade system that reduced all GHGs, not just CO₂.

⁶¹ There is a key distinction between the prices of the fuels themselves (Table 6) and the cost of using those fuels — which includes the allowance price — and which is examined below (Table 8).

economy is through its impacts on the production of electricity from various sources. Because of significant differences among sources of electricity in their carbon intensity, the gradually increasing CO₂ allowance prices that characterize both cap trajectories lead not only to (relatively small) reductions in electricity production, but to dramatic changes in the mix of fuels used to generate electricity (Table 7). Conventional coal-fired generation drops significantly even under the less aggressive policy, and disappears completely by 2040 under the more aggressive policy, being replaced mainly by generation from new plants with carbon capture and storage (CCS). In the short term, electricity generation from natural gas increases with CO₂ price increases, but this source of generation eventually declines with the higher CO₂ prices at the end of the period of analysis, as CCS technology becomes increasingly attractive.⁶²

3.2.4 *Impacts on the Cost of Using Fossil Fuels*

As indicated above, the cap-and-trade system has the effect of reducing demand for fossil fuels relative to BAU conditions and hence reducing fossil fuel prices *relative* to what those prices would be in the absence of policy. There is an important distinction, however, between the price of fuels themselves (Table 6) and the cost of using those fuels, which is illustrated in Table 8. For sample allowance prices of \$25, \$50, and \$100/ton of CO₂, the added cost is estimated for major fuels, including crude oil, gasoline, heating oil, wellhead natural gas, residential natural gas, and utility coal. These added costs of allowances to fuel users (which do not include the adjustment for the effects of the cap-and-trade policies on producer prices from Table 6) are compared with the average price of the respective fuels over a recent period of time.

Not surprisingly, the percentage impacts on costs for users of crude oil are greater than for users of derived products, such as gasoline and heating oil, because the costs of these products include capital and labor for refining beyond the cost of crude oil itself. Likewise, the percentage impact on the cost of wellhead natural gas is much greater than residential natural gas, which includes costs of transportation and distribution. Of course, by far the greatest impacts are on users of coal. In the case of gasoline, natural gas, and electricity, anticipated price impacts are actually relatively modest when compared with historical changes in prices since 1990. Also, the anticipated price increases will take place gradually over much longer periods of time than did recent spikes in energy prices (Aldy 2007, p. 12).

⁶² As explained previously, the predictions from the use of the EPPA model — like the predictions from any model — depend to a large degree on characteristics and assumptions of the model. As noted above, the analysis assumes that nuclear power is constrained to current levels, and is also quite optimistic regarding CCS potential.

3.2.5 Impacts on Aggregate Costs to the Economy

The cap-and-trade system, like any regulatory initiative, affects the behavior of individuals and firms, causing reallocation of resources, and thereby causing economic output to grow more slowly than it would in the absence of the policy. Impacts on gross domestic product (GDP) are measured relative to no policy (BAU), and so the reductions in GDP do not indicate that output would be lower than current levels, but rather that output would be lower than it would otherwise be expected to be.⁶³

Consistent with findings from other studies, the analysis indicates significant but affordable impacts on GDP, generally reductions below BAU of less than one-half of one percent in each year of the program for the less aggressive cap trajectory and ranging up to one percent below BAU each year for the more aggressive policy (Table 9).⁶⁴ These impacts on GDP by 2050 are equivalent to average annual GDP growth in the BAU case of 2.901 percent, and average annual GDP growth of 2.895 percent and 2.891 percent under the two cap trajectories, respectively.⁶⁵

3.2.6 Potential Revenue from CO₂ Allowance Auctions

The proposal is that initially half of the allowances be auctioned, with the share freely distributed gradually diminishing to zero over 25 years. How much revenue would auctions generate? If *all* allowances were auctioned, potential auction revenue would be very significant, equal to \$119 billion per year in 2015, increasing to \$473 billion by 2050 under the less aggressive program, and ranging from \$269 billion in 2015 to \$404 billion in 2050 under the more aggressive policy (Table 10).

To place these numbers in context, Table 10 also provides the potential tax reduction per family of four.⁶⁶ With the stabilization policy, this potential tax reduction increases from \$1,490 per family in 2015 to \$4,770 in 2050. With the policy of returning 2050 emissions to 50% of their 1990 level, the potential tax reduction increases from \$3,360 in 2015 to \$4,260 in 2040, and then decreases to \$4,060. The reason for the non-monotonic result is that while the CO₂ emissions price consistently increases, the number of allowances to be auctioned decreases as emissions are brought down.

⁶³ The EPPA model predicts that GDP will increase from 2005 to 2050 in the business-as-usual case from \$11,981 billion to \$44,210 billion (2005 dollars), that is, by 269 percent. The model predicts that GDP will increase over those years under two cap-and-trade scenarios from \$11,981 billion to \$44,086 billion (268%) and \$43,998 billion (267%), respectively.

⁶⁴ Given the monotonic increases in CO₂ allowance prices over the entire time period, continuous increases in GDP impacts might be expected, but the costs are driven by both direct cost of abatement and by price impacts resulting from climate policies in other countries. Thus, emissions paths and costs are driven partly by assumptions in the EPPA model regarding policies in other countries, in particular the increased stringency of policies in developing countries in 2035.

⁶⁵ A more robust measure of aggregate cost is provided by the change in welfare (equivalent variation), which includes not only changes in market consumption but also endogenous changes in the labor market. The estimated impacts of the two policies remain costly but affordable, but in this case the difference between the cost implications of the two cap trajectories is somewhat greater, with the less ambitious policy causing welfare losses of less than one-half of one percent, and the more ambitious policy causing losses of up to 1.5 percent annually by 2050 (Table 9).

⁶⁶ In keeping with Paltsev 2007a, these calculations divide annual auction revenue by anticipated national households, which is simply anticipated population divided by four.

By its construction, the EPPA model as employed in Paltsev *et al.* (2007a,b) cannot be used to examine quantitatively the cost savings associated with using such auction revenues to cut distortionary taxes, but a related study found — in the case of the more aggressive cap-and-trade policy — that welfare costs would be reduced by 24% if all auction revenues were used to lower taxes on capital, and welfare costs would be reduced by 9% if auction revenues were used to cut labor taxes (Gurgel *et al.* 2007).⁶⁷

3.3 Empirical Benefit Estimates

Given the global commons nature of climate change, a strict accounting of the direct benefits of either policy to the United States will produce results that are small relative to costs. Clearly, the benefits of the program can only be considered in the context of a global system. In the short term, the cap-and-trade system — like any meaningful domestic climate policy — may best be viewed as a step toward establishing U.S. credibility for negotiations on post-Kyoto international climate agreements.

To place the cost estimates in context, it is possible to ask how the estimated CO₂ allowance prices compare with marginal benefit estimates for what some analysts have indicated would be efficient policies. For example, a recent estimate from the DICE model suggests an optimal (efficient) allowance price (or tax) of approximately \$10/ton of CO₂ in 2015, rising to about \$23/ton of CO₂ in 2050 (Nordhaus 2007). This price path lies well below even the price path associated with the less aggressive of the two illustrative cap trajectories considered above.

More broadly, over one hundred estimates of the marginal damages of CO₂ emissions from 28 published studies were analyzed, with the result that the median marginal damage (hence, marginal benefit) estimate was approximately \$4/ton of CO₂, the mean about \$25/ton of CO₂, and the 95 percentile of the highly right-skewed distribution approximately \$95/ton of CO₂ (Tol 2005). These numbers illustrate the difficulty of relying on estimates of expected benefits, because small risks of catastrophic damages may be central to the problem (Weitzman 2007).

3.4 Distributional Impacts

Despite the fact that aggregate impacts on economic output (GDP) and welfare are relatively small, there can be very substantial impacts on particular sectors or groups of people. Regardless of how allowances are distributed, most of the cost of the program will be borne by consumers, facing higher prices of products, including electricity and gasoline — impacts that will continue as long as the program is in place. Also, workers and investors in the energy sectors and energy-intensive industries will experience losses in the form of lower wages, job losses, or reduced stock values. Such impacts are temporary, and workers or investors who enter an industry after the policy takes effect typically do not experience such losses (Dinan 2007). The fact that the policy is phased in gradually provides more time for firms and people to adapt.

The cost impacts can be regressive, because lower income households spend a larger share of their income than wealthier households, and energy products account for a larger share of spending

⁶⁷ The cost reductions would be greater in the stabilization scenario, because emissions are greater and hence there are more allowances to be auctioned.

by low-income households than wealthier households. As explained below, however, the distributional impacts of the policy will depend greatly on the specifics of policy design, including how allowances are allocated and how auction revenues are used.

3.4.1 *Effects on Industry*

A cap will have broad economic effects because it raises the cost of fossil fuel use and electricity generation. But certain sectors and firms will be particularly affected, including fossil fuel producers, the electricity sector, and energy-intensive industries.

Variation in a cap's economic impacts on fossil fuel producers illustrates that impacts on a particular sector do not depend on the sector's carbon-intensity alone, and that some impacts can be counter-intuitive. Coal production will be the most affected because coal is the most carbon-intensive fuel and opportunities exist for electricity generators and some industrial consumers to switch to less carbon-intensive fuels. Petroleum sector output will be much less affected, partly because demand for gasoline and other petroleum products is fairly insensitive to increased prices, at least in the short-term. Finally, even though natural gas accounts for about 20 percent of U.S. fuel-related CO₂ emissions, uncertainty exists regarding whether a cap would benefit or adversely affect output and profitability of natural gas producers (U.S. Energy Information Administration 2003, 2006c).⁶⁸

Assessments of impacts on the natural gas industry are complicated by changing conditions in natural gas markets. The increased cost of natural gas use under a cap-and-trade system tends to reduce demand for natural gas, but demand may increase because natural gas is the least carbon-intensive fossil fuel, making fuel switching to natural gas a potentially attractive emission reduction strategy. However, as the price of natural gas has increased considerably in recent years, so too has the cost of achieving emission reductions through fuel switching. While the cost of natural gas for electricity generation was little more than twice that of an equivalent amount of coal (on an energy content basis) in 1999, it grew to more than five times the cost of coal in 2005 (U.S. Energy Information Administration 2007).

Of course, the extent of impacts on coal producers and other industries depends on a cap's stringency — the more stringent the cap, the higher the market price of allowances, and the greater the impact on affected industries. Rather than creating abrupt and significant impacts, policies that gradually increase a cap's stringency may instead only slow the expansion of even the most affected industries, lessening transition costs as workers, communities, and regions adjust to a cap.⁶⁹

Among firms that consume fossil fuels and electricity, impacts will likely be most pronounced in energy and emissions-intensive industries (Bovenberg and Goulder 2003; Smith, Ross, and Montgomery 2002; U.S. Energy Information Administration 2003; Jorgensen *et al.* 2000). For example, some of the most affected industries will be petroleum refiners and manufacturers of

⁶⁸ There will likely be positive distributional impacts on non-fossil fuel producers of energy, including nuclear and renewable generators.

⁶⁹ For example, an EIA analysis of the National Commission on Energy Policy's (2004) proposed cap estimated that coal production would continue to grow through at least 2025, though at a slower rate than would be the case without a climate policy (U.S. Energy Information Administration 2005).

chemicals, primary metals, and paper.⁷⁰ Among industries experiencing similar increases in their costs, impacts will be greatest in globally competitive industries that are least able to pass through higher costs without experiencing reduced demand for their output. Also, some of the most economically affected industries may be relatively small, even with respect to their contribution to aggregate CO₂ emissions.⁷¹ Finally, industry-level impacts may obscure significant variation in firm-level impacts within an industry. The electricity sector offers an important example of this point.

3.4.2 *Effects on the Electricity Sector*

Regional variation in electricity sector impacts will be greater than in many other sectors because of regional differences in the composition of power plants (including fuel type), physical limits on interregional electricity trading, and state regulation of electricity markets. Increases in the cost of electricity generation depend on the carbon-intensity of a region's generation, which varies widely across the country. For example, Washington state, which has abundant hydroelectric power, emitted 0.15 tons of CO₂ per megawatt hour in 2005, while Indiana, which largely depends on coal-fired generation, emitted 0.94 tons per megawatt hour (U.S. Energy Information Administration 2006a).

The ultimate impact of these costs on consumers and generators depends, in large part, on state regulation of electricity markets. The mechanism by which generation costs are passed through to consumer rates fundamentally differs between states under traditional cost-of-service regulation and those with restructured electricity markets.⁷² Under cost-of-service regulation, rates reflect the average cost of all generation necessary to meet demand. Therefore, in cost-of-service regions, the cost of a cap will be passed through to consumers (net of the cost of allowance purchases or sales) in the form of rate increases that reflect increases in average generation costs. As a result, consumers in cost-of-service regions effectively bear all of the costs that a cap initially imposes on generators, while generators, for the most part, fully recover compliance costs through higher rates.⁷³ Two-thirds of U.S. electricity generation and more than three-quarters of all coal-fired generation are located in states with cost-of-service regulation.⁷⁴ So, much of a cap's impact on the electricity sector will be passed directly on to consumers.

In restructured markets, rates are based on wholesale electricity prices where, under typical

⁷⁰ These industries accounted for two-thirds of manufacturing sector CO₂ emissions in 2002, but only 13 percent of manufacturing employment and 25 percent of the value of manufacturing shipments. Unlike other industries listed here, refiners experience both increased production costs for their production-related emissions and reduced demand as consumers seek to limit emissions from the use of petroleum products (U.S. Energy Information Administration 2006d; U.S. Bureau of the Census 2005).

⁷¹ For example, lime manufacturing accounts for less than one percent of fuel-related manufacturing emissions, but it may incur among the greatest percentage increases in costs (Morgenstern *et al.* 2002; U.S. Energy Information Administration 2002).

⁷² This description of regulated and restructured markets simplifies many of the institutional differences that will affect the pass-through of allowance costs.

⁷³ Of course, regulated utilities experience some impacts, such as reduced electricity sales.

⁷⁴ Whereas coal accounted for 61 percent of total generation in cost-of-service regions in 2004, it accounted for only 35 percent of generation in restructured markets.

conditions, those prices are determined by the incremental cost of the most expensive generation required to meet demand. Therefore, in restructured markets, rate increases from a cap will depend on the cap's effect on the cost of marginal generation, regardless of its effect on total generation costs, and regardless of how allowances have been allocated. The cost of marginal generation typically varies less across the country than does average generation cost. As a result, there will likely be less regional variation in rate impacts across restructured markets than across markets still under cost-of-service regulation.

While generators subject to cost-of-service regulation will generally fully recover increased costs under a climate policy, a cap-and-trade system's effect on generator profitability in restructured regions depends on several factors, including how an individual generator's costs change relative to the cap's effect on wholesale electricity prices, the resulting effects on plant utilization, and the mechanism used for allowance allocation. For some generators, such as non-emitting renewable and nuclear plants that have no allowance costs, electricity price increases from the cap will lead to increased profitability. For others, such as coal-fired generators, price increases will not sufficiently offset increases in costs, leading to reduced profitability. However, even among the most adversely affected coal generators, some of a cap's costs will be offset by increased electricity prices.

3.4.3 Effects on Household Expenditures and Income

While attention often focuses on a cap's impacts on particular industries, the ultimate burden will be borne by households primarily in the form of increased expenditures on energy and other goods and services, but also through changes in labor income (including job losses) and investment income (i.e., stock and mutual fund returns) that arise from impacts on firms. Low-income households tend to spend a larger share of their income on energy-intensive (and, thereby, carbon-intensive) goods and services than do high-income households. As a result, higher fuel prices will likely have a regressive effect on households; that is, expenditures will increase by a greater percentage of household income for low-income than for high-income households. However, the degree of regressivity may not be very large (Poterba 1991; Metcalf 1999; Dinan 2007; Parry 2004). Further, this regressivity may be counterbalanced by the fact that adverse impacts on investment returns resulting from a cap's effect on the profitability of firms will fall most heavily on high-income households.

3.4.4 Effects on Government

Federal and state governments will also bear a significant share of the costs imposed by an emissions cap. By increasing energy and goods prices, a cap directly increases the level of government expenditures that is necessary to provide government services. These increased prices also indirectly lead to higher government spending on programs such as Social Security, whose outlays are adjusted to account for inflation. In addition, by reducing economic activity and thereby the tax base, a cap reduces government tax receipts. The Federal government can retain a share of auction revenue to offset any increased deficits (Smith, Ross, and Montgomery 2002; Dinan 2007). On the other hand, the government will receive increased corporate tax revenues from firms with increased profitability due to the cap-and-trade system.

3.4.5 Regional Variation in Impacts

Many effects from a CO₂ emissions cap will be similar nationwide, including impacts on the cost of using fossil fuels. However, there will be significant regional variation in economic impacts due to factors such as regional differences in electricity rate impacts and in the intensity of energy use. For example, one study found that an economy-wide cap imposing an allowance price of \$10 per ton of CO₂ would increase average annual household energy expenditures by a range of about \$100 to \$240 across different counties (Pizer *et al.* 2006). Because electricity accounts for a significant share of household energy use, regional differences in rate impacts are a key driver of this variation.

A cap's impact on regional economic activity and employment may vary more dramatically than impacts on household energy expenditures. First, regional economies vary greatly in their reliance on the industrial sectors that are most likely to be adversely affected by a cap. Second, the factors affecting impacts on a particular industry are quite varied, including the industry's energy-intensity, the carbon-intensity of energy used, electricity rate impacts, and the industry's ability to pass on increased costs to consumers. The carbon intensity of commercial and industrial output provides a proxy for some, but not all, of these factors. The carbon-intensity of output in some states can be over 15 times that in other states (Abt 2005).

3.4.6 *Illustrative Numerical Distribution of Costs*

Given the nature of the EPPA analysis used to estimate costs of the proposed cap-and-trade system (Paltsev *et al.* 2007a), that analysis cannot yield numerical estimates of the distribution of costs of the two policies. Instead, for illustrative purposes, Table 11 provides the approximate distribution of costs of another cap-and-trade proposal, the first of two from the National Commission on Energy Policy (2007a). The distribution is based upon an analysis using the U.S. Energy Information Administration's NEMS model, and — importantly — does not account for any cost-offsetting effects of the allowance allocation. That is, the potential effects of free distribution of allowances and the use of any auction revenues are not included. As discussed below, the allocation — whether free or auctioned — can be used to offset the costs to particular sectors.

Keeping in mind that the distribution of the actual cost burden of the program is largely independent of the point of regulation, Table 11 illustrates several general points. First, the cost burden to fossil fuel producers — overall⁷⁵ — represents a relatively small share of the total burden, less than 4 percent in this example. This is because most of the costs are passed forward. Likewise, fossil-fuel fired electricity generators bear a relatively small share of the burden, about 7 percent in this case, largely passing on costs to customers. Business and industry account for about 29 percent of the total cost burden for their primary energy use and another 26 percent for their electricity use, so that the total increase in business and industry expenditures amounts to about 55 percent of the total cost burden. The remaining 35 percent of the costs are borne by households in terms of their increased expenditures for primary energy (22 percent) and electricity (13 percent). In truth, the final household share of the cost burden is likely to be greater than this, because many businesses will pass some of their costs forward to consumers in the form of higher prices for goods and services (National Commission on Energy Policy 2007a).⁷⁶

⁷⁵ “Overall” refers to the fact that the statement is about the sector as a whole. Individual firms can bear disproportionately large or small burdens.

⁷⁶ Another perspective on the distribution of costs was provided by Goulder (2002) for a program that would cut emissions by 23 percent. He found that this would lower stock values by 54 percent in the coal sector, 20 percent for

3.4.7 *Distributional Impacts of the Allowance Allocation*

This proposal recommends that the cap-and-trade system begin with a hybrid approach to allowance allocation wherein half of the allowances are auctioned and half are freely distributed to entities in proportion to their burden under the policy. The half that are auctioned will generate revenue that can be used for public purposes, including compensation for program impacts on low-income consumers, public spending for related research and development, reduction of the Federal deficit, and reduction of distortionary taxes. The share of allowances that are freely distributed should decline over time, until there is no free allocation 25 years into the program.⁷⁷

The aggregate value of allowances will be much greater than the total cost burden to the economy. The value of allowances will be two to four times greater than the total cost of the program in most years under either of the cap trajectories (Table 12). Therefore, even a partial free distribution of allowances provides an opportunity to address the distributional cost burdens of the policy by using allowances to compensate the most burdened sectors and individuals.

While there are some important exceptions, in competitive markets the benefits of freely distributed allowances will generally accrue only to their recipients. While free allocations will increase recipients' profitability or wealth, free allocations generally will not benefit consumers, suppliers, or employees of those recipients. Hence, while the cost burden itself can be expected to ripple through the economy, as explained above, the benefits of free distribution of allowances will not do so. This is why in competitive markets (including deregulated electricity markets), free distribution of allowances should be directly targeted at those industries, consumers, and other entities that are particularly burdened. As the numbers in Table 12 indicate, only a share of allowances need to be freely distributed to meet compensation objectives.

On the other hand, in cost-of-service regulated markets utilities pass allowance costs on to consumers in modified rates, and so consumers are likely to be the beneficiaries of the value of freely distributed allowances.⁷⁸ Thus, free allocations to these utilities will reduce the rate impacts on consumers by reducing the net cost of the policy for the utilities.

4. COMPARISON OF CAP-AND-TRADE PROPOSAL WITH ALTERNATIVE PROPOSALS

The alternatives to the cap-and-trade approach that are most frequently considered by policy makers for the purpose of reducing CO₂ and other GHG emissions fall within the general category of

firms in the oil and gas sector, and 4 percent for electric and gas utilities. It should be noted that such losses in stock values are widely dispersed among investors.

⁷⁷ Over time the private sector will adjust to the carbon constraints, including industries with long-lived capital assets, reducing the justification for free distribution.

⁷⁸ In the case of the SO₂ allowance trading program, Lile and Burtraw (1998) found that state utility commissions required utilities to pass-through to consumers nearly all the cost savings from the use of freely allocated allowances (including any revenues from allowance sales).

standards-based policies (also often characterized as conventional regulatory approaches).⁷⁹ In addition, among economists and other policy analysts, there has been considerable discussion of the possible use of carbon taxes. In this section of the article, these two approaches are compared with cap-and-trade.

4.1 Standards Based Policies

Technology or performance standards are a commonly proposed means of achieving emission reductions. Examples include efficiency standards for appliances, vehicle fuel-economy standards, best available control technology (BACT) standards, and renewable portfolio standards for electricity generators. Standards could serve as either substitutes or complements to cap-and-trade system. For example, instead of including vehicle emissions under a cap, as proposed here, emission reductions from those sources could be achieved through more stringent Corporate Average Fuel Economy (CAFE) standards. Alternatively, CAFE standards could be increased within the context of an economy-wide cap.⁸⁰ In the sections following, I compare standards with cap-and-trade in regard to environmental effectiveness, cost effectiveness, and distributional equity.

4.1.1 Environmental-Effectiveness of Standards

Because of practical limitations, most standards to address CO₂ emissions would target energy use or emission rates from new capital equipment, such as appliances, cars, or electricity generators.⁸¹ The fact that standards would affect new, but not existing equipment limits the opportunity for near-term emission reductions. It also makes the level and timing of those reductions dependent on the rate of capital stock turnover, and thereby difficult to predict.

Moreover, by increasing the cost of new capital stock without affecting the cost of using the existing capital stock, standards on new sources have the perverse effect of creating incentives to delay replacement of existing capital stock, which can significantly delay the achievement of emission reductions (Stavins 2006). New Source Review regulations are a prominent example of how new source standards can delay capital stock turnover.⁸²

In addition, the tendency with standards (and taxes) to grant exemptions to address distributional issues weakens the environmental effectiveness of these instruments (and drives up costs), whereas distributional battles over the allowance allocation in a cap-and-trade system do not raise the overall cost of the program nor affect its climate impacts.

More broadly, if standards are applied for selective purposes but within the umbrella of an economy-wide CO₂ cap-and-trade system, the standards will offer no additional CO₂ benefits, as long as the cap-and-trade system is binding.

⁷⁹ Such policies are also frequently referred to as “command-and-control” regulation because they dictate the adoption of particular measures to reduce emissions or set source-specific emission limits.

⁸⁰ See, for example: National Commission on Energy Policy 2004.

⁸¹ In most cases, retrofitting equipment to increase efficiency or reduce CO₂ emissions is impractical.

⁸² Incentives to delay new investments would be lessened if standards were implemented along with a cap-and-trade system, which raises the cost of operating existing, more emissions-intensive equipment (Stavins 2006).

4.1.2 *Cost Effectiveness of Standards*

When considered as an alternative to a well-designed cap-and-trade system, standards-based approaches are less cost-effective.⁸³ The extent to which they are less cost-effective depends on several factors. First, administrative limitations constrain the scope of sources that can be covered by a standards-based approach, compared with an upstream, broad-based cap-and-trade system. For example, standards could not practically target all types of energy-consuming industrial equipment. As with a cap with a limited scope of coverage, this constraint on the scope of sources that standards can cover increases the cost of achieving emission reductions.

Second, standards may not target all determinants of emissions from covered sources. Consequently, they may not bring about many types of potentially cost-effective emission reductions from a given source. For example, technology standards do not influence the rate at which less-efficient capital stock is replaced or the intensities with which old and new capital stock are used. In fact, by lowering operating costs, standards that increase the energy efficiency of equipment can create incentives for more intensive use than would occur absent the standards.⁸⁴

Third, standards often impose uniform requirements on all entities using a given type of equipment or operating a given type of facility, even though the cost of emission reductions achieved by such standards may vary widely across regulated entities (Newell and Stavins 2003). Important sources of variation that standards typically fail to account for include variation in how intensively regulated equipment is used by different firms or households, and variations in the carbon-intensity of energy consumed. For example, air conditioner efficiency standards impose uniform requirements nationwide despite significant differences in air conditioner use — and hence differences in the value of increased efficiency — between hot and cool climates. Furthermore, these standards have the same effect on electricity use regardless of whether the avoided electricity generation is carbon-intensive (such as generation from coal plants in the Midwest), or non-emitting (such as generation from hydro facilities in the Northwest). While policymakers could lower the overall cost of standards by targeting them to reflect the myriad different circumstances of affected sources, such efforts are administratively infeasible.⁸⁵

Compared with market-based policies, standards yield weaker incentives for the development of new emission-reduction technologies. For example, air conditioner standards would not provide

⁸³ In theory, standards could potentially be more cost-effective when the measurement and monitoring of actual emissions or fuel use is particularly costly, compared with the measurement and monitoring of actions that could be required by standards.

⁸⁴ This “rebound effect” leads to an increase in emissions that offsets, to some degree, the reductions achieved by standards.

⁸⁵ Some of the cost disadvantages associated with standards can be reduced through careful design, including providing firms with greater compliance flexibility. For example, while air conditioning standards impose minimum efficiency requirements on all air conditioning units, CAFE standards allow manufacturers to meet fuel efficiency requirements on average. Moreover, a Congressional Budget Office study found that the cost of CAFE standards could be reduced by 16 percent if manufacturers were offered more flexibility to meet those standards, in the form of credits that could be traded among manufacturers (U.S. Congressional Budget Office 2003). In addition, many state Renewable Portfolio Standards allow utilities the flexibility to meet standards for minimum shares of renewable generation by purchasing credits from renewable electricity generators.

clear or certain rewards for the development of air conditioners that are more efficient than required by the standards. By contrast, market-based policies do not have such a threshold effect: they offer incentives for innovations that yield any level of increased efficiency or emission reductions. This difference in incentives is particularly acute for more advanced technologies that are still in the innovation phase and have not yet been sufficiently deployed to have any associated standards.

As new technologies emerge and increasingly stringent emission targets must be met, pursuit of a standards-based approach would require continual adjustments to the standards to ensure that emission reduction responsibilities continue to be distributed across regulated sources in a reasonably cost-effective manner. The administrative costs associated with this need for continual adjustments would be significant. By contrast, under a cap-and-trade system, only the emissions cap needs to be changed over time. Firms and households will respond to emerging technologies and increasing carbon price signals by adopting those technologies, measures, and efficiency improvements that offer the least costly emission reductions.

Standards have also been proposed as complements to market-based policies. A number of factors affect whether complementary use of standards would affect overall emission reduction costs. On the one hand, standards may needlessly restrict the flexibility that allows market-based policies to minimize the cost of achieving emission targets. For example, air conditioner standards require consumers to purchase more expensive, efficient equipment, regardless of whether they use the equipment enough to justify the increased cost. In contrast, a market-based policy would provide consumers with incentives to adopt more efficient equipment. But such a policy would still allow consumers to purchase equipment that strikes the best balance between long-run efficiency and up-front costs.

As indicated above, if standards are applied within the umbrella of an economy-wide CO₂ cap-and-trade system, the standards will offer no additional CO₂ benefits, as long as the cap-and-trade system is binding, but depending upon the nature of the standard and its associated costs, its placement can drive up aggregate costs.⁸⁶

On the other hand, as emphasized above, some market failures affecting the development and adoption of less emissions-intensive technologies may not be addressed by a cap-and-trade (or carbon tax) policy. For example, consumers may not have sufficient information to evaluate properly energy-efficiency investment decisions, such as information relating to the full life-cycle costs of alternative product models.⁸⁷ Simply increasing the cost of emitting GHGs will not address the core sources of this market failure. Standards can mandate desirable investments that would not otherwise be undertaken because of this market failure, but the resulting gains from addressing the market failure may be less than the costs of the standard, such as the costs of imposing a uniform requirement even though some individuals will not benefit from it. Furthermore, other policies may better address market failures that inhibit the development and deployment of new technologies without introducing the additional costs that can make standards undesirable. Examples of such alternative policies include programs targeted at promoting research and development or information provision.

⁸⁶ For an examination of how to merge CAFE standards cost-effectively with a cap-and-trade system by allowing trading between the CAFE program and the cap-and-trade system, see: Ellerman, Jacoby, and Zimmerman 2006.

⁸⁷ For a more complete discussion of the types of market failures that may make additional complementary policies desirable, see Jaffe *et al.* 2005.

4.1.3 *Distributional Impacts of Standards*

The distributional consequences of standards depend on the specific standards being implemented, and characteristics of the markets they affect. However, a key difference exists between the distributional effects of standards and those of a cap-and-trade system: standards only impose costs associated with the emission reductions and investments required by the standards, whereas market-based policies also impose costs associated with remaining emissions.⁸⁸ Although standards do not impose allowance (or tax) costs, the differences in distributional outcomes between standards and market-based policies can be complex. Any comparison must also consider the higher social cost of the standards-based approach and the fact that, unlike standards, market-based policies offer opportunities to mitigate distributional impacts through initial allocation decisions or redistribution of tax or auction revenue.

4.2 *Carbon Taxes*

A carbon tax is a market-based alternative to a cap-and-trade system. Both policies create a carbon price signal by placing a price on CO₂ emissions. However, there is a fundamental difference in the way in which the level of that carbon price signal is determined under these two policy instruments. A carbon tax fixes the price of CO₂ emissions, and allows the quantity of emissions to adjust in response to the level of the tax. In contrast, a cap-and-trade system fixes the quantity of aggregate emissions, and allows the price of CO₂ emissions to adjust to ensure that the emissions cap is met.

4.2.1 *Environmental Effectiveness, Cost Effectiveness, and Distributional Impacts of a Carbon Tax*

In terms of environmental effectiveness, a tax does not guarantee achievement of a given emissions target, unlike a cap-and-trade system. Individual sources reduce emissions up to the point where it is less costly to pay the tax than to achieve additional reductions. Given uncertainty regarding emission reduction costs, resulting emissions may either exceed or fall below the policy target. However, because a tax limits the costs that firms will incur to achieve additional emission reductions, it provides greater certainty regarding policy marginal costs. By contrast, a cap-and-trade system (that establishes rigid annual caps) offers less certainty about policy costs *because* it provides greater certainty about emissions.

As with a cap-and-trade system, a tax can achieve emission reductions in a cost-effective manner. Furthermore, if credible commitments are made to maintain a carbon tax in future years, a tax also lowers the long-run cost of achieving emission reductions — as does a cap-and-trade system — by providing incentives for investments in the development and deployment of new technologies.

As with a cap-and-trade system, an upstream, economy-wide carbon tax would be more cost-effective than a tax with a more limited scope of coverage. A tax with a narrower scope of coverage would achieve fewer emission reductions than a comparable economy-wide tax. Consequently, a higher tax rate would be required to maintain a given level of reductions. Similarly, as with a cap, a

⁸⁸ The costs associated with remaining emissions do not represent true social costs. Rather, they are transfers from those that must (pay a tax or) purchase allowances to either the government or firms that are freely allocated the allowances.

tax can be imposed upstream on fuel suppliers or downstream on emission sources. The administrative costs for an economy-wide tax would be minimized through an upstream point of regulation, that is, a tax on the carbon content of fossil fuels. While such a tax on the carbon content of fuel (or on direct emissions) would minimize the cost of emission reductions, that cost would be increased if the tax were set on some other basis, such as the energy content or value of fuel. Such taxes would create inefficient and uneven incentives for emission reductions.⁸⁹

The distributional consequences of a carbon tax would be similar to those of a cap-and-trade system in which all allowances are auctioned. Both approaches put policymakers in the position of having to decide how to use resulting revenues. Moreover, before any use or redistribution of that revenue, a tax's impacts on affected firms and households are the same as those from a cap-and-trade with an auction in which the resulting allowance price is identical to the tax. However, a carbon tax and a cap-and-trade system do differ in the options each presents to mitigate economic impacts. Although a tax cannot compensate affected entities through free allocation of allowances, policymakers can mitigate a tax's burden by redistributing tax revenue — much like in an auction — or by granting fixed tax exemptions (Goulder 2000; Nordhaus and Danish 2003).

Fixed exemptions reduce a firm's overall tax burden by taxing emissions only when they exceed the amount of the exemption. Unless the exemptions are tradable, however, their use may adversely affect the cost-effectiveness of a tax if a firm's exemption exceeds its actual emissions. In this case, the firm has no incentive to undertake emission reductions (no matter how cost-effective such reductions might be). In contrast, because a firm under a cap-and-trade system can sell any excess allowances (whether it purchased them or received them for free), it always has an incentive to reduce emissions, regardless of the initial quantity of allowances that it receives.

As with free allocations to a firm, exemptions for a taxed firm do not benefit that firm's workers, customers or suppliers, who indirectly experience a portion of the tax's burden. Thus, additional measures would be needed to compensate entities that are not directly subjected to the carbon tax. While tradable tax exemptions and redistribution of tax revenues theoretically provide flexibility to achieve the same distributional outcomes as could be achieved under a cap-and-trade approach, political and practical considerations may impose constraints on achieving similar outcomes in practice.

4.2.2 *Apparent Advantages of a Carbon Tax*

An upstream carbon tax — like an upstream cap-and-trade system — could include (tax) credits to provide incentives for downstream carbon capture and sequestration at electricity generators. Such an upstream carbon tax would appear to have some advantages over an equivalent upstream cap-and-trade system.

First is the simplicity of the carbon tax system, in which firms would not need to manage and trade allowances, and the government would not need to track allowance transactions and ownership. Experience with previous cap-and-trade systems, however, indicates that the costs of trading institutions are not great. Whether a policy as significant as a meaningful national carbon tax would turn out to be simple in its implementation is an open question. Second, the tax approach

⁸⁹ Compared with a carbon tax, it would cost 20 to 40 percent more to achieve a particular emissions target through a tax on energy content (for example, a BTU tax), and two to three times more through an *ad valorem* tax (Stavins 1997).

avoids the political difficulties related to making allowance allocations among economic sectors, but would — on the other hand — create pressures for tax exemptions.

Third, a carbon tax would raise revenues that can be returned to individuals, be used to lower distortionary taxes, finance climate-related programs, fund other government programs, reduce the deficit, or provide assistance to sectors most burdened by the policy. Of course, an auction mechanism under a cap-and-trade system can do the same. Particular attention has been given by economists to the potential use of tax revenue for reducing distortionary taxes, and thereby reducing the aggregate net costs of the policy. Considering the fact that a \$10/ton CO₂ tax would raise about \$50 billion per year — more than 7 percent of Federal personal income taxes — this is an attractive possibility. It should be recognized, however, that the carbon tax revenue might be spent on the “wrong tax cuts” and/or on other government programs that have benefits smaller than costs, thereby increasing the social costs of the climate policy, relative to free distribution of allowances under a cap-and-trade system.

Fourth, a tax approach eliminates the potential for price volatility that can exist under a cap-and-trade system. Some emissions trading markets have exhibited significant volatility in their early years, including: the U.S. NO_x Budget program (where prices increased in the presence of uncertainty about whether Maryland, a net supplier, would enter the program on time); the RECLAIM program in southern California (where price spikes were linked with flawed design and problems with electricity deregulation); and the European Union Emissions Trading Scheme (where a dramatic price crash occurred when data revealed that the overall allocation had been *above* the BAU level). In principle, such price volatility with a cap-and-trade approach could deter investments in carbon-reducing capital and in research and development with high up-front costs and uncertain longer-term payoff. From an economic perspective, it makes sense to allow emissions to vary from year to year with economic conditions that affect aggregate abatement costs; and this happens automatically with a carbon tax. With a cap-and-trade system, this temporal flexibility needs to be built in through provisions for banking and borrowing, as proposed above.

4.2.2 *Apparent Disadvantages of a Carbon Tax*

First among the disadvantages of a carbon tax, relative to cap-and-trade regime, is the overriding resistance to new taxes in the current political climate. However, no policy proposal should be ruled out on this basis, and it is conceivable that carbon taxes may be politically feasible in future years, when and if there are changes in political leadership and public opinion. In the meantime, a distinct advantage of a cap-and-trade system is the greater familiarity and comfort with it that exists among key stakeholders. Phrased differently, a tax approach focuses political attention on prices, revenues, and costs, whereas cap-and-trade discussions tend to keep the focus on the environment.

Second, in their simplest respective forms (a carbon tax *without* revenue recycling, and a cap-and-trade system *without* auctions), a carbon tax is more costly than a cap-and-trade system to the regulated sector, because with the former firms incur both abatement costs and the cost of tax payments to the government. In the case of the simplest cap-and-trade system, the regulated sector experiences only abatement costs, since the transfers associated with allowance purchase and sale remain within the private sector. This straightforward difference between taxes and cap-and-trade can be diminished or even eliminated, however, in the presence either of tax revenue recycling or allowance auctioning.

Third, cap-and-trade approaches leave distributional issues up to politicians, and provide a straightforward means to compensate burdened sectors, and address so-called “competitiveness concerns.” Of course, the compensation associated with free distribution of allowances based on historical activities can be mimicked under a tax regime, but it is legislatively more complex. The cap-and-trade approach avoids likely battles over tax exemptions among vulnerable industries and sectors that would drive up the costs of the program, as more and more sources (emission-reduction opportunities) are exempted from the program, thereby simultaneously compromising environmental integrity. Instead, a cap-and-trade system leads to battles over the allowance allocation, but these do not raise the overall cost of the program nor affect its climate impacts. Some observers seem to worry about the political process’ propensity under a cap-and-trade system to compensate sectors that effectively claim burdens (through free allowance allocations). A carbon tax is sensitive to the same pressures, and may be expected to succumb to them in ways that are ultimately more dangerous.

Fourth, a carbon tax provides much less certainty over emissions levels (in exchange for greater certainty over costs). Most climate policy proposals are for progressively greater cuts in emissions over time. Cap-and-trade is fundamentally well suited to this because it is a quantity-based approach. Progress under a carbon tax will be uncertain, mainly due to variations in economic conditions. More broadly, the flexibility provided by cap-and-trade means that it can replicate virtually all of the key aspects of a tax, such as by employing allowance auctions and a cost containment mechanism.

Fifth and finally, a cap-and-trade system is much easier to harmonize with other countries’ carbon mitigation programs, which are more likely to employ cap-and-trade than tax approaches. Cap-and-trade systems generate a natural unit of exchange for harmonization: allowances denominated in units of carbon content of fossil fuels (or CO₂ emissions).

Despite the differences between carbon taxes and cap-and-trade systems in specific implementations, the two approaches have much in common. Differences between the two approaches can begin to fade when various specific implementations of either program are carried out. Hybrid schemes that include features of taxes and cap-and-trade systems blur the distinctions between the two (Parry and Pizer 2007). In terms of the allocation mechanism, the government can auction allowances in a cap-and-trade system, thereby reproducing many of the properties of a tax approach. Mechanisms that deal with uncertainty in a cap-and-trade system also bring it close to a tax approach, including a cost containment mechanism that places a cap on allowance prices, banking that creates a floor under prices, and borrowing that provides flexibility similar to a tax. To some degree, the dichotomous choice between taxes and permits can turn out to be a choice of design elements along a policy continuum.

In the meantime, debate continues among economists regarding cap-and-trade and carbon taxes. In a recent comparison of these two approaches, the Hamilton Project staff at the Brookings Institution concluded that a well-designed carbon tax and a well-designed cap-and-trade system would have similar economic effects (Furman, Bordoff, Deshpande, and Noel 2007). Hence, they concluded, the two primary questions that should be used to decide between these two policy approaches are: (1) which is more politically feasible; and (2) which is more likely to be well-designed? In the context of the United States (and many other countries, for that matter), the answer to the first question is obvious. For the political economy reasons I described above, the answer to the second question also favors cap-and-trade. In other words, it is important to identify and design

policies that will be “optimal in Washington,” not just from the perspective of Cambridge, New Haven, or Berkeley.

5. COMMON OBJECTIONS AND RESPONSES

In the past, a variety of objections have been raised to the use of cap-and-trade systems in general or to the specific application of the cap-and-trade mechanism to CO₂ and other GHG reduction. In this section, these objections are briefly described, and brief responses are provided.

5.1 “*Cap-and-Trade is Unethical — It Allows Firms to Buy and Sell the Right to Pollute.*”

Over the 25 years in which market-based instruments have become an accepted part of the portfolio for environmental regulation, there has been considerable diminishment in the frequency of claims that cap-and-trade systems are morally flawed because they allow firms to “buy and sell the right to pollute.” But the argument has been made as recently as the late 1990s, and in the context of global climate change policy, that the cap-and-trade approach is unethical because it eliminates the moral stigma which should exist for polluting (Sandel 1997). However, few would agree that people are behaving immorally by cooking dinner, heating their homes, turning on a light, or using a computer, despite the fact that all of these activities result in CO₂ emissions (Gaines 1997).

5.2 “*Cap-and-Trade Creates Hot Spots of Pollution.*”

Because GHG emissions uniformly mix in the atmosphere, there are no hot spots of GHG emissions themselves. The question is whether localized pollutants whose emissions are correlated with the emissions of a GHG might become excessively concentrated in particular areas as a result of allowance trading activity. This concern has frequently been expressed in California’s debates regarding a potential cap-and-trade system to implement AB 32.

The answer to this concern is simple: a cap-and-trade system for GHG emissions would not supplant existing local air quality regulations. If a firm’s actions in engaging in an emission trade would violate local air quality regulations for NO_x emissions, for example, then such actions would be illegal and disallowed no matter how many GHG emission allowances were obtained. Thus, a cap-and-trade system for GHG emissions would not interfere with local air quality regulations — only legal trades would be legal.

5.3 “*Upstream Cap-and-Trade Will Have Minimal Effects on the Transportation Sector.*”

Approximately one-third of U.S. CO₂ emissions from energy consumption are from the transportation sector. An upstream cap-and-trade system that provides a uniform price signal for cost-effective emissions reductions economy-wide will lead to the achievement of those emissions reductions wherever they are least costly. This almost certainly will not mean proportionate reductions in emissions from each type of source or each economic sector. And it is quite true that the greatest percentage emissions reductions would be in the electric power sector, followed by the industrial sector, with much smaller percentage reductions in the commercial, transportation, and residential sectors. From an economic perspective (that is, cost effectiveness), this is both appropriate and desirable, if the reason for the policy is climate change. If there are other, non-climate related reasons for concerns about the use of transportation fuels, such as so-called oil-dependency, then those concerns should be addressed through other, appropriate policies (Sandalow

2007).

5.4 “It Would Be Better to Begin with Narrow Coverage Across a Few Sectors.”

It has been argued that for political expediency, it would be better to initiate a cap-and-trade system with narrow coverage of only a few sectors, and to broaden that coverage over time, rather than employing an economy-wide system such as that proposed here. There are several problems with beginning with narrow coverage. First, narrow coverage is inevitably more costly for whatever environmental gains are achieved, because some of the low-cost emission-reduction opportunities are unavailable. Second, in terms of the political forces that are at the heart of the recommendation for narrow coverage, it makes much more sense to begin broadly, and then go deep (Schmalensee 1998). Resistance from uncovered sectors will only increase as the stringency of policy and respective economic burdens increase, a lesson that can be observed in the debates surrounding proposals to expand the sectoral coverage of the European Union’s downstream cap-and-trade program.

5.5 “A Cap-and-trade System Will Create Barriers to Entry and Reduce Competition.”

It is true — in principle — that emissions allowances have considerable value, and could be used strategically by incumbent firms to keep new entrants from competing in respective product markets. It is for this reason that the SO₂ allowance trading program provides an annual allowance auction so that the government can be a source of last resort. In experience, however, there has been no evidence in any implemented cap-and-trade system that allowances have been withheld from the market by incumbent firms for strategic purposes. Furthermore, the proposed CO₂ cap-and-trade system includes a large auction of allowances from the very beginning.

5.6 “The Price Spike in RECLAIM and the Price Drop in the EU ETS Demonstrate that Extreme Price Volatility is an Inherent Part of Cap-and-Trade Systems.”

It is unquestionably true that a cap-and-trade system fixes the quantity of aggregate emissions, and allows the price of CO₂ emissions to adjust to ensure that the emissions cap is met. A cap-and-trade system (at least one that establishes *rigid* annual caps) therefore offers less certainty about costs *because* it provides greater certainty about emissions. But the significant price volatility that was observed in the RECLAIM program and the European Union Emissions Trading Scheme are associated with particular, problematic design features, as well as special circumstances.

The price spike observed for NO_x allowances during the California electricity crisis was partly a consequence of design flaws in the RECLAIM program and partly a consequence of the electricity crisis itself. RECLAIM does not allow banking from one period to the next, and thereby does not provide incentives for facilities to install pollution control equipment that would have allowed them to reduce their current emissions and bank allowances for the future. The result was that during the 2000-2001 electricity crisis some units facing high demand levels were unable to purchase allowances for their emissions. When emissions essentially exceeded allowances, an allowance price spike occurred. Even in the context of the electricity crisis and the absence of an allowance bank, the price spike would still not have occurred had a safety valve or other cost-containment mechanism been available in the RECLAIM market.⁹⁰

⁹⁰ In RECLAIM, a “safety-valve” price of \$15,000/ton had been written into the regulations as a feature that *could* be

In terms of the allowance price collapse observed in the spring of 2006 during the pilot phase of the EU ETS, this was a consequence of a combination of the design of the system, generous allowance allocations, data problems, and modeling mistakes. In the spring of 2006, when it became clear that the allocation of allowances had exceeded emissions, a dramatic fall in allowance prices occurred.

Another claim has been that as it now appears that the EU may not meet its aggregate target under Kyoto, the fault is with the EU ETS. The real reason is that the downstream system covers only 45% of European CO₂ emissions. The failures to reduce emissions are concentrated in the sectors *not* covered by the program.

Likewise, observations of windfall profits among electric power producers have been said to be evidence of an inherent problem with cap-and-trade. Here too, the evidence is otherwise. As explained above, the program's guidelines call for at least 95 percent of allowances to be freely distributed in the first compliance period, and most countries freely distributed 100 percent of their allowances. This is in contrast with the cap-and-trade system proposed here, which provides for 50 percent of the allowances to be auctioned initially, this share rising to 100 percent over 25 years.

5.7 “A Cap-and-Trade System Will Put the United States at a Competitive Disadvantage with Other Countries”

Ever since the passage of the Byrd-Hagel resolution in the U.S. Senate in 1997, there has been great concern, much of it understandable, about the effects of climate policy on domestic manufacturing and employment. In principle, any domestic policy that drives up the cost of producing goods and services in proportion to the CO₂ emissions caused by that production can have the effect of shifting comparative advantage in the production of those goods and services to other countries that are not taking on similar costs. This is the phenomenon behind emissions leakage.

It is for this reason that the cap-and-trade system proposed here is linked with the actions of other key nations. In particular, imports of highly carbon-intensive goods (in terms of their emissions generated during manufacture) from countries which have not taken climate policy actions comparable to those in the United States would be required to hold appropriate quantities of allowances. This will establish a level playing-field among domestically produced and imported products, reduce emissions leakage, and may help induce some key developing countries to join an international agreement.

6. SUMMARY AND CONCLUSIONS

The need for a domestic U.S. policy that seriously addresses climate change is increasingly apparent. A cap-and-trade system is the best approach for the United States in the short to medium term. Besides providing greater certainty about emissions levels, cap-and-trade offers an easy means of compensating for the inevitably unequal burdens imposed by climate policy; it is straightforward to harmonize with other countries' climate policies; it avoids the current political aversion in the United States to taxes; and it has a history of successful adoption.

made operational. It was *not* operational, however, when the price spike occurred and it was needed.

The system I describe in this article has several key features. It imposes an upstream cap on CO₂ emissions (carbon content measured at the point of fuel extraction, refining, distribution, or importation), with gradual inclusion of other greenhouse gases, to ensure economy-wide coverage while limiting the number of entities to be monitored. It sets a gradual downward trajectory of emissions ceilings over time, to minimize disruption and allow firms and households time to adapt. It also includes mechanisms to reduce cost uncertainty; these include provisions for banking and borrowing of allowances, and a cost containment mechanism to protect against price volatility.

Initially, half of the program's allowances would be allocated through auctioning and half through free distribution, primarily to those entities most burdened by the policy. This arrangement should help limit potential inequities while bolstering political support. The share distributed for free would be phased out gradually over twenty-five years. The auctioned allowances would generate revenue that could be used for a variety of worthwhile public purposes.

The system would operate at the federal level, eventually asserting supremacy over all regional, state, and local systems, while building on any institutions already developed at those levels. The system would also provide for linkage with international emissions reduction credit arrangements, harmonization over time with effective cap-and-trade systems in other countries, and appropriate linkage with other actions taken abroad to maintain a level playing field between imports and import-competing domestic products. To address potential market failures that might render the system's price signals ineffective, certain complementary policies should be implemented, for example in the areas of consumer information and research and development.

Like other market-based emissions reduction schemes, the one described here reduces compliance costs by offering regulated entities flexibility. Rather than mandating specific measures on all sources, it allows emissions to be reduced however, wherever, and, to some extent, whenever they are least costly. To illustrate the potential cost savings, I have reported empirical cost estimates for two hypothetical trajectories for emissions caps. The first stabilizes CO₂ emissions at their 2008 level by 2050, whereas the second reduces emissions from their 2008 level to 50 percent below the 1990 level by 2050. Both are consistent with the often cited global goal of stabilizing CO₂ atmospheric concentrations at between 450 and 550 ppm, provided all countries take commensurate action. The analysis found significant but affordable impacts on GDP under both trajectories: generally below 0.5 percent a year for the less aggressive trajectory, and ranging up to 1 percent a year for the more aggressive one.

The impact of any U.S. policy will ultimately depend on the actions of other nations around the world. Without an effective global climate agreement, each country's optimal strategy is to free-ride on the actions of others. But if all countries do this, nothing will be accomplished, and the result will be the infamous tragedy of the commons. A cooperative solution—one that is scientifically sound, economically rational, and politically pragmatic—must remain the ultimate goal. Given these realities, a major strategic consideration in initiating a U.S. climate policy should be to establish international credibility. The cap-and-trade system described and assessed in this article offers a way for the United States to demonstrate its commitment to an international solution while making its own real contribution to addressing climate change.

Getting serious about greenhouse gas emissions will not be cheap and it will not be easy. But if the current state-of-the-science predictions about the consequences of another few decades of inaction are correct, the time has arrived for a serious and sensible approach.

Table 1: CO₂ Emissions from Energy Consumption by Sector and Fuel Type, 2005
(Million Metric Tons)

| Sector | Coal | Oil | Natural Gas | Total ^v (Share of Total) | Indirect Emissions from Electricity Use | Total Including Indirect Electricity Emissions (Share of Total) |
|-----------------------------------|------------------|------------------|------------------|--|---|--|
| Residential | 1 | 105 | 262 | 368 (6.2%) | 886 | 1,254 (21.1%) |
| Commercial | 8 | 55 | 166 | 230 (3.9%) | 821 | 1,051 (17.7%) |
| Transportation | 0 | 1,922 | 32 | 1,953 (32.9%) | 5 | 1,959 (32.9%) |
| Industrial | 185 | 431 | 400 | 1,020 (17.1%) | 663 | 1,682 (28.3%) |
| Electricity | 1,944 | 100 | 319 | 2,375 (39.9%) | N/A | N/A |
| Total (Share of Total) | 2,138 (36.0%) | 2,614 (44.0%) | 1,178 (19.8%) | 5,945 (100.0%) | — | 5,945 (100.0%) |

SOURCE: U.S. Energy Information Administration 2006.

^aIndustrial sector total includes emissions from net coke imports not accounted for in first three columns, electricity sector total includes emissions from geothermal and waste-to-energy generation not accounted for in first three columns. Grand total also includes these additional emission sources.

Table 2: Alternative Points of Regulation for a U.S. Cap-and-Trade System

| Point of Regulation | COAL | OIL | NATURAL GAS |
|----------------------------|--|---|--|
| Upstream | Mining & Imports (500 companies) | Production Wells & Imports (750 companies) | Production Wells & Imports (750 companies) |
| Midstream | Rail, Barge, & Trucking (not addressed) | Refining (200 refineries) | Pipelines & Processing (200 pipelines or 1,250 LDCs and 500 NGL plants ^a) |
| Downstream | Power Plants (500 plants) | Mobile Sources, Industrial Boilers, and Power Plants (millions of sources) | Industrial Boilers, Commercial and Residential Furnaces, and Power Plants (millions of sources) |

SOURCE: Cambridge Energy Research Associates (2006).

^aLDCs are local distribution companies, and NGL plants are operations that produce natural gas liquids.

Table 3: BAU Emissions and Two Illustrative Cap Trajectories
(CO₂-Equivalent Million Metric Tons)

| | Scenario ^a | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---------------------------------|-----------------------|------|------|------|------|------|------|-------|-------|-------|-------|
| GHG Emissions | BAU | 7092 | 7680 | 8202 | 8596 | 9219 | 9884 | 10711 | 11507 | 12433 | 13283 |
| | Stabilize | 7092 | 7680 | 7383 | 7382 | 7382 | 7381 | 7378 | 7376 | 7374 | 7369 |
| | 50% b/1990 | 7092 | 7680 | 7226 | 6629 | 6032 | 5434 | 4836 | 4236 | 3636 | 3041 |
| CO₂ Emissions | BAU | 5984 | 6517 | 6995 | 7357 | 7915 | 8518 | 9283 | 10013 | 10871 | 11656 |
| | Stabilize | 5984 | 6517 | 6710 | 6740 | 6759 | 6782 | 6804 | 6806 | 6793 | 6762 |
| | 50% b/1990 | 5984 | 6517 | 6570 | 6036 | 5481 | 4896 | 4310 | 3702 | 3086 | 2504 |
| CH₄ Emissions | BAU | 583 | 602 | 612 | 617 | 631 | 643 | 652 | 664 | 677 | 683 |
| | Stabilize | 583 | 602 | 400 | 387 | 371 | 354 | 332 | 331 | 338 | 351 |
| | 50% b/1990 | 583 | 602 | 389 | 354 | 322 | 313 | 302 | 307 | 317 | 303 |
| N₂O Emissions | BAU | 385 | 388 | 381 | 372 | 366 | 365 | 372 | 381 | 391 | 407 |
| | Stabilize | 385 | 388 | 264 | 246 | 241 | 233 | 233 | 231 | 234 | 247 |
| | 50% b/1990 | 385 | 388 | 259 | 232 | 220 | 217 | 216 | 219 | 225 | 227 |
| FG^b Emissions | BAU | 140 | 174 | 214 | 250 | 308 | 359 | 404 | 451 | 496 | 539 |
| | Stabilize | 140 | 174 | 9 | 10 | 11 | 11 | 10 | 9 | 9 | 10 |
| | 50% b/1990 | 140 | 174 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 9 |

SOURCE: Paltsev, *et al.* 2007b, pp. 1, 5, 6.

^a“BAU” (business as usual) is the reference case from Paltsev *et al.* 2007a,b; “Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

^bFG refers to three groups of fluorinated gases: sulfur hexafluoride (SF₆), HFCs, and PFCs.

Table 4: BAU and Two Predicted Emissions Paths
(CO₂-Equivalent Million Metric Tons)

| | Scenario ^a | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---------------------------------|-----------------------|------|------|------|------|------|------|-------|-------|-------|-------|
| GHG Emissions | BAU | 7092 | 7680 | 8202 | 8596 | 9219 | 9884 | 10711 | 11507 | 12433 | 13283 |
| | Stabilize | 7092 | 7680 | 6962 | 6897 | 6715 | 6866 | 7867 | 8217 | 7739 | 7804 |
| | 50% b/1990 | 7092 | 7680 | 6331 | 6004 | 5454 | 4615 | 5700 | 5288 | 4141 | 3515 |
| CO₂ Emissions | BAU | 5984 | 6517 | 6995 | 7357 | 7915 | 8518 | 9283 | 10013 | 10871 | 11656 |
| | Stabilize | 5984 | 6517 | 6328 | 6287 | 6132 | 6290 | 7265 | 7605 | 7126 | 7175 |
| | 50% b/1990 | 5984 | 6517 | 5740 | 5443 | 4914 | 4085 | 5169 | 4650 | 3588 | 2945 |
| CH₄ Emissions | BAU | 583 | 602 | 612 | 617 | 631 | 643 | 652 | 664 | 677 | 683 |
| | Stabilize | 583 | 602 | 375 | 365 | 343 | 338 | 353 | 360 | 359 | 369 |
| | 50% b/1990 | 583 | 602 | 348 | 331 | 314 | 307 | 305 | 310 | 319 | 328 |
| N₂O Emissions | BAU | 385 | 388 | 381 | 372 | 366 | 365 | 372 | 381 | 391 | 407 |
| | Stabilize | 385 | 388 | 252 | 237 | 230 | 228 | 239 | 241 | 245 | 252 |
| | 50% b/1990 | 385 | 388 | 239 | 222 | 217 | 214 | 218 | 220 | 226 | 234 |
| FG^b Emissions | BAU | 140 | 174 | 214 | 250 | 308 | 359 | 404 | 451 | 496 | 539 |
| | Stabilize | 140 | 174 | 8 | 9 | 10 | 11 | 11 | 10 | 10 | 10 |
| | 50% b/1990 | 140 | 174 | 7 | 8 | 9 | 9 | 9 | 9 | 9 | 9 |

SOURCE: Paltsev, *et al.* 2007b, pp. 1, 2, 3.

^a“BAU” (business as usual) is the reference case from Paltsev *et al.* 2007a,b; “Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

^bFG refers to three groups of fluorinated gases: sulfur hexafluoride (SF₆), HFCs, and PFCs.

Table 5: Anticipated CO₂ Emissions Reductions Under Two Illustrative Caps
(Million Metric Tons)

| Scenario ^a | | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|-----------------------|--------------------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| BAU | Emissions | 5984 | 6517 | 6995 | 7357 | 7915 | 8518 | 9283 | 10013 | 10871 | 11656 |
| | | | | | | | | | | | |
| Stabilize | Emissions | 5984 | 6517 | 6328 | 6287 | 6132 | 6290 | 7265 | 7605 | 7126 | 7175 |
| | Reduction ^b | 0 | 0 | -667 | -1070 | -1783 | -2228 | -2018 | -2408 | -3745 | -4481 |
| | % Reduction ^c | 0 | 0 | -10% | -15% | -23% | -26% | -22% | -24% | -34% | -38% |
| 50% b/1990 | Emissions | 5984 | 6517 | 5740 | 5443 | 4914 | 4085 | 5169 | 4650 | 3588 | 2945 |
| | Reduction | 0 | 0 | -1255 | -1914 | -3001 | -4433 | -4114 | -5363 | -7283 | -8711 |
| | % Reduction | 0 | 0 | -18% | -26% | -38% | -52% | -44% | -54% | -67% | -75% |

SOURCE: Paltsev, *et al.* 2007b, pp. 1, 2, 3.

^a“BAU” (business as usual) is the reference case from Paltsev *et al.* 2007a,b; “Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

^bCompared with business-as-usual emissions in the same year.

^cCompared with business-as-usual emissions in the same year.

Table 6: Predicted CO₂ and Fossil Fuel Prices^a Under Two Illustrative Caps

| | Scenario ^b | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|-----------------------|------|------|------|------|------|------|------|------|------|------|
| CO₂ Price^c | BAU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Stabilize | 0 | 0 | 18 | 22 | 26 | 32 | 39 | 47 | 57 | 70 |
| | 50% b/1990 | 0 | 0 | 41 | 50 | 61 | 74 | 90 | 109 | 133 | 161 |
| Petroleum Product | BAU | 1.0 | 1.2 | 1.3 | 1.5 | 1.7 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 |
| | Stabilize | 1.0 | 1.2 | 1.3 | 1.5 | 1.6 | 1.7 | 1.4 | 1.4 | 1.5 | 1.5 |
| | 50% b/1990 | 1.0 | 1.2 | 1.3 | 1.5 | 1.5 | 1.6 | 1.3 | 1.4 | 1.3 | 1.2 |
| Natural Gas | BAU | 1.0 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 | 2.7 | 3.1 | 3.6 |
| | Stabilize | 1.0 | 1.1 | 1.2 | 1.5 | 1.9 | 2.4 | 2.5 | 2.8 | 2.8 | 2.8 |
| | 50% b/1990 | 1.0 | 1.1 | 1.2 | 1.4 | 1.8 | 2.1 | 2.1 | 2.2 | 2.2 | 2.0 |
| Coal | BAU | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 |
| | Stabilize | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 |
| | 50% b/1990 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.2 |

SOURCE: Paltsev, *et al.* 2007b, pp. 1, 2, 3.

^aAll fossil fuel prices are price indexes, with 2005 set equal to 1.00. Note that the price indexes do not include the cost of allowances, but do include the effects of changes in fossil-fuel supply and demand (induced by impacts of allowance prices on downstream users of respective fossil fuels).

^b“BAU” (business as usual) is the reference case from Paltsev *et al.* 2007a,b; “Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

^cYear 2005 dollars per ton of CO₂-equivalent.

Table 7: Electricity Production under Two Illustrative Caps^a

| | Scenario | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|------------|------|------|------|------|------|------|------|------|------|------|
| Coal (w/o CCS) | BAU | 7 | 8 | 8 | 9 | 10 | 12 | 13 | 15 | 17 | 19 |
| | Stabilize | 7 | 8 | 7 | 6 | 4 | 3 | 6 | 7 | 4 | 4 |
| | 50% b/1990 | 7 | 8 | 6 | 4 | 3 | 1 | .4 | 0 | 0 | 0 |
| Oil (w/o CCS) | BAU | .3 | .3 | .3 | .2 | .4 | .4 | .4 | .5 | .5 | .6 |
| | Stabilize | .3 | .3 | .2 | .2 | .1 | .1 | .2 | .3 | .2 | .2 |
| | 50% b/1990 | .3 | .3 | .2 | .2 | .1 | .1 | 0 | 0 | 0 | 0 |
| Natural Gas (w/o CCS) | BAU | 2 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 2 | 2 |
| | Stabilize | 2 | 3 | 3 | 5 | 9 | 10 | 8 | 6 | 4 | 2 |
| | 50% b/1990 | 2 | 3 | 3 | 5 | 8 | 9 | 6 | 4 | 3 | 1 |
| Nuclear | BAU | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | Stabilize | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | 50% b/1990 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Hydro | BAU | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Stabilize | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 50% b/1990 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Other Renewables | BAU | .2 | .2 | .2 | .3 | .3 | .3 | .4 | .5 | .6 | .6 |
| | Stabilize | .2 | .2 | .3 | .4 | .3 | .5 | .4 | .6 | .6 | .6 |
| | 50% b/1990 | .2 | .2 | .1 | .6 | .3 | .5 | .4 | .5 | .6 | .6 |
| Natural Gas w/CCS | BAU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Stabilize | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 50% b/1990 | 0 | 0 | 0 | .2 | .1 | .4 | .8 | .5 | .3 | .2 |
| Coal w/CCS | BAU | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Stabilize | 0 | 0 | 0 | .1 | .1 | .3 | 1 | 2 | 9 | 13 |
| | 50% b/1990 | 0 | 0 | 0 | .2 | .6 | 2 | 7 | 11 | 15 | 18 |
| Total Electricity Production | BAU | 13 | 15 | 16 | 17 | 18 | 20 | 21 | 23 | 25 | 26 |
| | Stabilize | 13 | 15 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 25 |
| | 50% b/1990 | 13 | 15 | 14 | 15 | 16 | 17 | 19 | 21 | 22 | 24 |

^aBAU, Stabilize, and 50% b/1990 as defined in previous tables. CCS = carbon capture and storage. Electricity production measured in exajoules (EJ); 1 EJ = 10¹⁸ joules. Source: Paltsev, *et al.* 2007b, pp. 1, 2, 3.

Table 8: Relationship Between CO₂ Allowance Prices and Recent Fuel Prices

| Fuel | Average Base Price ^a 2002-2006 | Added Fuel Cost for Various Allowance Prices ^b | | |
|--|--|---|------------------|------------------|
| | | \$25 | \$50 | \$100 |
| Crude Oil (\$/bbl) | \$40.00 | \$11.30 28% | \$22.60 57% | \$45.20 113% |
| Gasoline (\$/gallon) | \$1.82 | \$0.24 13% | \$0.48 26% | \$0.96 53% |
| Heating Oil (\$/gallon) | \$1.35 | \$0.27 20% | \$0.54 40% | \$1.08 80% |
| Wellhead Natural Gas (\$/mcf) | \$5.40 | \$1.38 26% | \$2.76 51% | \$5.52 102% |
| Residential Natural Gas (\$/mcf) | \$11.05 | \$1.39 13% | \$2.78 25% | \$5.56 50% |
| Utility Coal (\$/short ton) | \$26.70 | \$51.20 192% | \$102.40 384% | \$204.80 767% |

SOURCE: For base prices, Paltsev *et al.*, 2007a; added fuel costs are from author's calculations, drawing upon Table 5, page 53, in same source.

^a2005 dollars.

^bAdded cost does not include adjustment for the effects of respective cap-and-trade policies on producer prices; see Table 6.

**Table 9: Predicted Aggregate Costs — GDP and Welfare Impacts
Under Two Illustrative Caps**

| | Scenario ^a | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|--|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| BAU^b | GDP | 11,981 | 14,339 | 16,921 | 19,773 | 22,846 | 26,459 | 30,534 | 34,929 | 39,530 | 44,210 |
| | Welfare | 9,656 | 11,773 | 13,933 | 16,342 | 18,948 | 22,016 | 25,414 | 29,032 | 32,780 | 36,553 |
| % Change GDP from BAU | Stabilize | 0 | 0 | -0.22 | -0.38 | -0.55 | -0.68 | -0.33 | -0.29 | -0.36 | -0.28 |
| | 50% b/1990 | 0 | 0 | -0.51 | -0.79 | -0.67 | -0.56 | -1.18 | -1.00 | -0.61 | -0.48 |
| % Change Welfare from BAU | Stabilize | 0 | 0 | -0.01 | -0.13 | -0.36 | -0.45 | -0.19 | -0.12 | -0.24 | -0.18 |
| | 50% b/1990 | 0 | 0 | -0.04 | -0.32 | -0.69 | -1.08 | -0.77 | -0.92 | -1.28 | -1.45 |

SOURCE: Paltsev, *et al.* 2007b, pp. 1, 2, 3.

^a“BAU” (business as usual) is the reference case from Paltsev *et al.* 2007a,b; “Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

^bBillions of year 2005 dollars.

**Table 10: Potential Revenue from CO₂ Allowance Auctions
Under Two Illustrative Caps**

| Scenario ^a | | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|-----------------------|--|-------|-------|-------|-------|-------|-------|-------|-------|
| Stabilize | Total Potential CO ₂ Allowance Auction Revenue (billions of dollars per year) | 119 | 145 | 177 | 216 | 264 | 322 | 390 | 473 |
| | Potential Tax Reduction per Family of Four (dollars per year) | 1,490 | 1,730 | 2,050 | 2,410 | 2,860 | 3,400 | 4,020 | 4,770 |
| | Potential Allowance Revenue as a Share of Non-CO ₂ Federal Tax Revenue (%) | 6 | 6 | 6 | 7 | 7 | 8 | 8 | 9 |
| 50% b/1990 | Total Potential CO ₂ Allowance Auction Revenue (billions of dollars per year) | 269 | 301 | 332 | 361 | 386 | 404 | 410 | 404 |
| | Potential Tax Reduction per Family of Four (dollars per year) | 3,360 | 3,610 | 3,820 | 4,030 | 4,180 | 4,260 | 4,230 | 4,060 |
| | Potential Allowance Revenue as a Share of Non-CO ₂ Federal Tax Revenue (%) | 14 | 13 | 13 | 12 | 11 | 10 | 9 | 8 |

SOURCE: Calculations by author, based on Paltsev, *et al.* 2007b, pp. 2, 3, 5, 6.

^a“Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

**Table 11: Illustrative Distribution of Private Costs
of a Cap-and-Trade System, Without Offsetting Gains from Allocation^a**

| Sector | Energy Category | Share of Total Private Costs | |
|---|------------------------|-------------------------------------|-------|
| Cost to Fossil Fuel Producers (Coal, Oil, Natural Gas) | | 3.6% | |
| Increase in Business/Industry Expenditures | for Primary Energy | 28.8% | 54.7% |
| | for Electricity | 25.9% | |
| Cost to Fossil-Fuel Fired Electric Generators | | 6.9% | |
| Increased in Household Expenditures | for Primary Energy | 21.5% | 34.7% |
| | for Electricity | 13.1% | |
| Total | | 100.0% ^b | |

SOURCE: National Commission on Energy Policy, 2007a.

^aThese illustrative results, adopted from the first proposal from the National Commission on Energy Policy (2007a) refer to the theoretical distribution of net private costs if all allowances were auctioned and none of the revenues were recycled. In other words, the potential offsetting effects of free distribution of allowances and the potential offsetting effects of using revenues to cut taxes or otherwise return revenues to businesses or individuals are not included.

^bSome columns do not add up because of rounding error.

**Table 12: Aggregate Costs and Value of CO₂ Allowances
Under Two Illustrative Caps**

| Scenario ^a | | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|-----------------------|--|------|------|------|------|------|------|------|------|
| Stabilize | Total Potential CO ₂ Allowance Auction Revenue (billions of dollars per year) | 119 | 145 | 177 | 216 | 264 | 322 | 390 | 473 |
| | Total Economic Cost — GDP Impact (billions of dollars per year) | 37 | 75 | 126 | 180 | 101 | 101 | 142 | 124 |
| 50% b/1990 | Total Potential CO ₂ Allowance Auction Revenue (billions of dollars per year) | 269 | 301 | 332 | 361 | 386 | 404 | 410 | 404 |
| | Total Economic Cost — GDP Impact (billions of dollars per year) | 86 | 156 | 153 | 148 | 360 | 349 | 241 | 212 |

SOURCE: Tables 9 and 10, this study.

^a“Stabilize” is based on the 287 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b; and “50% b/1990” refers to 2050 emissions capped at 50% below the 1990 level, and is based on the 203 cumulative CO₂-e bmt case from Paltsev *et al.* 2007a,b.

Table 13: Previous Use of Tradable Permit Mechanisms

| Country | Program | Traded Commodity | Period of Operation | Environmental and Economic Effects |
|----------------|---|--|--|--|
| Canada | <i>ODS Allowance Trading*</i> | <i>CFCs and Methyl Chloroform HCFCs Methyl Bromide</i> | <i>1993-1996 1996-Present 1995-Present</i> | <i>Low trading volume, except among large methyl bromide allowance holders</i> |
| | PERT GERT | NO _x , VOCs, CO, CO ₂ , SO ₂ CO ₂ | 1996-Present 1997-Present | Pilot program Pilot program |
| Chile | <i>Santiago Air Emissions Trading*</i> | <i>Total suspended particulates emission rights trading among stationary sources</i> | <i>1995-Present</i> | <i>Low trading volume; decrease in emissions since 1997 not definitively tied to TP system</i> |
| European Union | <i>ODS Quota Trading*</i> | <i>ODS production quotas under Montreal Protocol</i> | <i>1991-1994</i> | <i>More rapid phaseout of ODS</i> |
| Singapore | <i>ODS Permit Trading*</i> | <i>Permits for use and distribution of ODS</i> | <i>1991-Present</i> | <i>Increase in permit prices; environmental benefits unknown</i> |
| United States | Emissions Trading Program | Criteria air pollutants under the Clean Air Act | 1974-Present | Performance unaffected; savings = \$5-12 billion |
| | Leaded Gasoline Phasedown | Rights for lead in gasoline among refineries | 1982-1987 | More rapid phaseout of leaded gasoline; \$250 million annual savings |
| | Water Quality Trading | Point-nonpoint sources of nitrogen & phosphorous | 1984-1986 | No trading occurred, because ambient standards not binding |
| | <i>CFC Trades for Ozone Protection*</i> | <i>Production rights for some CFCs, based on depletion potential</i> | <i>1987-Present</i> | <i>Environmental targets achieved ahead of schedule; effect of TP system unclear</i> |
| | Heavy Duty Engine Trading | Averaging, banking, and trading of credits for NO _x and particulate emissions | 1992-Present | Standards achieved; cost savings unknown |
| | <i>Acid Rain Reduction*</i> | <i>SO₂ emission reduction credits; mainly among electric utilities</i> | <i>1995-Present</i> | <i>SO₂ reductions achieved ahead of schedule; savings of \$1 billion/year</i> |
| | <i>RECLAIM Program*</i> | <i>SO₂ and NO_x emissions among stationary sources</i> | <i>1994-Present</i> | <i>Emission reductions over 50%; 40% cost savings, or \$58 million annually</i> |
| | <i>N.E. Ozone Transport*</i> | <i>Primarily NO_x emissions by large stationary sources</i> | <i>1999-Present</i> | <i>Emissions reductions of 40%; compliance cost savings of 44%</i> |

SOURCES: Hahn and Hester (1989); Hahn (1989); Schmalensee, Joskow, Ellerman, Montero and Bailey (1998); Montero, and Sánchez (1999); Klaassen (1999); and Haites (1996). "TP" refers to tradable permits; ODS, ozone-depleting substances; CFCs, chlorofluorocarbons; and CA, State of California.

*Cap-and-trade systems are in italics; other instruments are credit-based tradable permit systems.

APPENDIX: APPLICATIONS OF CAP-AND-TRADE MECHANISMS

Tradable permit programs are of two basic types, credit programs and cap-and-trade systems (Table 13). The focus of this appendix is on applications of the cap-and-trade approach.

A.1 Previous Use of Cap-and-Trade Systems for Local and Regional Air Pollution^a

The first important example of a trading program in the United States was the leaded gasoline phasedown that occurred in the 1980's. Although not strictly a cap-and-trade system, the phasedown included features, such as trading and banking of environmental credits, that brought it closer than other credit programs to the cap-and-trade model and resulted in significant cost-savings. Subsequent examples of cap-and-trade systems include CFC trading under the Montreal Protocol to protect the ozone layer, SO₂ allowance trading under the Clean Air Act Amendments of 1990, the Regional Clean Air Markets (RECLAIM) program in the Los Angeles area, and the NO_x trading program initiated in 1999 to control regional smog in the eastern United States.

A.1.1 Leaded Gasoline Phasedown

The purpose of the U.S. lead trading program, developed in the 1980s, was to allow gasoline refiners greater flexibility in meeting emission standards and thereby cut compliance costs at a time when the lead-content of gasoline was reduced to 10 percent of its previous level. In 1982, the U.S. Environmental Protection Agency (EPA) authorized inter-refinery trading of lead credits, a major purpose of which was to lessen the financial burden on smaller refineries, which were believed to have significantly higher compliance costs. If refiners produced gasoline with a lower lead content than was required, they earned lead credits. Unlike a cap-and-trade program, there was no explicit allocation of permits, but to the degree that firms' production levels were correlated over time, the system implicitly awarded property rights on the basis of historical levels of gasoline production (Hahn 1989).

In 1985, EPA initiated a program allowing refineries to bank lead credits, and subsequently firms made extensive use of this option. In each year of the program, more than 60 percent of the lead added to gasoline was associated with traded lead credits (Hahn and Hester 1989), until the program was terminated at the end of 1987, when the lead phasedown was completed.^b

The lead program was clearly successful in meeting its environmental targets, although it may have produced some (temporary) geographic shifts in use patterns (Anderson, Hofmann and Rusin 1990). Although the economic benefits of the trading scheme are more difficult to assess, the level of trading activity and the rate at which refiners reduced their production of leaded gasoline suggest that the program was cost-effective (Kerr and Maré 1997; Nichols 1997). The high level of

^aThe appendix draws, in part, on Stavins (2003).

^bUnder the banking provisions of the program, excess reductions made in 1985 could be banked until the end of 1987, thereby providing an incentive for early reductions to help meet the lower limits that existed during the later years of the phasedown. The official completion of the phasedown occurred on January 1, 1996, when lead was banned as a fuel additive (Kerr and Newell 2000).

trading between firms far surpassed levels observed in earlier environmental markets.^c EPA estimated savings from the lead trading program of approximately 20 percent over alternative programs that did not provide for lead banking, a cost savings of about \$250 million per year (U.S. Environmental Protection Agency, Office of Policy Analysis 1985). Further, the program provided measurable incentives for cost-saving technology diffusion (Kerr and Newell 2000).

A.1.2 Ozone-Depleting Substances Phaseout

A cap-and-trade system was used in the United States to help comply with the Montreal Protocol, an international agreement aimed at slowing the rate of stratospheric ozone depletion. The Protocol called for reductions in the use of CFCs and halons, the primary chemical groups thought to lead to ozone depletion.^d The system places limitations on both the production and consumption of CFCs by issuing allowances that limit these activities.

The Montreal Protocol recognized the fact that different types of CFCs are likely to have different effects on ozone depletion, and so each CFC is assigned a different weight on the basis of its depletion potential. If a firm wishes to produce a given amount of CFC, it must have an allowance to do so, calculated on this basis (Hahn and McGartland 1989). This is the approach that would be used for a multi-GHG trading system, where allowances would be denominated in terms of their radiative-forcing potential, often characterized as “CO₂-equivalent.”

Through mid-1991, there were 34 participants in the market and 80 trades. However, the overall efficiency of the market is difficult to determine, because no studies have been conducted to estimate cost savings. The timetable for the phaseout of CFCs was subsequently accelerated, and a tax on CFCs was introduced, principally as a “windfall-profits tax” to prevent private industry from retaining scarcity rents created by the quantity restrictions (Merrill and Rousso 1990). The tax may have become the binding (effective) instrument. Nevertheless, low transaction costs associated with trading in the CFC market suggest that the system was relatively cost-effective.

In similar fashion, production quotas for ozone-depleting substances (ODS) were transferred within and among European Union (EU) countries between 1991 and 1994, until production was nearly phased out. During that period, there were 19 transfers (all but two of which were intrafirm), accounting for 13 percent of the EU’s allowable ODS production.

Singapore has operated a cap-and-trade system for ODS since 1991. The government records ODS requirements and bid prices for registered end-users and distributors, and total national ODS consumption (based on the Montreal Protocol) is distributed to registered firms by auction and free allocation. Firms can trade their allocations. Auction rents, captured by the government, have been used to subsidize recycling services and environmentally-friendly technologies (Annex I Expert Group of the United Nations Framework Convention on Climate Change 1997). Likewise, New Zealand implemented a CFC import permit system in 1986, whereby CFC permits are

^cFor those earlier programs, see Table 13. The program did experience some relatively minor implementation difficulties related to imported leaded fuel. It is not clear that a comparable command-and-control approach would have done better in terms of environmental quality (U.S. General Accounting Office 1986).

^dThe Montreal Protocol called for a 50 percent reduction in the production of particular CFCs from 1986 levels by 1998. In addition, the Protocol froze halon production and consumption at 1986 levels beginning in 1992.

distributed by the Ministry of Commerce (based on the Montreal Protocol), and trading is allowed among permit holders.

Canada has also used cap-and-trade systems for ozone-depleting substances since 1993. A system of tradable permits for CFCs and methyl chloroform operated from 1993 to 1996, when production and import of these substances ceased. Producers and importers received allowances for use of CFCs and methyl chloroform equivalent to consumption in the base year and were permitted to transfer part or all of their allowances with the approval of the federal government. There were only a small number of transfers of allowances during the three years of market operation, however (Hautes 1996).

Canada first distributed tradable allowances for methyl bromide in 1995. Due to concerns about the small number of importers (five), allowances were distributed directly to Canada's 133 users of methyl bromide. Use and trading of allowances was active among large allowance holders. In addition, Canada has operated an HCFC allowance system since 1996, distributing consumption permits for its maximum allowable use under the Montreal Protocol.

A.1.3 SO₂ Allowance Trading Program

The most important application made in the United States of a market-based instrument for environmental protection is arguably the cap-and-trade system that regulates SO₂ emissions, the primary precursor of acid rain. This system, which was established under Title IV of the U.S. Clean Air Act Amendments of 1990, is intended to reduce sulfur dioxide and nitrogen oxide emissions by 10 million tons and 2 million tons, respectively, from 1980 levels.^e The first phase of sulfur dioxide emissions reductions was started in 1995, with a second phase of reduction initiated in the year 2000.

In Phase I, individual emissions limits were assigned to the 263 most SO₂-emissions intensive generating units at 110 plants operated by 61 electric utilities, and located largely at coal-fired power plants east of the Mississippi River. After January 1, 1995, these utilities could emit sulfur dioxide only if they had adequate allowances to cover their emissions. During Phase I, the EPA allocated each affected unit, on an annual basis, a specified number of allowances related to its share of heat input during the baseline period (1985-87), plus bonus allowances available under a variety of special provisions.^f Cost-effectiveness was promoted by permitting allowance holders to transfer their permits among one another and bank them for later use.

^eFor a description of the legislation, see: Ferrall 1991.

^fUtilities that installed scrubbers received bonus allowances for early clean up. Also, specified utilities in Ohio, Indiana, and Illinois received extra allowances during both phases of the program. All of these extra allowances were essentially compensation intended to benefit Midwestern plants that rely on high-sulfur coal. On the political origins of this aspect of the program, see: Joskow and Schmalensee 1998.

Under Phase II of the program, beginning January 1, 2000, almost all electric power generating units (all units with capacity greater than 25 MW) were brought within the system. If trading allowances represent the carrot of the system, its stick is a penalty initiated at \$2,000 (in 1990 dollars) per ton of emissions that exceed any year's allowances, indexed to subsequent inflation (and a requirement that excess emissions be offset the following year).

In 2005, the Environmental Protection Agency further reduced the program's emission cap by promulgating the Clean Air Interstate Rule. This rule — in effect — reduced the denomination of the emissions allowances that will be issued starting in the year 2010, but did not affect current allowances that firms might bank for future years. This had the effect of encouraging firms to reduce their emissions without undermining the value of banked allowances.

A robust market of SO₂ allowance trading emerged from the program, resulting in cost savings on the order of \$1 billion annually, compared with the costs under some command-and-control regulatory alternatives (Carlson, Burtraw, Cropper, and Palmer 2000). Although the program had low levels of trading in its early years (Burtraw 1996), trading levels increased significantly over time (Schmalensee *et al.* 1998; Stavins 1998; Burtraw and Mansur 1999; Ellerman *et al.* 2000). The program has also had a significant environment impact: SO₂ emissions from the power sector decreased from 15.7 million tons in 1990 to 10.2 million tons in 2005 (U.S. Environmental Protection Agency 2005). Because the program allowed firms to bank allowances, SO₂ emissions dropped quickly in the early years of the program, leading to environmental benefits that were earlier and larger than expected.

Concerns were expressed early on that state regulatory authorities would hamper trading in order to protect their domestic coal industries, and some research indicates that state public utility commission cost-recovery rules provided poor guidance for compliance activities (Rose 1997; Bohi 1994). Other analysis suggests that this has not been a major problem (Bailey 1996). Similarly, in contrast to early assertions that the structure of EPA's small allowance auction market would cause problems (Cason 1995), the evidence indicates that this has had little or no effect on the vastly more important bilateral trading market (Joskow, Schmalensee, and Bailey 1998).

The allowance trading program has apparently had exceptionally positive welfare effects, with benefits being as much as six times greater than costs (Burtraw, Krupnick, Mansur, Austin, and Farrell 1998). The large benefits of the program are due mainly to the positive human health impacts of decreased local SO₂ and particulate concentrations, not to the ecological impacts of reduced long-distance transport of acid deposition. This contrasts with what was assumed and understood at the time of the program's enactment in 1990.

Furthermore, the geographic distribution of emissions reductions has been fairly equitable. The program did not result in significant regional shifts in pollution (Kinner and Birnbaum 2004). In fact, the largest emissions reductions occurred in Midwestern states where emissions were high and emissions reduction costs were low (Ellerman *et al.* 2000). Poor communities were not disproportionately affected by emissions from the program (Coburn 2001).

Ever since the program's initiation, downwind states, in particular, New York, have been somewhat skeptical about the effects of the trading scheme, driven by concern that the allowance trading program was failing to curb acid deposition in the Adirondacks in northern New York State (Dao 2000). The empirical evidence indicates that New York's concern is essentially misplaced.

The first question is whether acid deposition has increased in New York State. If the baseline for comparison is the absence of the Clean Air Act Amendments of 1990, then clearly acid deposition is less than it would have been otherwise. If the baseline for comparison is the original allocation of allowances under the 1990 law, but with no subsequent trading, then acid deposition in New York State is approximately unchanged.

Of course, such comparisons ignore the fact, emphasized above, that the greatest benefits of the program have been with regard to human health impacts of localized pollution. When such effects are also considered, it becomes clear that the welfare effects of allowance trading on New York State, using *either* baseline, have been positive and significant (Burtraw and Mansur 1999; Swift 2000).

A.1.4 RECLAIM Program

The South Coast Air Quality Management District, which is responsible for controlling emissions in a four-county area of southern California, launched a cap-and-trade program in 1994 to reduce nitrogen oxide and sulfur dioxide emissions in the Los Angeles area.^g This Regional Clean Air Incentives Market (RECLAIM) program set an aggregate cap on NO_x and SO₂ emissions for all power plants, cement factories, refineries, and other industrial sources with emissions greater than four tons per year. Although these 353 sources accounted for only a quarter of ozone-forming emissions in the four county area (the remainder of emissions were primarily from the transportation sector), the program set an ambitious goal of reducing aggregate emissions from regulated sources by 70 percent by 2003.

Trading under the RECLAIM program was restricted in several ways, with positive and negative consequences. First, the trading program incorporates zonal restrictions, whereby trades are not permitted from downwind to upwind sources. In this way, this geographically-differentiated emissions trading program represents one step toward an ambient trading program. Second, temporal restrictions in the program^h may not have provided incentives for facilities to install pollution control equipment that would have allowed them to reduce their current emissions and bank allowances for the future. This problem became particularly severe during the 2000-2001 electricity crisis, when some units facing high demand levels were unable to purchase allowances for their emissions. As a result, emissions exceeded allowances, and allowance price spikes occurred, as would be expected under such conditions.ⁱ

By June of 1996, the participants in the RECLAIM program had traded more than 100,000 tons of NO_x and SO₂ emissions, at a value of over \$10 million (Brotzman 1996). Despite problems with a surplus of allowances in the first years of the program, RECLAIM has generated environmental benefits: NO_x emissions in the regulated area fell by 60 percent between 1994 and 2004, and SO_x emissions fell by 50 percent over the same time period (South Coast Air Quality

^gFor a detailed case study, see: National Academy of Public Administration 1994. Also see: Thompson 1997; and Harrison 1999.

^hAlthough the program does not have explicit provision for banking from one period to the next, there is limited banking and borrowing in RECLAIM through the device of over-lapping compliance periods.

ⁱThe source is the South Coast Air Quality Management District (2003), cited in Market Advisory Committee (2007).

Management District 2006). Furthermore, the program has reduced compliance costs for regulated facilities. One prospective analysis predicted 42 percent cost savings, amounting to \$58 million annually (Anderson 1997).

A.1.5 NO_x Budget Program

Under the U.S. Environmental Protection Agency guidance, twelve northeastern states and the District of Columbia implemented a regional NO_x cap-and-trade system in 1999 to reduce compliance costs associated with the Ozone Transport Commission (OTC) regulations of the 1990 Amendments to the Clean Air Act. This program established the Northeast Ozone Transport Region, which included three geographic zones.^J Emissions caps from 1999-2003 were 35 percent of 1990 emissions in the Inner Zone, and 45 percent in the Outer Zone (Farrell et al. 1999).

The program was modified in 2003, when a new rule (NO_x SIP Call) reduced the cap on emissions and created a larger trading region that included nineteen states plus the District of Columbia. Including reductions achieved under the NO_x SIP Call, NO_x emissions fell from 1.86 million tons in 1990 to .49 million tons in 2006. The trading program initially covered emissions from 1,000 large stationary combustion sources, but expanded under the SIP Call to include over 2,500 sources (Market Advisory Committee 2007).

Under the program, EPA distributes NO_x allowances to each state, and states then allocate allowances to sources in their jurisdictions. Each source receives allowances equal to its restricted percentage of 1990 emissions, and sources must turn in one allowance for each ton of NO_x emitted during the ozone season. Sources may buy, sell, and bank allowances, although a system of “progressive flow control” limits the total number of banked allowances that can be used during the ozone season.

Potential compliance cost savings of 40 to 47 percent have been estimated for the period 1999-2003, compared to a base case of continued command-and-control regulation without trading or banking (Farrell *et al.* 1999). Due to delays in the implementation of the program and the allocation of allowances, prices were volatile in the first year of trading. But in subsequent years, prices stabilized as the market equilibrated. NO_x allowance trading is complicated by existing command-and-control regulations on many sources, the seasonal nature of ozone formation, and the fact that problems tend to result from a few high-ozone episodes and are not continuous (Farrell *et al.* 1999).

A.2 CO₂ and Greenhouse Gas Cap-and-Trade Systems

Although cap-and-trade has proven to be a successful means to control conventional air pollutants, cap-and-trade has a very limited history as a method of reducing CO₂ emissions. But several ambitious programs are in the planning stages or have been launched. First, the Kyoto

^JThe Inner Zone includes the Atlantic coast from Northern Virginia to New Hampshire, to varying distances inland. The Outer Zone is adjacent to the Inner Zone, from western Maryland through most of New York State. The Northern Zone includes northern New York and New Hampshire, and all of Vermont and Maine.

Protocol, the international agreement that was signed in Japan in 1997, includes a provision for an international cap-and-trade system among countries. Second, by far the largest existing active cap-and-trade program in the world is the European Union Emissions Trading Scheme, which has operated for the past two years with considerable success, despite some initial — and predictable — problems. Two frequently-discussed U.S. CO₂ cap-and-trade systems that have not yet been implemented are the Regional Greenhouse Gas Initiative, a program among 10 northeastern states that will be implemented in 2009 and begin to cut emissions in 2015, and California's Greenhouse Gas Solutions Act of 2006, which is intended to begin to reduce emissions in 2012 and may employ a cap-and-trade approach.

A.2.1 Kyoto Protocol (Article 17)

In 1990, the United Nations General Assembly initiated negotiations that led to the Framework Convention on Climate Change (FCCC), which entered into force in 1994 with 190 countries as parties, and established a general long-term environmental goal of stabilizing greenhouse gas concentrations “at a level that would prevent dangerous anthropogenic interference with the climate system” (Article 2). In Kyoto, Japan, in December, 1997, the parties to the FCCC agreed on the terms of what came to be known as the Kyoto Protocol. This agreement took a step toward the FCCC's objective by setting ambitious, near-term quantitative targets for industrialized countries.

The agreement was intended to result in industrialized countries' emissions declining in aggregate by 5.2 percent below 1990 levels by the year 2012. In 2001, industrialized countries began to ratify the Kyoto Protocol. Despite the withdrawal of the United States and Australia, the Kyoto Protocol entered into force in 2005, having met the dual requirements that 55 Annex I countries had ratified the agreement and that they jointly accounted for 55 percent of 1990 Annex I emissions.

The Protocol includes provision for cost-effective implementation through a set of tradable permit mechanisms, two of which are credit programs — joint implementation and the Clean Development Mechanism — and one of which is a cap-and-trade system — the international trading provision in Article 17. These are provided as options which countries can employ. There are few details available on the international cap-and-trade system laid out in Article 17,^k but that article — together with the Kyoto Protocol's special provision (in Annex B) that allows European emissions to be counted as a whole, rather than individually — has set the stage for the member states of the European Union to address their commitments under the Kyoto Protocol partially through a regional cap-and-trade system.

^kArticle 17 reads as follows: “The Conference of the Parties shall define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading. The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling their commitments under Article 3. Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under that Article” (United Nations 1998). For an assessment of the limitations of this cap-and-trade system, see: Hahn and Stavins 1999.

A.2.2 European Union Emissions Trading Scheme

In order to meet its commitments — in part — under the Kyoto Protocol, the European Union created the European Union Emissions Trading Scheme (EU ETS), a cap-and-trade system for CO₂ allowances. This system, which was adopted in 2003 and became active with a pilot phase in 2005, covers about half of EU CO₂ emissions in a region of the world that accounts for about 20 percent of global GDP and 17 percent of world energy-related CO₂ emissions (Ellerman and Buchner 2007). The 11,500 emitters regulated by the *downstream* program include large sources such as oil refineries, combustion installations over 20 MWth, coke ovens, cement factories, ferrous metal production, glass and ceramics production, and pulp and paper production. The program does not cover sources in the transportation, commercial, or residential sectors (Ellerman and Buchner 2007).

The EU ETS was designed to be implemented in phases: a pilot or learning phase from 2005 to 2007, a Kyoto commitment period phase from 2008 to 2012, and a series of subsequent phases. Penalties for violations increase from 40 Euros per ton of CO₂ in the first phase to 100 Euros in the second phase. Although the first phase allows trading only in carbon dioxide, the second phase potentially broadens the program to include other GHGs.

The process for setting caps and allowances in member states is decentralized (Kruger, Oates, and Pizer 2007). Each member state is responsible for proposing its own national carbon cap that reflects variables such as the source mixture and carbon intensity of national energy supplies, GDP, and expected growth rates, and these caps are subject to review by the European Commission. This created incentives for individual countries to try to be generous with their allowances to protect their economic competitiveness (Convery and Redmond 2007). By analogy, picture a U.S. national program that left it up to individual states to establish their own caps. The anticipated result might be an aggregate cap that exceeded BAU emissions, which is what happened initially in the EU ETS.

In the spring of 2006, it became clear that the allocation of allowances in 2005 — on net, overall — had exceeded emissions by about 4 percent of the overall cap. This led, as would be anticipated, to a dramatic fall in allowance prices. In January, 2005, the price per ton was approximately €8; by December, 2005, it reached €21; and in the next year, it fluctuated and then fell back to about €8 (Convery and Redmond 2007). This volatility has been attributed to the absence of good emissions data at the beginning of the program, a surplus of allowances, energy price volatility, and a program feature that *prevents banking* of allowances from the first phase to the second phase (Market Advisory Committee 2007). In truth, the “over-allocation” (which might — in principle — be due to low electricity output, abatement, or a generous allocation) was concentrated in a few countries, particularly in Eastern Europe, and in the non-power sectors (Ellerman and Buchner 2007).

The intention is that scarcity (a cap below BAU) will be enforced by the European Commission, which reviews national plans and can reduce caps as necessary to ensure they are compatible with achievement of Kyoto commitments and do not exceed BAU emissions. Within each country, allocation of allowances is based on distributional and political economy concerns. The first and second phases of the EU ETS require member states to distribute almost all of the emissions allowances (95 percent and 90 percent, respectively) freely to regulated sources, but beginning in 2013, member states may be allowed to auction larger shares of their allowances. The value of allowances distributed under the EU ETS is over \$40 billion, compared with about \$5 billion under the U.S. SO₂ allowance trading program (Ellerman and Buchner 2007).

The free distribution of allowances led to complaints from energy-intensive industrial firms about “windfall profits” among electricity generators, when energy prices increased significantly in 2005. But the higher electricity prices were only partly due to allowance prices, higher fuel prices also having played a role; and it is unclear whether the large profits reported by electricity generators were due mainly to their allowance holdings or to having low-cost nuclear or coal generation in areas where the (marginal) electricity price was set by higher-cost natural gas (Ellerman and Buchner 2007).

In its first two years of operation, the EU ETS has produced a functioning CO₂ market. Weekly CO₂ trading volumes have typically ranged between 5 million tons and 15 million tons, with spikes in trading activity occurring along with major price changes. Beyond the observations above regarding the design of the EU ETS, it is much too soon to provide a definitive assessment of the system’s performance.

A.2.3 Regional Greenhouse Gas Initiative

The Regional Greenhouse Gas Initiative (RGGI) is a *downstream* cap-and-trade program that is intended to limit CO₂ emissions from power sector sources in ten northeastern states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont). The program will take effect in 2009, pending approval by individual state legislatures, and sets a goal of limiting emissions from regulated sources to current levels in the period from 2009 to 2014. Beginning in 2015, the emissions cap will decrease by 2.5 percent each year until it reaches an ultimate level 10 percent below current emissions in 2019. This goal will require a reduction that is approximately 35 percent below business-as-usual, or equivalently, 13 percent below 1990 emissions levels.

Because RGGI only limits emissions from the power sector, incremental monitoring costs are low, because U.S. power plants are already required to report their hourly CO₂ emissions to the Federal government (under provisions for continuous emissions monitoring as part of the SO₂ allowance trading program). The system sets standards for certain categories of CO₂ offsets, and limits the number and geographic distribution of offsets, in contrast to what is proposed above. The program requires participating states to auction at least 25 percent of their allowances and to use the proceeds for energy efficiency and consumer-related improvements. The remaining 75 percent of allowances may be auctioned or distributed freely.

Given that the RGGI cap-and-trade system will not come into effect until 2009, at the earliest, it is obviously not possible to assess its performance. Several problems with its design, however, should be noted. First is the leakage problem, which is potentially severe for any state or regional program, particularly given the inter-connected nature of electricity markets (Burtraw, Kahn, and Palmer 2005). Second, the program is downstream for just one sector of the economy, and so very limited in scope. Third, despite considerable cost uncertainty, a true firm safety-valve mechanism was not adopted. Instead, there are trigger price that allow greater reliance on offsets and external credits in the expectation that these can increase supply. Fourth, as mentioned above, the program limits the number and geographic origin of offsets.

A.2.4 California’s Global Warming Solutions Act

California's Assembly Bill 32, the Global Warming Solutions Act, was signed into law in 2006, and assigns the California Air Resources Board the task of adopting measures to reduce California's emissions of greenhouse gases to 1990 levels by the year 2020. The Act provides for the reductions of emissions of six types of greenhouse gases – carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride – to the “maximum technologically feasible level using the most cost-effective policies possible,” a requirement that has caused considerable debate and some confusion.

Although the Global Warming Solutions Act does not require the use of market-based instruments, it does allow for their use, albeit with restrictions that they must not result in increased emissions of criteria air pollutants or toxics, that they must maximize environmental and economic benefits in California, and that they must account for localized economic and environmental justice concerns (Market Advisory Committee 2007). This mixed set of objectives potentially interferes with the development of a sound policy mechanism (Stavins 2007a).

To explore the potential role of market-based tools, Governor Schwarzenegger asked the California Secretary for Environmental Protection to create a Market Advisory Committee of experts and stakeholders. On June 30, 2007, the Committee submitted its non-binding advisory report recommending the implementation of a cap-and-trade program in California (Market Advisory Committee 2007). The report suggests a gradual phase-in of emissions caps leading up to a reduction to 1990 levels by 2020. Other features of the program include coverage of most sectors of the economy, with an initial focus on targeting limited sectors through what may be a downstream or a mixed point of regulation; a requirement that the first seller of electricity generated out of state surrender allowances to cover the out-of-state emissions from generation; an allowance distribution system that uses both free distribution and auctions of allowances, with a shift toward more auctions in later years; and recognition of offsets (Market Advisory Committee 2007).

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