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Robert N. Stavins

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

The Brookings Institution

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

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Abstract

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 in the short to medium term. Besides providing 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 in this country. The paper proposes a specific cap-and-trade system with several key features including: an upstream cap on CO_2 emissions with gradual inclusion of other greenhouse gases; a gradual downward trajectory of emissions ceilings over time to minimize disruption and allow firms and households time to adapt; and mechanisms to reduce cost uncertainty. 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 should help limit potential inequities while bolstering political support. The share distributed for free would phase out over twenty-five years. The auctioned allowances would generate revenue that could be used for a variety of worthwhile public purposes. The system would 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 that maintains a level playing field between imports and import-competing domestic products.

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I. Introduction

The megadisaster film *The Day After Tomorrow*, about the apocalyptic consequences of the greenhouse effect, had less scientific basis than *The Wizard of Oz*, but the reality is disturbing enough. There is now a near consensus that anthropogenic emissions of greenhouse gases are very likely to change the earth's climate in ways than many people will regret.

The basic story has been explained many times, but it merits repeating. Two trace constituents of the atmosphere, carbon dioxide (CO_2) and water vapor, create a thermal blanket for the planet much as glass on a greenhouse traps the sun's energy within. It is a good thing, too: without greenhouse warming, the earth 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 CO_2 are produced from the combustion of fossil fuels—coal, petroleum, and natural gas—and deforestation. Meanwhile the direct warming effects of CO_2 and other greenhouse gases—methane, nitrous oxide, and halocarbons—are indirectly amplified because the warming increases the evaporation of water, raising atmospheric water vapor concentrations (Intergovernmental Panel on Climate Change 2007a).

Average global surface temperatures have risen by about 1.25 degrees Fahrenheit over the past 150 years, with most of the increase occurring since 1970. This fits the predictions of modern computer models of climate change that also take account of increases in atmospheric dust (dust cools the earth by reflecting sunlight) and variations in the sun's energy output. Changes in temperatures in the middle of continents and at high latitudes have been two to four times greater than the average global change—also as predicted.

Warmer days and nights (which would surely be welcome in some places) are only part of the story. 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 levels, and changes in storm frequency and intensity (Intergovernmental Panel on Climate Change 2007b). That is why it is important to view the problem as global climate change rather than global warming alone.

But moving from predictions of average global temperature change to predictions of regional climate impacts is difficult. The best computer models cannot yet produce reliable estimates of these impacts. What is obvious, however, is that 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.

Four years after Kyoto, the Bush administration announced that it would not submit the Kyoto Protocol, initialed by the Clinton White House, to the U.S. Senate for ratification. Of course, the Clinton administration also chose not to submit the agreement to the Senate, and it is very unlikely that Al Gore or John Kerry, had either been elected president, would have done so. Even before the Kyoto conference, the Senate had resolved, by a vote of 95-0 in the Byrd-Hagel resolution, that it would not approve a climate control pact along the lines of the Kyoto accord.

Many analysts—particularly economists—have been highly critical of the Kyoto Protocol, noting that, because of specific deficiencies, it will accomplish little, and that at a relatively high cost (Aldy, Barrett, and Stavins 2003). Others have been more supportive, noting that Kyoto 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 (2008-

12), the international policy community as a whole has begun to search for a better global policy architecture for the second (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, 2007b), 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, which are no longer limited on this issue to the usual environmental interest groups; religious lobbies, for example, have also been vocal. All this has been reflected in greatly heightened attention by the news media. The result is that a large and growing share of the U.S. population now believe that government action is warranted (Bannon et al. 2007).[1]

In the absence of a responsive federal policy, regions, states, and even cities have moved forward with their own proposals to reduce emissions of CO_2 and other greenhouse gases. Ten northeastern states, for example, have developed a cap-and-trade program under their Regional Greenhouse Gas Initiative (RGGI), and California's Assembly Bill 32 may do likewise for the nation's largest state. Partly in response to fears of a fractured set of regional policies, an increasing number of large corporations—sometimes acting individually, other times in coalition with environmental advocacy groups—have announced their support for serious national action.[2] Building on this initiative is the April 2007 U.S. Supreme Court decision that the administration has the legislative authority to regulate CO_2 emissions,[3] as well as ongoing demands from European allies and other nations that the United States reestablish its international credibility in this realm by enacting a meaningful domestic climate policy. Indeed, in June 2005 the Senate balanced its distinctly negative view of the Kyoto Protocol with an aggressive sense-of-the-Senate resolution, adopted by unanimous consent, regarding domestic climate policy.[4]

Thus momentum is clearly building toward 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 the details of such a policy's design will greatly affect its ability to achieve its 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.[5] That certainly does not mean that action

1. Not surprisingly, the public focus in this domain is on the goals of public policy, not on the specific means. When asked, the general public appears to be predisposed to conventional regulatory approaches; but when confronted with a possible trade-off between the promised benefits and the perceived cost of conventional regulation, public enthusiasm for cost-effective, market-based policy instruments increases (Bannon et al. 2007).
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 … 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, 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, the National Wildlife Federation, the Natural Resources Defense Council, the Nature Conservancy, the Pew Center on Global Climate Change, and the 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. The resolution states: "Congress should enact a comprehensive and effective national program of mandatory, market-based limits and incentives on emissions of greenhouse gases that slow, stop, and reverse the growth of such emissions at a rate and in a manner that (1) will not significantly harm the United States economy; and (2) will encourage comparable action by other nations that are major trading partners and key contributors to global emissions." The proposal set forth in this paper is consistent with that resolution.
5. By comparison, the cost (in 2001 dollars) of all U.S. Environmental Protection Agency regulations enacted from 1996 to 2006 is estimated at $25 billion 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 of GDP (Jaffe et al. 1995; Morgenstern, Pizer, and Shih 2001).

should not be taken, but it does mean that the costs should be recognized if effective and sensible policies are to be designed and implemented.

It is important to identify an appropriate policy instrument at the outset, 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 change. For example, any policy of significant scope, once implemented, leads to institutional investments in both the public and the private sectors. And as people learn how to operate within the policy, status quo bias sets in. Some sectors and interests will benefit from any policy, and these groups will resist subsequent reform. 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 detract from the development of and commitment to a more effective long-run policy. In the case of climate change, choosing an inferior approach could be exceptionally costly: the difference between a cost-effective approach and an inferior one could be as great as $150 billion annually (1 percent of today's GDP), or $1.8 trillion over a decade (Repetto 2007). And because of the unique characteristics of the climate change problem, simply relying on existing and familiar policy models will not lead to the best solutions.

Alternative Policy Instruments to Reduce Greenhouse Gas Emissions

There is general consensus among economists and policy analysts that a market-based policy instrument targeting CO_2 emissions—and potentially some non-CO_2 greenhouse gas emissions—should be a central element of any domestic climate policy.[6] Two alternative market-based instruments—a cap-and-trade system and a carbon tax—have been advocated. Although there are trade-offs between them, this paper will argue that the better approach and the one more likely to be adopted in the short to medium term in the United States is a cap-and-trade system.

The environmental effectiveness of a domestic cap-and-trade system for climate change can be maximized and its costs and risks minimized by inclusion of several specific features. The system should target all fossil fuel-related CO_2 emissions through an economy-wide cap on those emissions. The cap should be imposed "upstream," that is, on fossil fuels at the point of extraction, processing, or distribution, not at the point of combustion. The system should set a trajectory of caps over time that begin modestly and gradually become more stringent, establishing a long-run price signal to encourage investment in emission-reducing technology. It should adopt mechanisms to protect against cost uncertainty. And it should include linkages with the climate policy actions of other countries. Importantly, by providing politicians with the option to mitigate economic impacts through the distribution of emissions allowances, this approach can establish consensus for a policy that achieves meaningful 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, for example to phase out the use of lead in gasoline, limit emissions of sulfur dioxide (SO_2) and nitrous oxides (NO_X), and phase out chlorofluorocarbons (CFCs; Stavins 2003; see also the online appendix at www.hamiltonproject.org).

Cap-and-trade should not be confused with emissions reduction credits or other credit-based programs, in which those reporting emissions reductions receive credits that others either may or must buy to offset obligations under some other policy. Credit-based programs have often been considered as a means of encouraging emissions reductions from activities outside the scope of a cap-and-trade system, emissions tax, or standards-based policy. But

6. This perspective is embodied in international assessments of national policy instruments as well (Intergovernmental Panel on Climate Change 2007c).

an important limitation of credit-based programs is that they typically require measurement—or, more likely, estimation—of emissions *reductions*, which, unlike emissions themselves, cannot be directly observed. Hence these programs generally face difficulties in establishing that reported reductions would not have occurred in the absence of the program. This is the so-called baseline or "additionality" problem: how to compare actual outcomes with an unobserved and fundamentally unobservable hypothetical. Despite this obstacle, cost savings still may be achieved through the selective use of credit-based programs targeting certain activities. As discussed later, these include various types of carbon-saving land management that otherwise would be too costly or infeasible to integrate into a cap-and-trade (or a tax) system.

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 emissions 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 in fact, those costs would be significantly greater than under sound market-based policies, because standards offer firms and consumers far less flexibility in reducing emissions, and they cannot target many low-cost emissions reduction opportunities. Moreover, the effectiveness of standards in achieving nationwide emissions targets is highly uncertain, in part because they could cover only a fraction of those emissions, leaving many sources unregulated. In contrast, market-based policies can cover all sources of fossil fuel-related CO_2 emissions, and unlike other alternatives, a cap-and-trade system can essentially guarantee achievement of emissions targets for sources covered by the cap.

The Focus on Cap-and-Trade

A cap-and-trade system places a cap, or ceiling, on the aggregate emissions of a group of regulated sources by creating a limited number of tradable emissions allowances for a given period and requiring firms to surrender a quantity of allowances equal to their emissions during that period.[7] The system imposes no particular limits on emissions from any given firm or source. A firm may emit as much as it chooses, as long as it obtains sufficient allowances to do so. The government may initially distribute the allowances for free or sell them at auction. In either case, the need to surrender valuable allowances to cover any emissions and the opportunity to trade those allowances establishes a price on emissions. In turn, this price 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 emissions reduction efforts necessary to keep emissions within the cap is determined by market forces. Those sources that find it cheaper to reduce their emissions than to continue emitting and pay for allowances will do so, and those that find it cheaper to purchase allowances will do so. Through the trading of allowances, the price adjusts until emissions are brought down to the level of the cap. Firms' ability to trade emissions allowances creates a market in which allowances migrate toward their highest-valued use, covering those emissions that are the most costly to reduce. A well-designed cap-and-trade system thus minimizes the costs of achieving any given emissions target. Overall, a cap-and-trade system provides certainty regarding emissions from the regulated sources as a group, because *aggregate* emissions from all regulated entities cannot exceed the total number of allowances.[8]

7. This description is of what is called a "downstream" cap-and-trade system for CO_2, which regulates the sources that emit CO_2 by burning fossil fuels. This paper proposes an upstream system, as defined above, because of its economy-wide coverage.
8. The trade-off for such emissions certainty is uncertainty regarding the policy's costs, as regulated sources will meet the cap regardless of cost. In contrast, a carbon tax provides greater certainty over program costs but does not guarantee achievement of a specific emissions target. Later in this paper, the trade-off between cost uncertainty and emissions uncertainty is examined, and specific means of reducing a cap-and-trade system's cost uncertainty are identified.

The cost of achieving significant greenhouse gas emissions reductions in future years will depend critically on the availability and cost of low- or nonemitting technologies. A cap-and-trade system that establishes caps extending decades into the future generates price signals that provide incentives for firms to invest in the development and deployment of such technologies, thereby lowering the future cost of reducing emissions. To create these incentives, a cap-and-trade system must provide credible commitments to meeting long-run emissions targets.[9] If a lack of credibility makes the payoff from investments in the new technologies highly uncertain, these investments will lag (Montgomery and Smith 2007). On the other hand, policymakers also need to maintain flexibility to adjust long-term targets as new information is obtained regarding the benefits and costs of mitigating climate change. Managing this trade-off between the credibility of long-run targets and flexibility is important 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 if it does not address certain well-known market failures, in particular those associated with investments that create knowledge with a public good nature (Jaffe et al. 2005, Newell 2007). 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 emissions reduction costs. Additional policies may be necessary to increase government funding or incentives for private funding of such research.[10]

Applications of Cap-and-Trade Mechanisms

Over the past two decades, tradable permit systems for pollution control have been adopted 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 is on applications of the cap-and-trade approach.[11] The programs described below are examined in more detail in the online appendix to this paper.

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

The first important example of an environmental trading program in the United States was the phasedown of leaded gasoline in the 1980s. 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 program was successful in meeting its environmental targets, and the system was cost-effective, with estimated cost savings of about $250 million a year (Stavins 2003). Also, the program provided measurable incentives for the diffusion of cost-saving technology (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 later accelerated, and the system appears to have been relatively cost-effective.

The most important application in the United States to date of a market-based instrument for environmental protection is arguably the cap-and-trade system that regulates SO_2 emissions, the primary precursor of acid rain. The program, established under the U.S. Clean Air Act Amend-

9. Although no legislation can guarantee that future commitments will be met, legislated targets increase credibility by increasing the political costs to legislators of altering future requirements.
10. See, for example, National Commission on Energy Policy (2007b). Such complementary policies are examined later in this paper.
11. This section draws, in part, on Stavins (2003).

ments of 1990, is intended to reduce SO_2 and NO_X emissions by 10 million tons and 2 million tons, respectively, from 1980 levels. A robust market in SO_2 allowances emerged under the program, resulting in cost savings on the order of $1 billion annually compared with some command-and-control alternatives (Carlson et al. 2000). The program has also had a significant environmental impact: SO_2 emissions from the electric 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 NO_X and SO_2 emissions in the Los Angeles area. This program, called the Regional Clean Air Incentives Market (RECLAIM), set an aggregate cap on NO_X and SO_2 emissions for all significant sources, with an ambitious goal of reducing aggregate emissions 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_2 emissions by 50 percent. The program has also reduced compliance costs for regulated facilities, with the best available analysis suggesting cost savings of 42 percent, 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's (OTC) regulations under the 1990 amendments to the Clean Air Act. Emissions caps for two zones from 1999-2003 were set at 35 percent and 45 percent of 1990 emissions. Compliance cost savings of 40 to 47 percent have been estimated for the period, compared with a base case of continued command-and-control regulation without trading or banking (Farrell et al. 1999).

Greenhouse Gas Cap-and-Trade Systems

Although cap-and-trade has proved to be a cost-effective means to control conventional air pollutants, it has a very limited history as a method of reducing CO_2 emissions. Several ambitious programs are in the planning stages or have been launched.

First, the Kyoto Protocol, the international agreement 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. This system, the European Union Emissions Trading Scheme (EU ETS) for CO_2 allowances, is by far the largest active cap-and-trade program in the world. It has operated for two years with considerable success, despite some initial—and predictable—problems. The 11,500 emissions sources regulated by the downstream program include large sources such as oil refineries, combustion installations, coke ovens, cement factories, and ferrous metal, glass and ceramics, and pulp and paper producers, 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, allows trading only in CO_2, the second phase, 2008-12, potentially broadens the program to include other greenhouse gases. In its first two years of operation, the EU ETS has produced a functioning CO_2 allowances market, with weekly trading volumes ranging between 5 million and 15 million tons, and with spikes in trading activity accompanying major price changes. Apart from identifying some problems with the program's design and early implementation (discussed in the online appendix), it is much too soon to provide a definitive assessment of the system's performance.

In the United States, RGGI, a program among ten northeastern states, will be implemented in 2009 and begin to cut emissions in 2015. RGGI is a downstream cap-and-trade program intended to limit CO_2 emissions from electric power sector sources. Beginning in 2015 the emissions cap will decrease by 2.5 percent each year until 2019, when it will be 10 percent below current emissions, or about 35 percent below the business-as-usual (BAU) estimate, and 13 percent below 1990 emissions levels. Because RGGI limits emissions from the power sector only, incremental monitoring costs are low, as U.S. power plants are already required to report their hourly CO_2 emissions to the federal government, under provisions of the SO_2 allowance trading program. The program requires participating states to auction at least 25 percent of their allowances; the remainder may also be auctioned or distributed free. It is obviously not yet possible to assess the system's performance, but several problems with its design are examined in the online appendix.

Finally, under California's Global Warming Solutions Act (Assembly Bill 32), signed into law in 2006, the state will begin in 2012 to reduce emissions to 1990 levels by 2020, and may employ a cap-and-trade approach. Although the act does not require the use of market-based instruments, it does allow for them, with restrictions: they must not result in increased emissions of criteria air pollutants or toxics, they must maximize environmental and economic benefits in California, and they must take localized economic and environmental justice concerns into account. This mixed set of objectives may interfere with the development of a sound policy mechanism. The Governor's Market Advisory Committee has recommended 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, with a shift toward more auctions in later years.

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.[12]

Environmental Effectiveness

The first criterion any proposed climate policy must meet is environmental effectiveness: Can the proposed instrument achieve its intended targets? This will depend, in the case of a standards-based approach, on the technical ability of policymakers to design and the administrative ability of governments to implement standards that are sufficiently diverse to address all of the sources of CO_2 emissions in a modern economy. In the case of a tax, it will depend on the ability of political systems to impose taxes that are sufficiently high to achieve meaningful emissions reductions (or limits on global greenhouse gas concentrations, or limits on temperature changes).

The evaluation must also consider how certain it is that the proposed policy will achieve its emissions or other targets. Different policy designs may be expected to achieve identical targets, but with different degrees of certainty. A cap-and-trade system can achieve emissions targets with high certainty because guaranteed emissions levels are built into the policy. With a carbon tax or technology standards, on the other hand, actual emissions are difficult to predict because of current and future uncertainty about future energy prices or how quickly new technologies will be adopted. Such policies may aim to achieve particular emissions targets, but actual emissions may either exceed or fall below those targets, depending on factors beyond policymakers' control.

12. Efficiency is ordinarily a key criterion for assessing public policies but is less useful when comparing alternative domestic policy instruments to address climate change. The efficiency criterion requires a comparison of benefits and costs, but 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 benefits 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 this paper 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 other 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 a carbon tax) policy is political: the likelihood of some national climate policy being enacted is increasing, and it is preferable that such a policy be implemented cost-effectively rather than through more costly conventional regulatory approaches.

Moreover, the tendency for exemptions to be granted from taxes and standards so as 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 neither raise the total cost of the program nor affect its climate impacts.

To be effective, any domestic U.S. program needs to be accompanied by meaningful policies in 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 as prepared to adopt a meaningful domestic program.

Cost Effectiveness

The cost effectiveness criterion compares a policy's cost of achieving a given emissions target with the costs of alternative policy designs.[13] Many categories of economic costs are relevant to this evaluation.[14] The costs to the government of administering and enforcing the policy may be so great as to effectively make a policy infeasible, but for most climate policy alternatives these administrative costs are anticipated to be a small fraction of the policy's total cost to society. Much more important are the compliance costs, the direct operating and capital expenditures that emissions sources must make to comply with the regulations.

Because of the long-term nature of the climate problem, both the short-run and the long-run—or static and dynamic—cost-effectiveness of a policy is an important consideration. An analysis of *static cost-effectiveness* compares the compliance costs of alternative policies in the short run, given the current capital stock and available technologies. *Dynamic cost-effectiveness* relates to how a policy encourages investments in capital stock and development of new technologies that will lower the costs of achieving future emissions targets.

When evaluating the economic implications of a climate policy, it is important to distinguish between social and firm-level costs. A policy's *social costs* reflect the value of resources used as a result of the policy that cannot be employed in some other activity, whether inside or outside the firm. A policy's social cost-effectiveness depends on how its social costs compare with those of other policies that achieve the same result. *Firm-level costs* represent the net economic impact on (the cost to) the affected firms only; these are significant determinants of a policy's distributional implications and political feasibility. Not all firm-level costs are social costs. For example, expenditures by firms on emissions allowances or carbon taxes do not represent social costs because they involve only the *transfer* of assets from one entity to another; one entity's costs are entirely offset by the other's gains. Resources are redistributed, but not lost, as a result of such expenditures.

By imposing direct costs on particular entities, and through its effects on market prices, a climate policy also leads to indirect *general equilibrium costs*. These are the costs to entities operating in markets outside the one to which the regulation directly applies. Such costs result from interactions between the targeted market and other parts of the economy. Some important general equilibrium costs can occur when a climate policy's impact on energy markets adversely affects labor supply or investment decisions elsewhere in the economy. In addition, climate policies will impose *transition costs* associated with the necessary adjustments in employment and capital stock. Such costs are greater when policies

13. Comparisons of the cost of alternative policies should be made on an equal footing, against a common emissions target. Of course, less cost-effective policies may limit the extent of emissions reductions that are politically tolerable. On the other hand, transparent policies, 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).

require rapid changes in capital stock, markets, and consumer choices. Finally, policies may also create *negative costs* (or *co-benefits*) by reducing the cost of complying with other environmental regulations, such as those targeting SO_2 and NO_X emissions, or by bringing about other non-climate-related benefits, including increased energy security.

Distributional Equity

The economic impacts of any climate policy will be broadly felt but will vary across regions, industries, and households. The ultimate distribution 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: direct regulatory costs that reduce their profit margins, and changes in demand for their products. A policy's initial burden on directly regulated firms may be partially offset as the introduction of direct regulatory costs leads to increases in those firms' product prices, or reductions in prices of some inputs, or both. As a result of these price changes, 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.

Any comprehensive climate policy will adversely affect many firms, but some may experience windfall profits. For example, firms making less carbon-intensive products 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, after all adjustments in market prices, rather than just its initial impacts on costs.

Although 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 workers. As producers pass through their increased costs, consumers experience increased prices of energy and nonenergy goods and may reduce their 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 may experience changes in employment and wages.

The benefits (that is, the avoided damages) of climate policy are also unevenly distributed. Alternative policy instruments are very unlikely to result in different geographic distributions of climate impacts, because greenhouse gases mix uniformly in the atmosphere. On the other hand, emissions of non-greenhouse gas pollutants that are correlated with emissions of CO_2 may have local impacts and be sensitive to the choice of policy instrument.

Organization of the Paper

Section II of this paper proposes a comprehensive U.S. CO_2 cap-and-trade system and describes its key elements: a gradual trajectory of emissions reductions; tradable allowances; upstream regulation with economy-wide effects; mechanisms to reduce cost uncertainty; allowance allocations that combine auctions with free distribution, with auctions becoming more important over time; availability of offsets for underground and biological carbon sequestration; supremacy over state and regional systems; and linkage with international emissions reduction credit and cap-and-trade systems and climate policies in other countries.

Section III provides an economic assessment of the proposal, including an analysis of aggregate costs and distributional impacts. Section IV compares the proposal with alternative approaches to the same policy goal, with particular attention to command-and-control regulation and carbon taxes. Section V examines some common objections to the proposed policy and provides responses. Section VI concludes.

II. A Comprehensive Cap-and-Trade System for Greenhouse Gases

The United States can launch a scientifically sound, economically rational, and politically feasible approach to reducing its greenhouse gas emissions by adopting an upstream, economy-wide CO_2 cap-and-trade system that implements a gradual trajectory of emissions reductions over time. The approach proposed here also includes mechanisms to reduce cost uncertainty, such as multiyear compliance periods, provisions for banking and borrowing, and possibly a cost containment mechanism to protect against extreme price volatility.[15]

Allowances under the system would be allocated through a combination of free distribution and open auction. This is intended to balance, on the one hand, the legitimate concerns of those who will be particularly burdened by this (or any) climate policy with, on the other hand, the opportunity to achieve important public purposes with funds generated by the auctions. The share of free allowances would decrease over time as the private sector adjusts to the carbon constraints, with all allowances being auctioned after twenty-five years.

Offsets would be made available for both underground and biological carbon sequestration, to achieve short-term cost-effectiveness and create long-term incentives for appropriate technological change. The cap-and-trade system would be a federal program, with supremacy over all U.S. regional, state, and local systems, to avoid duplication, double counting, and conflicting requirements. It would also provide for harmonization over time with emissions reduction credit and cap-and-trade systems in other nations, as well as related international systems.

Major Though Not Exclusive Focus on CO_2

This proposal focuses on reductions of fossil fuel-related CO_2 emissions, which accounted for nearly 85 percent of the 7.1 billion metric tons of U.S. greenhouse gas emissions in 2005.[16] CO_2 emissions arise from a broad range of activities involving the use of different fuels in many different economic sectors (Figure 1). In addition, biological sequestration and reductions in non-CO_2 greenhouse gas emissions can contribute substantially to minimizing the cost of limiting total greenhouse gas concentrations (Reilly, Jacoby, and Prinn 2003; Stavins and Richards 2005). Some non-CO_2 emissions might be addressed under the same framework as for CO_2 in a multigas cap-and-trade system.[17] But challenges associated with measuring and monitoring other non-CO_2 emissions and biological sequestration may require separate programs tailored to their specific characteristics, as described later.

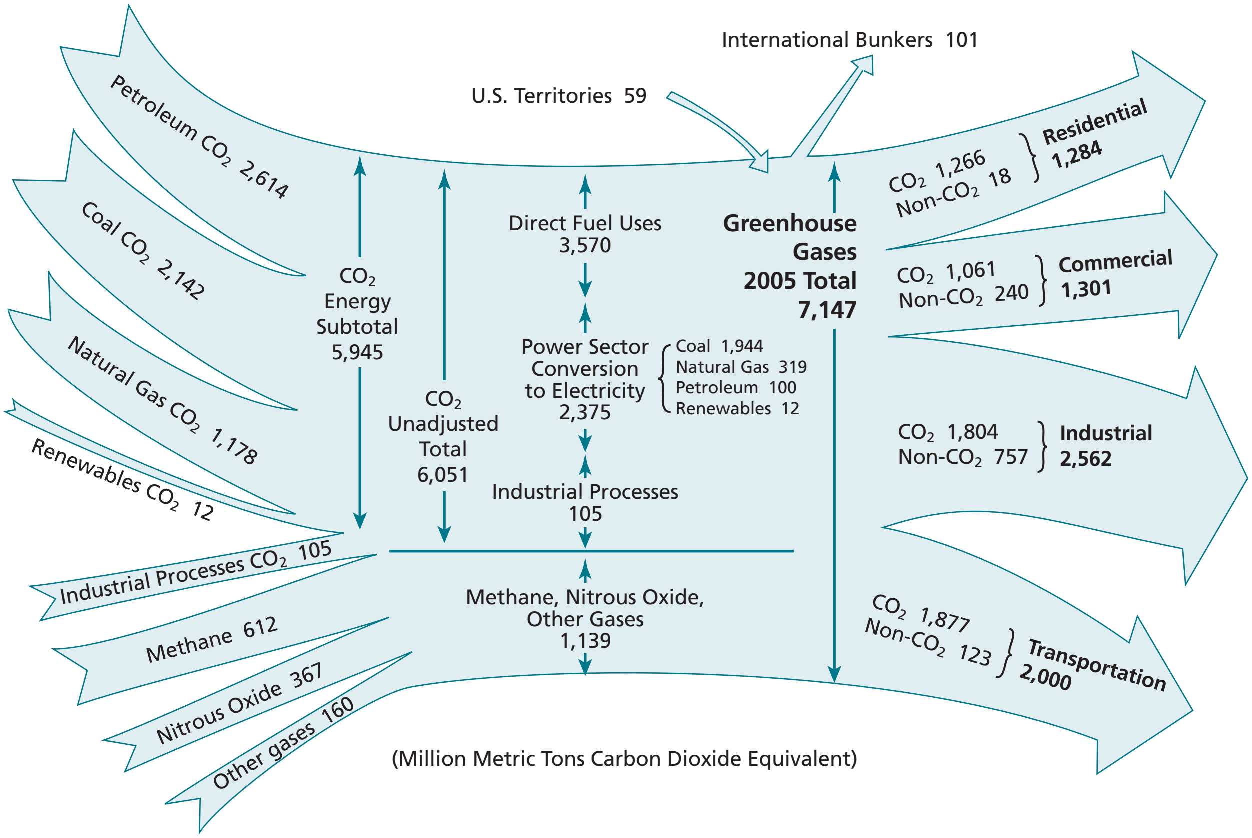
Gradually Increasing Trajectory of Emissions Reductions over Time

Because climate change is a long-term problem, policies can be somewhat flexible regarding when emissions reductions actually occur. Policies that take advantage of this "when" flexibility, for example by setting annual emissions targets that gradually increase in stringency, can avoid many of the costs associated with taking stringent action too quickly, without sacrificing environmental benefits (Wigley, Richels, and Edmonds 1996). Premature retirement of existing capital stock can be avoided, as can many production and siting bottlenecks.

15. For a review of alternative designs for a national cap-and-trade system, see Cambridge Energy Research Associates (2006).
16. This figure measures greenhouse gases in CO_2-equivalent terms; that is, quantities of greenhouse gases other than CO_2 are converted to quantities of CO_2 of the same radiative forcing potential over their average duration in the atmosphere.
17. Because landfill methane emissions are already monitored, and monitoring of industrial (as opposed to agricultural) non-CO_2 greenhouse gases would not be difficult, regulation of these sources might be integrated with CO_2 policies (Reilly, Jacoby, and Prinn 2003).

FIGURE 1

U.S. Greenhouse Gas Emissions, 2005



Source: U.S. Energy Information Administration (2006).

Gradually phased-in targets also provide time to incorporate advanced technologies into long-lived investments (Goulder 2004; Jaffe, Newell, and Stavins 1999).[18] Thus, for any given cumulative emissions target or associated atmospheric concentration objective, a climate policy's cost can be reduced by gradually phasing in efforts to reduce emissions.

The long-term nature of the climate problem and the need for technological change to bring about lower-cost emissions reductions also make it essential that the caps be instituted gradually over a long period. The development and eventual adoption of new low-carbon and other relevant technologies will depend on the predictability of future carbon prices, which themselves will be affected by the cap's constraints. Therefore the cap-and-trade policy should incorporate medium- to long-term targets, not just short-term targets.

It would be a mistake, however, to think that "when" flexibility is a reason to allow delay in enacting a mandatory policy. On the contrary, the earlier a mandatory policy is established, the more flexibility there will be to set emissions targets that gradually depart from BAU levels while still achieving a long-run objective for atmospheric concentration. The longer it takes to establish a mandatory policy, the more stringent the near-term emissions targets will need to be to achieve a given long-run concentration objective.

18. In addition, given the time value of money (the opportunity cost of capital), environmentally neutral delays in the timing of emissions reduction investments can be socially advantageous.

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

Several alternative types of policy-target trajectories are possible, including trajectories for emissions caps, emissions reduction targets, global concentration targets, and allowance prices. Given the long-term nature of the problem, the best measure of policy stringency may be the sum of national emissions permitted over some extended period. As explained later, if banking and borrowing of allowances are allowed, then only the sum of capped national emissions over time matters, not the specific trajectory, because trading of allowances will generate the cost-minimizing trajectory. Of course, if there is too much delay in bringing down emissions, then the timing of emissions reductions can affect total damages, even if cumulative emissions are the same.

How should the appropriate sum of capped national emissions be identified? The classic economic approach is to choose targets that maximize the difference between expected benefits and expected costs, but such an approach is simply not feasible in this context, for several reasons. Reliable information about anticipated damages—even in biophysical, let alone economic terms—is lacking. In any case such a calculation could be made only at the global, not the national, level given that the problem affects the global commons. Finally, it is increasingly clear that an analysis that merely compares expected benefits with expected costs is inadequate, since it is the small risks of catastrophic damages that are at the heart of the problem (Weitzman 2007).

The cost assessment presented later in this paper adopts and assesses a pair of trajectories for 2012-50 to establish a reasonable range of possibilities for illustrative purposes. The less ambitious trajectory involves stabilizing CO_2 emissions at their 2008 level over 2012-50, as predicted by Paltsev and others (2007a, 2007b). 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, also defined over 2012-50, would reduce CO_2 emissions to 50 percent below their 1990 level. 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 has several significant attributes. First, both are consistent with the frequently cited global goal of stabilizing atmospheric concentrations of CO_2 at between 450 and 550 parts per million (ppm), if all nations were to take commensurate actions.[19] Second, the caps gradually become more stringent over an extended period, thus reducing costs by avoiding the necessity of premature retirement of existing capital stock, by reducing vulnerability to siting bottlenecks and other risks that arise with rapid capital stock transitions, and by ensuring that firms have the opportunity to incorporate appropriate advanced technology in their long-lived capital investments.[20]

19. "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).

20. An alternative to the type of caps recommended here, which are denominated in tons of CO_2 emissions, is the use of intensity-based targets, where emissions intensity is specified by the ratio of emissions to economic activity. Any aggregate output index could serve as the denominator, but a target based on CO_2 emissions per dollar of GDP has been frequently proposed. Under such a GDP-indexed cap, allowable emissions in each year would be equal to the intensity cap multiplied by GDP. The Bush administration's climate policy includes emissions intensity targets of this type (Pizer 2005a). Intensity-based caps are not inherently more or less stringent than absolute caps: given a GDP forecast, an intensity-based cap can be designed to yield the same expected emissions level as any absolute cap. An intensity-based cap does introduce uncertainty regarding emissions levels, but at the same time it reduces cost uncertainty. However, intensity-based targets would create problems for linking with cap-and-trade systems in other nations. Total emissions under linked systems may either increase or decrease if one or both systems employ an intensity-based rather than an absolute cap. It should be noted that the correlation

TABLE 1

CO_2 Emissions from Energy Consumption by Sector and Fuel Type, 2005

Millions of metric tons except where stated otherwise[a]

	Sector's direct emissions							
Sector	Coal	Oil	Natural gas	All fuel types	Sector's direct emissions as share of total for all sectors (percent)	Sector's indirect emissions from electricity use	Sector's direct and indirect emissions	Sector's direct and indirect emissions as share of total for all sectors (percent)
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[b]	17.1	663	1,682	28.3
Electricity	1,944	100	319	2,375[c]	39.9	NA	NA	NA
All sectors	2,138	2,614	1,178	5,945			5,945	
All sectors as share of total (percent)	36.0	44.0	19.8		100.0			100.0

Source: U.S. Energy Information Administration (2006).

a. Emission totals differ from those in figure 1 because figure 1 includes CO_2 emissions from industrial processes and because of minor differences in measurement, such as treatment of emissions from U.S. territories.

b. Includes emissions from net coke imports not accounted for in the first three columns.

c. Includes emissions from geothermal and waste-to-energy generation not accounted for in the first three columns.

Upstream Point of Regulation and Economy-Wide Scope of Coverage

Any cap-and-trade system for CO_2 must define the set of emissions 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). To achieve economy-wide coverage, the point of regulation should be upstream, collecting allowances according to the carbon content of fuels at the point of their extraction, import, processing, or distribution.[21] The first sellers of extracted fossil fuels would be required to hold allowances: for coal, at the mine shipping terminus; for petroleum, at the refinery gate; for natural gas, at the first distribution point; and for imports, at the point of importation. Such a cap would effectively cover all sources of CO_2 emissions throughout the economy (Table 1).[22]

Any upstream program should include a credit mechanism, to address both the small portion of fossil fuels that are not combusted and the use of

between GDP and emissions varies substantially across countries, ranging from 0.70 for the United States to only 0.10 for France (Newell and Pizer 2006). Where the relationship between GDP and emissions is weak, an intensity-based cap may exacerbate fluctuations in emissions reduction efforts by overadjusting emissions targets in response to economic fluctuations. More broadly, an intensity target need not take the form of a simple ratio, and more sensible outcomes would be associated with slightly more complex formulas (Aldy 2004).

21. Regulation at the point of transportation or distribution is sometimes referred to as midstream regulation. A downstream program imposes allowance requirements at the point of emissions, for example at electric power plants or factories. An upstream point of regulation has been used in the past 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 were phased out through limits on their production rather than 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 electric power and transportation sectors account for over 70 percent of total CO_2 emissions; when the industrial sector is included, these three sectors account for nearly 90 percent of emissions. But electric power sector emissions result from electricity use by all other sectors. The last column of Table 1 includes indirect emissions from electricity use in reporting each of the other sectors' emissions.

postcombustion emissions reduction technologies, such as carbon capture and sequestration (CCS). It should also include a credit-based arrangement for fossil fuel exports so that exporters are not placed at a competitive disadvantage relative to foreign suppliers that do not face allowance requirements. Emissions reductions from CCS technologies can be readily measured. Also, unlike some credit-based programs, a program for CCS runs no risk of granting credits for fictitious emissions reductions: because emissions sources have no incentive to install CCS equipment in the absence of a climate policy, emissions reductions achieved by CCS are clearly additional. CCS technologies are expected to play a significant role in achieving long-run emissions reduction goals; therefore 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 the initial allowance allocation decision. The point of regulation does not dictate or in any way limit who may receive allowances if allowances are distributed for free. The point-of-regulation decision also has no direct effect on either the costs of emissions reduction or the distribution of resulting economic burdens.[23] A cap has the same impact on the effective cost of fuel for downstream users 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, all will include it in the prices they set for downstream customers. With downstream regulation, the downstream customer pays for the allowances and the 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 emissions reduction efforts—and thereby incur the same emissions reduction costs—in either case, because they face the same carbon price signal.

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

Environmental Effectiveness

An economy-wide cap provides the greatest certainty of achieving a given national emissions target. Limiting the scope of coverage to a subset of emissions sources leads to emissions uncertainty through two channels. First, exogenous changes in emissions from unregulated sources can cause national emissions to deviate from expected levels, even if emissions from regulated sources meet the target.[24] Second, a limited scope of coverage can cause leakage, in which market adjustments

23. 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, again, these costs would be small relative to the overall cost of a well-designed cap-and-trade system.

24. For example, the EU ETS covers CO_2 emissions from facilities accounting for about 45 percent of EU greenhouse gas emissions. As a result, the European Union'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 also the online appendix).

resulting from the regulation lead to increased emissions from unregulated sources outside the cap that partially offset reductions under the cap. For example, a cap that includes emissions by the electric power sector (and thereby affects electricity prices) but excludes emissions from natural gas or heating oil use in commercial and residential buildings may encourage substitution of unregulated natural gas or oil heating for electric heating in new buildings. As a result, increased emissions from natural gas and oil heating will offset some of the reductions achieved in the electric power sector.

Some stakeholders have argued for a downstream point of regulation for at least some emissions sources.[25] If downstream regulation of some facilities is allowed, broad coverage of emissions will require a hybrid point-of-regulation approach, in which some sources are regulated upstream and others downstream. As commonly proposed, 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. This approach has two significant problems. First, a hybrid system may fail to provide complete coverage. Some emissions sources may fall through the cracks, covered by neither downstream nor 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 would increase administrative complexity and the potential for noncompliance.[26]

Cost Effectiveness

The aggregate costs of emissions reductions undertaken to meet a cap are directly affected by the scope of coverage. Emissions reduction programs are subject to economies of scope: costs decline more than proportionately as the program's scope increases. An upstream point of regulation makes economy-wide coverage feasible, thus exploiting these economies.

Three factors contribute to these lower costs. First, a broader cap expands the pool of low-cost emissions reduction opportunities that can contribute to meeting a national target. Even if a sector may contribute only a small portion of reductions, including that 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, it has been estimated that the cost of achieving a 5 percent reduction in U.S. CO_2 emissions could be cut in half under an economy-wide cap compared with a cap limited to the electric power sector (Pizer et al. 2006).

Second, an economy-wide cap provides important flexibility to achieve emissions targets given uncertainties in emissions reduction costs across sectors. By drawing from a broader, more diverse set of emissions reduction opportunities, an economy-wide cap reduces the risk of unexpectedly high costs, much as investing in 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 con-

25. 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).

26. An alternative approach that may address the objectives of downstream proponents while reducing administrative complexity would be to adopt a pure upstream cap-and-trade system as proposed here, but allow certain downstream sources—such as electric power generators using CCS—to choose downstream regulation. This would be an alternative to the credits for CCS proposed elsewhere in this paper. Under this optional downstream regulation, sources would be granted allowances reflecting their fuel consumption to offset the effect of upstream regulation on their fuel costs, but would be required to surrender allowances for their emissions. Since any sources subject to downstream regulation need to be monitored in any event, this approach would be far less administratively complex than requiring upstream sources to determine their allowance requirements for fuel supplied based on the identity of the end consumer. To the extent that there are real benefits of downstream regulation, such an approach could capture some of these benefits without sacrificing the complete coverage achieved by pure upstream regulation, while minimizing the administrative complexity that usually comes with a hybrid point-of-regulation system.

tribute cost-effective emissions 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, a policy that proposes to eventually expand an initially narrow scope of coverage might create broad incentives for innovation. But achieving that subsequent expansion would be difficult in practice, given that the adjustments that sectors face upon joining the cap will only become greater over time as the cap's stringency increases. Thus political obstacles to expanding the cap may 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 that number increases, the administrative costs to regulators and firms rise. The point of regulation should be chosen to facilitate regulation and minimize the administrative costs of a desired scope of coverage.[27]

An upstream point of regulation makes an economy-wide cap-and-trade system administratively feasible: nearly all U.S. CO_2 emissions could be capped with regulation of just 2,000 upstream entities (Bluestein 2005). It would be administratively infeasible to implement an economy-wide cap-and-trade (or carbon tax) system through downstream regulation, as this would require regulation of hundreds of millions of commercial establishments, homes, and vehicles. An upstream program also eliminates the regulatory need for facility-level greenhouse gas emissions inventories, which would be essential for monitoring and enforcing a downstream cap-and-trade system. 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). Because monitoring is of little use without enforcement, meaningful and credible penalties are also important, such as fees set at up to ten times marginal abatement costs, plus the requirement for firms to make up the difference. Such provisions have resulted in virtually 100 percent compliance in the case of the SO_2 allowance trading program (Stavins 1998).

Distributional Consequences

An economy-wide emissions cap spreads the cost burden of emissions reductions across all sectors. In contrast, limiting the scope of coverage both increases the overall cost (as discussed above) and concentrates the burden among certain sectors, regions, and income groups.

Limiting the scope of coverage may also have unintended consequences. For example, limiting coverage to the electric power 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 would alter regional variation in household impacts because of regional differences in household use of electricity, heating oil, and natural gas.

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

A cap-and-trade system minimizes the cost of meeting an emissions target, but emissions reduction costs can be greater than anticipated. This risk arises because, without mechanisms (described below) that control costs, regulated sources will have to meet the emissions cap regardless of the cost. This cost uncertainty is one argument offered in favor of a carbon tax, which largely eliminates cost uncertainty (but introduces uncertainty about the quantity of emissions reduction) by setting the carbon price at a predetermined level. But policymakers can protect against cost uncertainty under a cap-and-trade system, while largely maintaining

27. The size of the regulated sources also affects aggregate administrative costs. The EU ETS, a downstream scheme, covers 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.

TABLE 2

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

	Fossil fuel category		
Point of regulation	**Coal**	**Oil**	**Natural gas**
Upstream	Mining and imports (500 companies)	Production wells and imports (750 companies)	Production wells and imports (750 companies)
Midstream	Rail, barge, and trucking (not addressed)	Refining (200 refineries)	Pipelines and processing (200 pipelines, or 1,250 local distribution companies and 500 liquified natural gas plants)
Downstream	Electric power plants (500 plants)	Mobile sources, industrial boilers, and electric power plants (millions of sources)	Industrial boilers, commercial and residential furnaces, and electric power plants (millions of sources)

Source: Cambridge Energy Research Associates (2006).

certainty over emissions, by adopting a few key design elements: provision for banking and borrowing of allowances, and possible inclusion of a cost containment mechanism.

The Nature of Cost Uncertainty

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

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 NO_X emissions is a frequently cited example. RECLAIM had *no* automatic mechanism for relaxing emissions caps in the face of unexpectedly high costs, and in 2000 allowance prices spiked to more than twenty times their historical levels (Pizer 2005b).[28] Cost uncertainty may increase the long-run cost of emissions caps, because uncertainty about future allowance prices may deter firms from undertaking socially desirable but capital-intensive emissions reduction investments, forcing greater reliance on less capital-intensive but more costly measures. Firms facing investments in irreversible (sunk) costs require greater returns as uncertainty about costs or revenue increases (Dixit and Pindyck 1994). Furthermore, although the populations directly affected by allowance price spikes may be relatively small, the higher prices 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 CO_2 emissions.

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

28. Because electric power 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 electric power generators to standards-based regulation in response to the economic disruptions that occurred (Harrison 2003; see also the online appendix).

timing of emissions reductions in the face of unexpectedly high or low costs.[29] If the cost of achieving targets is unexpectedly and temporarily high, firms can use banked or borrowed allowances instead of undertaking costly reductions. Banking of allowances—undertaking extra emissions 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 for so long that the banked allowances face exhaustion. This problem may be particularly acute in a cap's early years, when relatively few allowances have been banked. Borrowing of allowances from future years' allocations can be a particularly useful form of cost protection in these early years.

Banking offers this cost protection while still guaranteeing achievement of long-run cumulative emissions targets. Although banking may shift some emissions out in time, from when allowances are banked to when they are used, cumulative emissions at any point can never exceed the number of allowances issued up to that point.

Credible mechanisms need to be established to ensure that borrowed allowances are "repaid" through future emissions reductions. For example, firms could be allowed to borrow from their own future supplies, while entering into a contractual—possibly bonded—agreement with the government to repay the borrowed emissions at a subsequent date. Or the government could allocate allowances from a future year to be used this year, decreasing the firm's future allocation by the same amount.

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 allowances. With such a market, offsets—discussed elsewhere—can play a key 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 inclusion of a sensible cost-containment mechanism. Such a mechanism could allow capped sources to purchase additional allowances at a predetermined price, set sufficiently high (say, from twice to ten times the expected level of allowance prices, not 10 or 20 percent above) to make it unlikely to have any effect unless allowance prices exhibit truly drastic spikes. The resulting revenue would be dedicated exclusively to financing emissions reductions by uncapped sources, such as of non-CO_2 greenhouse gases, or to buy back allowances in future years. This is very different from standard proposals for a "safety valve," both because the environmental integrity of the program (the cap) is maintained by using the revenue for the specific uses just mentioned, and because the high predetermined price has no effect unless there are drastic price spikes.

The predetermined trigger price for the cost-containment mechanism would place a ceiling on allowance prices and hence on abatement costs, because firms will not undertake emissions reductions more costly than the trigger price (Jacoby and Ellerman 2002).[30] To be effective as an insurance mechanism, the trigger price should be set at the maximum incremental emissions 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 is set too high would provide no insurance against excessive costs.

29. All existing 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 SO_2 allowance trading program, and five years in the case of the Kyoto Protocol's "commitment periods."

30. An alternative that would maintain and possibly exceed long-run emissions 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 emissions reduction opportunities below a given cost, which may exceed the amount of reductions necessary to meet the cap. The need for a price floor may decrease, however, with banking.

Importantly, because revenue from the trigger price mechanism 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 and increase cost-effectiveness, while simultaneously maintaining environmental effectiveness.

Allocation of Allowances

The cap-and-trade system would create a new commodity, a CO_2 allowance, which would have value because of its scarcity: only as many allowances would be issued as is consistent with the emissions target. The government could distribute allowances for free 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 in a nationwide system would be substantial. Indeed, if all allowances are auctioned, annual auction receipts would amount to a significant share of federal revenue.[31] For firms needing to buy auctioned allowances, total allowance costs would significantly exceed the cost of emissions reductions that would meet a modest cap. The reason is that under an economy-wide emissions cap that reduces nationwide emissions by 5 percent, for example, regulated firms would incur costs associated with reducing those emissions but would have to purchase allowances for the remaining 95 percent of their emissions.

The magnitude of these firm-level costs indicates that the choice of allocation method (auctioning versus free distribution) and the use of auction revenue can have important distributional implications. By contrast, the allocation choice does not affect the achievement of the emissions 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 would be possible to distribute allowances for free 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 industries for the impact of a climate policy, since they could then sell the allowances to firms directly regulated under the cap.

The Choice Between Auction and Free Distribution: Overall Cost Concerns

Beyond the distributional consequences of allocation decisions, the choice of whether allowances will be auctioned or distributed for free can affect the program's overall cost. Generally speaking, the choice between auctioning and allocating allowances for free does not influence firms' production and emissions reduction decisions.[32] Firms face the same emissions cost regardless of the allocation method. Even when it uses an allowance that it received for free, a firm loses the opportunity to sell that allowance and thus incurs an opportunity cost.

31. Under the economy-wide program proposed here, annual auction revenue (if all allowances were auctioned) would exceed $100 billion, compared with federal net tax revenue in fiscal year 2006 of $351 billion from the corporation income tax, $994 billion from the individual income tax, and $810 billion from employment taxes (U.S. Energy Information Administration 2006b).

32. Two exceptions are allocations to regulated utilities (discussed below) and "updating allocations." If allowances are freely allocated, the allocation should be on the basis of some historical measure or measures, not on the basis of measures that firms can influence. Updating allocations, which involve periodically adjusting allocations over time to reflect changes in firms' operations, violate this principle. 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. Selective use of updating allocations has nevertheless been recommended by some to preserve industry competitiveness and reduce emissions leakage in sectors with high CO_2 emissions intensity and unusual sensitivity to international competition. This paper recommends an alternative approach, namely, a requirement that imports of a small set of specific commodities carry with them CO_2 allowances (see below). Two closely related issues, which must be addressed even when allocations are historically based, are whether to allocate allowances for free 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). This has apparently happened under the EU ETS.

But the choice to distribute allowances for free can affect a cap's cost in two ways. First, free distribution forgoes the collection of auction revenue that could be used to reduce the costs of the existing tax system or fund other socially beneficial policies. Second, free allocations may affect electricity prices in regulated cost-of-service electricity markets, thereby affecting the extent to which reduced electricity demand contributes to limiting emissions cost-effectively.[33]

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 would stimulate additional economic activity, offsetting some of the cap's costs. These tax reductions could be significant. Studies indicate that "recycling" auction revenue by using it to reduce personal income tax rates could offset 40 to 50 percent of the economy-wide social costs that a cap would impose if allowances were distributed for free (Bovenberg and Goulder 2003).

Achieving such gains may be difficult in practice, because the types of tax reform that would achieve them might not be those most politically likely to be enacted. 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, it would have a smaller (perhaps no) effect on incentives to work and invest. On the other hand, auction revenue could yield economic gains without tax reform by reducing fiscal imbalances, thereby reducing the need for future tax increases.

In general, auctioning generates revenue that can be put toward innumerable uses. Although all uses of public funds have distributional implications, some offer 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 (for example, through measures that offset the cap's potentially adverse fiscal impacts) and funding of 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 distributing allowances for free, depends fundamentally on the use to which the auction revenue is ultimately put.

The Choice Between Auction and Free Distribution: Distributional Concerns

Although the revenue from auctions has the potential to reduce a climate policy's economy-wide costs depending on how that revenue is used, free distribution of allowances has its advantages as well, in that it provides an opportunity to address the distribution of a climate policy's economic impacts. (In principle, auction revenue could be redistributed in a manner equivalent to any free distribution of allowances, but such a proposal would likely encounter greater political challenges.) Free distribution can be used to redistribute a cap's economic burdens in ways that mitigate the impacts on those most affected. A sensible principle for allocation would be to try to compensate those sectors and individuals most burdened by the climate policy. Such redistribution of impacts may also help establish political consensus on a climate policy that achieves meaningful emissions reductions. Thus the choice between auctioning and free allocations introduces a potential trade-off between a cap's aggregate cost and the achievement of distributional objectives.

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

With some important exceptions, in a competitive market the benefits of free allowances generally accrue only to their recipients, increasing their profitability or wealth, and generally do not benefit the consumers, suppliers, or employees of those recipients. Hence, although the cost of allowance requirements can be expected to ripple through the economy, the benefits of free allocations will not.[34] Therefore, if markets (including deregulated electricity markets) are competitive, free distribution of allowances for purposes of compensation should be directly targeted at those industries, consumers, and other entities that policymakers wish to benefit. 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 the 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 needs to be distributed for free to meet specific compensation objectives. A permanent allocation of all allowances to affected firms would, in the aggregate,[35] significantly overcompensate them for their financial losses (Goulder 2000; Bovenberg and Goulder 2003; Smith, Ross, and Montgomery 2002).[36] 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. Therefore, allocating *all* allowances for free in perpetuity to affected firms would overcompensate them in the aggregate and would use up resources that could be put toward other uses, including compensating the consumers who bear much of the ultimate burden.

Proposal for a Mixed System of Auction and Free Distribution

Given these important differences in the implications of free allocation versus auctioning, the best alternative is to begin with a hybrid approach wherein some (half in the present proposal) of the allowances are *initially* auctioned and the rest are distributed free to entities burdened by the policy, including suppliers of primary fuels, electric power producers, energy-intensive manufacturers, and particularly trade-sensitive sectors. The share of free allowances should decline over time until it eventually (after twenty-five years in the present proposal) reaches zero. The reason is that, over time, the private sector, including those industries with long-lived capital assets, will have an opportunity to adjust to the new system. Thus the justification for free distribution diminishes over time. In the short term, however, free distribution provides flexibility to address distributional concerns that might otherwise impede initial agreement on a policy. Meanwhile the portion of allowances that are initially auctioned will generate revenue that can be used for public purposes, including compensation for the program's impacts on low-income consumers, public spending for related research and development, reduction of the federal budget deficit, and reduction of distortionary taxes.

Why this particular pattern of a 50-50 initial allocation with phase-out of the free allocation over twenty-five years? The answer is that this time path is consistent with analyses of the share of allowances that would need to be distributed for free to compensate firms for equity losses. In a series of

34. 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.

35. Even if all firms, in the aggregate, are overcompensated, some may still experience losses, because of unequal cost incidence at the firm level.

36. According to these studies, the coal, natural gas, and petroleum industries would be fully compensated if fewer 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 electric power sector, see Burtraw and others (2002) and Burtraw and Palmer (2006).

analyses that considered the share of allowances that would be required *in perpetuity* for full compensation, Bovenberg and Goulder (2003) found that a 13 percent share would be sufficient to compensate the fossil fuel extraction sectors. In a scenario consistent with the Bovenberg and Goulder study, Smith, Ross, and Montgomery (2002) found that free distribution of 21 percent of allowances would be needed to compensate primary energy producers and electric power generators.[37]

The time path recommended here for an economy-wide program—half of allowances initially distributed free, with this share declining to zero after 25 years—is equivalent in terms of present discounted value to perpetual allocations (like 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 principle 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.

Credits and Offsets for Specified Activities

Any well-designed emissions reduction scheme will need to include provision for offsets or credits for certain specific activities. This is a potentially advantageous means of encouraging emissions reductions from activities outside the scope of the cap-and-trade system, and lowering costs. An important concern, however, is the additionality problem discussed above, 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 simply infeasible to integrate into the cap-and-trade system.

The proposed upstream program would include selective use of the credit mechanism to address the small portion of fossil fuels that are not combusted, for example those used in some petrochemical feedstocks, because these uses do not contribute to greenhouse gas emissions. Credits would also be issued for fuel exports, as mentioned earlier.

A third proposed use of credits would be to address the use of downstream emissions reduction technologies such as CCS. As explained above, emissions reductions from CCS technologies can be readily measured, and because there is no incentive to install CCS equipment in the absence of a climate policy, emissions reductions achieved by CCS are clearly additional. CCS technologies may play a significant role in achieving long-run emissions reduction goals (U.S. Energy Information Administration 2007; Deutch and Moniz 2007), making this credit mechanism an essential component of the upstream cap. Indeed, it might even be desirable to intentionally overcompensate CCS activities with credits, to provide a stronger incentive for research and development.

A program of credits for selected cases of biological sequestration through land use changes should also 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 slowing of deforestation (Stavins 1999; Stavins and Richards 2005; Lubowski, Plantinga, and Stavins 2006).[38] 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 are technologically feasible through third-party verification using remote sensing, but the 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 defores-

37. Analyses by Burtraw and Palmer (2006) and Burtraw and others (2002) appear to corroborate these findings.
38. For example, Stavins and Richards (2005) estimated that more than 1 billion metric tons of CO_2 could be sequestered annually at a cost ranging from about $8 to $23 per ton.

tation. 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 is 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).[39]

Finally, provision should be made to expand coverage over time to non-CO_2 greenhouse gases. Although CO_2 is by far the most important anthropogenic greenhouse gas, responsible for 84 percent of radiative forcing linked with emissions in 2005 (Figure 1), it is by no means the only one of concern. CO_2, methane (CH_4), nitrous oxide (N_2O), and three groups of fluorinated gases—sulfur hexafluoride (SF_6), hexafluorocarbons (HFCs), and polyvinyl fluorocarbons (PFCs)—are the major greenhouse gases and the focus of the Kyoto Protocol.[40] And because reductions in emissions of some of these gases 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 numerous 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 or offset mechanisms, taking care to grant credits in CO_2-equivalent terms only for well-documented reductions. Over time such approaches could be developed for industrial emissions of methane and NO_2 and for the manufacture of key industrial gases in the case of refrigerants (HFCs), circuits (PFCs), and transformers (SF_6). (Agricultural emissions are probably too dispersed to be subject to a workable program.) Thus cap-and-trade of non-CO_2 greenhouse gases would likely combine upstream and downstream points of regulation.

More broadly, because of concerns about additionality and related perverse incentives, the role of project-based offsets should be defined carefully.[41] In particular, offsets must be given only for real, additional, verifiable, and permanent reductions in emissions. Constraints should not be set 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.

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

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

Linkage with Other Domestic Cap-and-Trade Systems

In the absence of a national climate policy, ten northeastern states have planned a downstream cap-and-trade system among electric power generators in the RGGI program (described above), and California is considering implementing a cap-and-trade program at the state level. The economy-wide, national, upstream cap-and-trade system proposed here could take the place of any regional, state, and local systems so as to avoid duplication, double counting, and conflicting requirements

39. A cap-and-trade (or other) climate policy, by increasing the cost of fossil fuels, may provide incentives for the production of fuels from biomass, which can result in the conversion of forested areas to agricultural production, thereby increasing net CO_2 emissions due to the change in land use.

40. 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.

41. For an optimistic assessment of the role of offsets, see Natsource (2007).

(Stavins 2007). 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.

Linkage with Cap-and-Trade and Emissions Reduction Credit Systems Outside the United States

In the long run, linking of the U.S. cap-and-trade system with cap-and-trade systems in other countries or regions, such as the EU ETS, will clearly be desirable to reduce the overall cost of reducing greenhouse gas emissions and achieving any future global concentration targets (Jaffe and Stavins 2007). But what level and type of linkage are desirable in the early years of the development of a U.S. cap-and-trade system is open to debate. In the short term it may be best for the United States to focus on linkages with emissions reduction credit programs, such as the Kyoto Protocol's Clean Development Mechanism (CDM), for several reasons.[42]

First, by tapping low-cost emissions reduction opportunities in developing countries, linkage of the U.S. system with CDM has greater potential to achieve significant cost savings for the United States than does linkage with cap-and-trade systems in other industrialized countries, where abatement costs are more similar to those in the United States. (Concerns about additionality associated with CDM credits are addressed later in this section.)

Second, linkage with an emissions reduction credit system such as CDM can only lower, not raise, domestic allowance prices, since the transactions would be unidirectional, involving only U.S. purchases of (low-cost) CDM credits. In contrast, bidirectional linkage of the U.S. system with another cap-and-trade system could either decrease *or* increase the domestic allowance price, depending upon which country has the higher marginal abatement costs. Similarly, other countries contemplating linking their cap-and-trade 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 United States 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 link its ETS with a U.S. system that employs a safety valve or other such cost containment measure. On the other hand, the United States could link with emissions reduction credit systems, such as CDM, even with a cost containment measure in place. In summary, compared with linking with other cap-and-trade 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 cap-and-trade systems, such as the European Union's, will likely themselves be linked with CDM, linking the U.S. system with CDM would have the effect of linking the U.S. system with those other systems indirectly, 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 emissions reductions associated with resulting increased emissions in the United States would come from Europe, not from the countries that originally supplied the CDM credits.

Fifth, this indirect linkage should reduce the 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 it will differ significantly from what it would be if the United States were the only country doing the linking. Although significant additionality concerns as-

42. The Clean Development Mechanism, one of the so-called "flexibility mechanisms" in the Kyoto Protocol, provides that industrialized countries, which have taken on binding targets under the Protocol, can meet those targets in part by financing projects in developing countries which result in emissions reductions.

sociated with CDM credits may indeed arise, many of the credits that the U.S. system would ultimately purchase would be used by other linked systems if the United States did not link with CDM. Hence, for these credits, the U.S. decision to link with CDM raises no incremental additionality concerns. Any U.S. use of these credits would result in emissions reductions in the other linked systems that would otherwise have used the credits.

Finally, the indirect linkage created by a U.S. link with CDM can achieve some and perhaps much of the same cost savings that would arise from direct linkage with other cap-and-trade systems. CDM credits can be sold on the secondary market and so will ultimately go to the linked system with the highest allowance price, thus promoting the same convergence of allowance prices that direct linkage would achieve. If low-cost CDM credits are in sufficient supply, direct linkages between the various systems and CDM would achieve the same outcome as direct linkages among the systems themselves. 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 systems.

For all 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.

Linkage with Other Countries' Climate Policies

The fact that climate change is a phenomenon affecting the global commons means that it can be sensible to condition the goals and operations of the proposed U.S. cap-and-trade program on other countries' efforts to reduce greenhouse gas emissions. One approach would be to include a provision for tightening the overall U.S. emissions cap when and if the president or Congress determines that other major CO_2-emitting nations have taken certain specific climate policy actions. This kind of "issue linkage" can be effective, particularly if the United States does not participate 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 (goods whose manufacture generates large quantities of CO_2 relative to their value) from countries that 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 participant 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 imported and import-competing domestic products, thereby reducing emissions leakage and inducing key developing countries to join an international agreement (Morris and Hill 2007).

Such a mechanism would raise some understandable concerns. First is economists' natural resistance to tampering with free trade to achieve other ends. Second is the difficulty of calculating the appropriate quantities of allowances for manufactured imports. Third is the inescapable irony that the United States might adopt a mechanism for use with other countries that itself was recently proposed by Europeans for use against the United States (although with a border tax) because of its failure to ratify the Kyoto Protocol. Finally, and 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 restricting the mechanism 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 CO_2 emissions-intensive goods. The requirement would not apply to countries that are taking actions comparable to the United States to reduce their greenhouse gas emissions, and exemptions could be provided for countries with very low levels of emissions and at the lowest levels of economic development.

To be compatible with World Trade Organization (WTO) rules, the burden imposed on imported and domestic goods must be roughly comparable, with no discrimination among nations with similar conditions (Pauwelyn 2007).[43] 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.[44] Properly designed and constrained, this mechanism could be a useful intermediate step of international linkage on the way to U.S. participation in a sound international agreement.

Associated Climate Policies

The price signals generated by a well-functioning upstream cap-and-trade system will be rendered ineffective if the markets on which the system depends fail at their basic functions. If these market failures are large enough and the cost of correcting them is small enough to warrant policy intervention, an argument can be made to attack these other market failures directly (Newell, Jaffe, and Stavins 1999).

Examples of such market failures include information problems that lead consumers to undervalue the expected energy cost savings when purchasing energy-efficient durable goods ranging from room air conditioners to motor vehicles. There is also, in theory, a principal-agent problem: landlords may underinvest in energy-efficient appliances because their tenants pay their own electricity costs. Perhaps the most important example of market failure is that involving research and development, whose characteristics as a public good—the knowledge generated may not be exclusive, so that the economic returns cannot be fully captured—lead to underinvestment. 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. The National Commission on Energy Policy has recommended a variety of such policies (2004, 2007b).[45]

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

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

45. A conceptually distinct issue is that other policy problems—an example is “energy security”— may call for public policies that have their own climate impacts. For examples, see Sandalow (2007).

III. Economic Assessment of the Proposal

This economic assessment of the proposed cap-and-trade system begins with a qualitative examination of the system's implications 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 CO_2 emissions caps. In addition, the analysis considers the challenge of estimating the benefits of a U.S. program that addresses a global commons problem, and it reports numerical benefit estimates from previous sources to place the cost estimates in context. The section closes with an extensive consideration of the distributional impacts of the proposed system, including illustrative numerical estimates of the sectoral cost impacts.

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 CO_2 emissions reduction stems largely from certain characteristics of global climate change itself. First, the climate impacts depend on the stock of greenhouse gases that accumulate in the atmosphere, not on the flow at any point in time. Given the long persistence of greenhouse gases in the atmosphere, cumulative emissions over decades are the appropriate focus of policy action. Second, a given quantity of emissions has the same effect on the global atmospheric stock no matter where it is generated. Thus a given reduction in emissions produces the same benefits no matter how, where, or, to a large extent, when it is achieved. This allows for considerable flexibility in achieving reductions, thereby lowering costs without compromising the ultimate goal. A cap-and-trade system (and likewise a carbon tax) takes advantage of what has been termed "what, where, and when" flexibility.

The cap-and-trade system minimizes compliance costs through "what" flexibility by exploiting the fact that many different types of actions offer low-cost CO_2 emissions reduction opportunities. Among these are adopting more efficient or lower-emitting technologies, adjusting the use of equipment that generates emissions, and accelerating the replacement of existing equipment. The cap-and-trade system allows—indeed, encourages—emissions reductions to be achieved through whatever measures are least costly.

The cap-and-trade system also minimizes compliance costs through "where" flexibility, exploiting the fact that control costs vary widely across industries and across sources within an industry. Costs can vary significantly even across households or firms that use identical equipment. The cap-and-trade system exploits this variation by encouraging the reduction of emissions wherever it is least costly. Lower-cost opportunities to reduce emissions may also 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 emissions in other regions. Moreover, emissions reduction costs will change over time as new technologies are developed. What may be the most cost-effective distribution of emissions reduction efforts across sectors, technologies, and regulated entities today will not be so ten years from now. The cap-and-trade system adjusts automatically as control costs change over time.

As emphasized earlier, the cap-and-trade system also minimizes costs through "when" flexibility. Because climate change results from the accumulation of emissions over decades to centuries, allowing for flexibility in the timing of emissions reductions is cost-effective. The cap-and-trade system can provide this temporal flexibility through the design elements proposed above: allowing the banking of allowances for use in future years; permitting allowances to be borrowed from future allocations for use today; and setting multiyear compliance periods, to give firms flexibility in how they distribute their emissions within the compliance period. By 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. It also helps prevent existing emissions reduction technologies from being locked into long-lived capital investments when better technologies may be available later. Likewise, the system avoids forcing complying firms to undertake unnecessarily costly emissions reductions in one year because of unusual circumstances, when less costly offsetting reductions can be achieved in other years. For example, annual variations in weather may affect the availability of renewable energy resources, such as hydroelectric power. Allowing "when" flexibility thus achieves cost-effectiveness without compromising cumulative emissions targets.

Given the long-term nature of climate change, it is exceptionally important that the cap-and-trade approach provide incentives for long-term technological change. Technologies yet to be developed may 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 and in how fossil fuels are used. By rewarding emissions reductions, however they are accomplished, the cap-and-trade system provides broad incentives for innovations that lower the cost of achieving emissions targets.

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 greenhouse gas targets. Such analyses have been used to estimate the costs associated with a domestic cap-and-trade system or a carbon tax. Three modeling groups have carried out analyses under the U.S. government's Climate Change Science Program,[46] and a much larger set of modeling teams worked together under Stanford University's Energy Modeling Forum project, EMF-21 (Chesnaye and Weyant 2006).

Two such 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),[47] 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).[48]

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 on key assumptions regarding a wide variety of current and future parameters and variables. The factors found to have the greatest effects on the cost estimates are: the forecast business-as-usual (BAU) emissions path (the model's prediction of what emissions will be in

46. 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 emissions 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 and others (2006).

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

48. EPPA is a component of the IGSM. For a summary of findings from the models, see Aldy (2007).

the absence of public policy intervention); policy stringency and its trajectory; the scope of policy coverage across the economy; assumed opportunities for fuel switching and energy efficiency improvements; availability of offsets; and uses of the revenue 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 its authors (Paltsev et al. 2007a, 2007b) applied the model to examining an upstream cap-and-trade system that in its stylized form is close to what is proposed here.

As with any analytical model, certain aspects of the EPPA model and its analysis affect the cost estimates. Some of the 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 model that assumes perfect, frictionless markets (marginal costs are equated among emissions sources), with full employment of resources and no transition costs (this is important for the short term). In essence, emissions reductions, not policies themselves, are modeled. 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, the model's assumption of perfect information will tend to understate actual costs. On the other hand, the cost-saving properties of specific design elements that reduce cost uncertainty cannot really be captured. Finally, it is assumed that other regions of the world undertake commensurate climate policies; this is a significant assumption because of the effects on international fuel and other prices.[49]

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 a hypothetical program that covers all greenhouse gases, each of which is reduced cost-effectively and in the proper proportion. Compared with a CO_2-only program, this is not a problem for the estimation of CO_2 allowance prices, but it does result in overestimates of the impacts on GDP as reported in this paper, because those impacts are for more ambitious programs that include both the indicated CO_2 emissions reductions and additional reductions in non-CO_2 greenhouse gases.[50] 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 trading in allowances or credits for project-level activities. Fourth, expansion of nuclear power is assumed to be limited by concerns for safety and siting of new plants, so nuclear capacity is not allowed to expand despite economic signals that would encourage its use.

With these various model characteristics and assumptions operating in opposite directions, on balance the EPPA analysis can be employed simply to offer some illustrative cost estimates. In addition, the EPPA model does not take into account the existence of state and regional programs. Ignoring such programs in place could tend to overstate the costs of achieving some national cap, but such programs can also lead to inefficiencies through path dependence, leading to a suboptimal national program that drives up costs. However, the major impacts of state or regional programs—assuming they are

49. In particular, Europe, Australia, Canada, 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 them to and holds them at their 2015 emissions through 2034, and then returns them to and holds them at their 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 that policy would depend on policies in the rest of the world.

50. On the other hand, any given set of climate targets (such as targets expressed in terms of CO_2 equivalent) can be achieved at lower cost with a multigas program than with a CO_2-only program. However, the EPPA model's treatment of non-CO_2 greenhouse gases, in which measurement (policy implementation) problems are assumed away, likely has the effect of understating to some degree the aggregate costs of control.

TABLE 3

Emissions Cap Trajectories under Two Illustrative Scenarios, 2005-50

Millions of metric tons of CO_2 equivalent

Greenhouse gas	Scenario	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
All greenhouse gases	BAU[a]	7,092	7,680	8,202	8,596	9,219	9,884	10,711	11,507	12,433	13,283
	Stabilize at 2008 level[b]	7,092	7,680	7,383	7,382	7,382	7,381	7,378	7,376	7,374	7,369
	Reduce to 50% of 1990 level[c]	7,092	7,680	7,226	6,629	6,032	5,434	4,836	4,236	3,636	3,041
CO_2	BAU	5,984	6,517	6,995	7,357	7,915	8,518	9,283	10,013	10,871	11,656
	Stabilize at 2008 level	5,984	6,517	6,710	6,740	6,759	6,782	6,804	6,806	6,793	6,762
	Reduce to 50% of 1990 level	5,984	6,517	6,570	6,036	5,481	4,896	4,310	3,702	3,086	2,504
CH_4	BAU	583	602	612	617	631	643	652	664	677	683
	Stabilize at 2008 level	583	602	400	387	371	354	332	331	338	351
	Reduce to 50% of 1990 level	583	602	389	354	322	313	302	307	317	303
N_2O	BAU	385	388	381	372	366	365	372	381	391	407
	Stabilize at 2008 level	385	388	264	246	241	233	233	231	234	247
	Reduce to 50% of 1990 level	385	388	259	232	220	217	216	219	225	227
Fluorinated gases[d]	BAU	140	174	214	250	308	359	404	451	496	539
	Stabilize at 2008 level	140	174	9	10	11	11	10	9	9	10
	Reduce to 50% of 1990 level	140	174	9	8	9	9	9	9	9	9

Source: Paltsev and others (2007b, 1, 5, 6).

a. Reference case from Paltsev and others (2007b).

b. Based on the 287 cumulative CO_2-e bmt case from Paltsev and others (2007a, 2007b).

c. Based on the 203 cumulative CO_2-e bmt case from Paltsev and others (2007a, 2007b).

d. Sulfur hexafluoride, HFCs, and PFCs.

binding—will be primarily distributional, driving up costs (requiring more abatement) for states with such policies in place and reducing the costs of the national program for other states (Stavins 2007).

Anticipated Emissions Under Two Illustrative Cap Trajectories

The first illustrative trajectory involves stabilizing CO_2 emissions at their 2008 level over 2012-50 (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 2012-50, involves reducing CO_2 emissions from their 2008 level to 50 percent below their 1990 level.[51] This trajectory, also 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 CO_2 emissions well below the cap in the early years, generating a bank of allowances to be used in later years.

Relative to forecast business-as-usual CO_2 emissions, both implementations of a cap-and-trade system would achieve dramatic emissions reductions (Table 5). Under the less aggressive policy, emissions would be 10 percent below BAU in 2015, just three years into the program, and would fall to 38 percent below BAU by 2050. Under the more aggressive policy, emissions are predicted to be 18 percent below BAU in 2015 and fully 75 percent in 2050.

CO_2 Allowances and Fossil Fuel Prices

Tradable CO_2 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 per ton of CO_2 in 2015 to $70 per ton in 2050 for the less aggressive policy, and from $41 per ton in 2015 to $161 per ton in 2050 for the more aggressive policy (Table 6). Actual current allowance prices for the Kyoto Protocol phase of the EU ETS, about $20 per ton of CO_2, 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 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. (The prices reported in Table 6 include the effects of allowance prices on fossil fuel supply and demand but not the cost of the allowances themselves.)

Impacts on Electric Power Production

One of the ways in which the cap-and-trade system cost-effectively de-carbonizes the economy is through its impacts on the production of electricity from various sources. Because sources of electricity differ greatly in their carbon intensity, the gradually increasing CO_2 allowance prices that characterize both cap trajectories lead not only to (relatively small) reductions in electricity production, but also to dramatic changes in the mix of fuels used to generate electricity (Table 7). Conventional coal-fired generation drops sharply even under the less aggressive policy and disappears completely by 2040 under the more aggressive policy, replaced mainly by generation from new plants using CCS. In the short term, electric power generation from natural gas increases with the price of CO_2, but this source

51. Tables 3 and 4 report the caps and anticipated emissions, respectively, for CO_2 and other greenhouse gases. Although the focus of the proposed cap-and-trade system is initially on CO_2, it can be expanded over time as explained above to include some of the other greenhouse gases. The EPPA model was applied by Paltsev and others (2007a) to an analysis of a cap-and-trade system that reduced all greenhouse gases, not just CO_2.

TABLE 4

Greenhouse Gas Emissions Under Two Illustrative Scenarios

Millions of metric tons of CO_2 equivalent

Greenhouse gas	Scenario[a]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
All greenhouse gases	BAU	7,092	7,680	8,202	8,596	9,219	9,884	10,711	11,507	12,433	13,283
	Stabilize at 2008 level	7,092	7,680	6,962	6,897	6,715	6,866	7,867	8,217	7,739	7,804
	Reduce to 50% of 1990 level	7,092	7,680	6,331	6,004	5,454	4,615	5,700	5,288	4,141	3,515
CO_2	BAU	5,984	6,517	6,995	7,357	7,915	8,518	9,283	10,013	10,871	11,656
	Stabilize at 2008 level	5,984	6,517	6,328	6,287	6,132	6,290	7,265	7,605	7,126	7,175
	Reduce to 50% of 1990 level	5,984	6,517	5,740	5,443	4,914	4,085	5,169	4,650	3,588	2,945
CH_4	BAU	583	602	612	617	631	643	652	664	677	683
	Stabilize at 2008 level	583	602	375	365	343	338	353	360	359	369
	Reduce to 50% of 1990 level	583	602	348	331	314	307	305	310	319	328
N_2O	BAU	385	388	381	372	366	365	372	381	391	407
	Stabilize at 2008 level	385	388	252	237	230	228	239	241	245	252
	Reduce to 50% of 1990 level	385	388	239	222	217	214	218	220	226	234
Fluorinated gases[b]	BAU	140	174	214	250	308	359	404	451	496	539
	Stabilize at 2008 level	140	174	8	9	10	11	11	10	10	10
	Reduce to 50% of 1990 level	140	174	7	8	9	9	9	9	9	9

Source: Paltsev and others (2007b, 1, 5, 6).

a. See table 3 for details of the scenarios.

b. Sulfur hexafluoride, HFCs, and PFCs.

TABLE 5

Reduction in CO_2 Emissions from Business as Usual Under Illustrative Scenarios, 2005-50
Units as indicated

Scenario[a] and reduction in emissions from BAU level	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Stabilize at 2008 level										
Millions of metric tons	0	0	667	1,070	1,783	2,228	2,018	2,408	3,745	4,481
Percent of BAU	0	0	10	15	23	26	22	24	34	38
Reduce to 50% of 1990 level										
Millions of metric tons	0	0	1,255	1,914	3,001	4,433	4,114	5,363	7,283	8,711
Percent of BAU	0	0	18	26	38	52	44	54	67	75

Source: Paltsev and others (2007b, 1, 5, 6).
a. See table 3 for details of the scenarios.

TABLE 6

Predicted Prices of CO_2 Allowances and of Fossil Fuels Under Illustrative Scenarios, 2005-2050
Units as indicated

Scenario[a]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO_2 allowance price (2005 dollars per ton of CO_2 equivalent)										
BAU	0	0	0	0	0	0	0	0	0	0
Stabilize at 2008 level	0	0	18	22	26	32	39	47	57	70
Reduce to 50% of 1990 level	0	0	41	50	61	74	90	109	133	161
Fossil fuel prices (2005 price = 1.0)[b]										
Petroleum products										
BAU	1.0	1.2	1.3	1.5	1.7	1.9	2.0	2.1	2.2	2.3
Stabilize at 2008 level	1.0	1.2	1.3	1.5	1.6	1.7	1.4	1.4	1.5	1.5
Reduce to 50% of 1990 level	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 at 2008 level	1.0	1.1	1.2	1.5	1.9	2.4	2.5	2.8	2.8	2.8
Reduce to 50% of 1990 level	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 at 2008 level	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2
Reduce to 50% of 1990 level	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.2

Source: Paltsev and others (2007b, 1, 2, 3).
a. See table 3 for details of the scenarios.
b. 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 fossil fuels.

TABLE 7

Electricity Production Under Illustrative Scenarios, 2005-2050

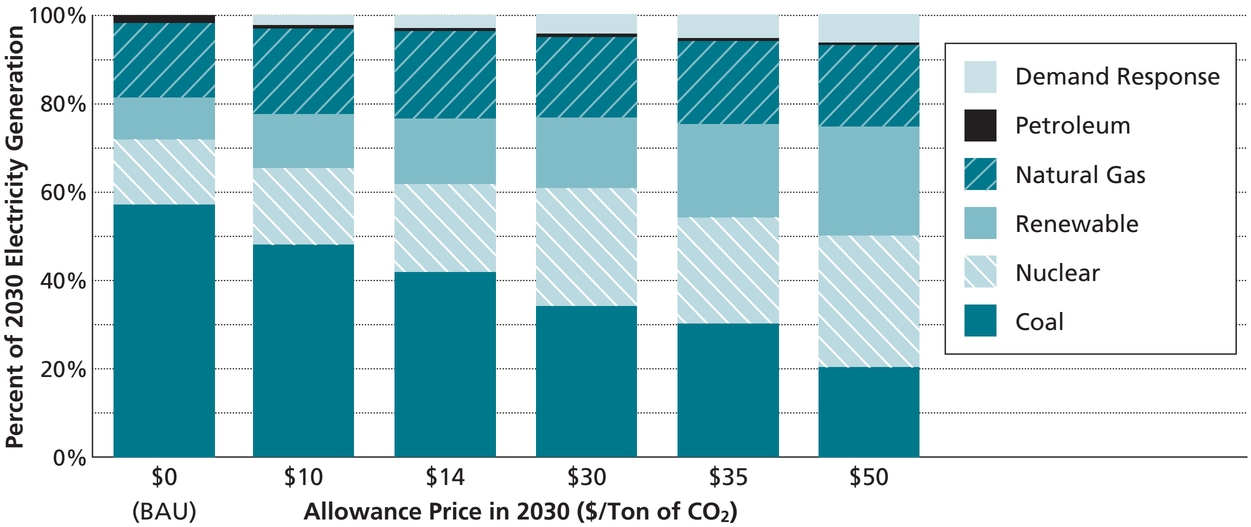
Exajoules

Fuel source and scenario[a]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Coal without CCS										
BAU	7	8	8	9	10	12	13	15	17	19
Stabilize at 2008 level	7	8	7	6	4	3	6	7	4	4
Reduce to 50% of 1990 level	7	8	6	4	3	1	0.4	0	0	0
Oil										
BAU	0.3	0.3	0.3	0.2	0.4	0.4	0.4	0.5	0.5	0.6
Stabilize at 2008 level	0.3	0.3	0.2	0.2	0.1	0.1	0.2	0.3	0.2	0.2
Reduce to 50% of 1990 level	0.3	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Natural gas										
BAU	2	3	3	4	3	3	3	3	2	2
Stabilize at 2008 level	2	3	3	5	9	10	8	6	4	2
Reduce to 50% of 1990 level	2	3	3	5	8	9	6	4	3	1
Nuclear										
BAU	3	3	3	3	3	3	3	3	3	3
Stabilize at 2008 level	3	3	3	3	3	3	3	3	3	3
Reduce to 50% of 1990 level	3	3	3	3	3	3	3	3	3	3
Hydroelectric										
BAU	1	1	1	1	1	1	1	1	1	1
Stabilize at 2008 level	1	1	1	1	1	1	1	1	1	1
Reduce to 50% of 1990 level	1	1	1	1	1	1	1	1	1	1
Other renewable fuels										
BAU	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.5	0.6	0.6
Stabilize at 2008 level	0.2	0.2	0.3	0.4	0.3	0.5	0.4	0.6	0.6	0.6
Reduce to 50% of 1990 level	0.2	0.2	0.1	0.6	0.3	0.5	0.4	0.5	0.6	0.6
Natural gas with CCS										
BAU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stabilize at 2008 level	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reduce to 50% of 1990 level	0.0	0.0	0.0	0.2	0.1	0.4	0.8	0.5	0.3	0.2
Coal with CCS										
BAU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stabilize at 2008 level	0.0	0.0	0.0	0.1	0.1	0.3	1.0	2.0	9.0	13.0
Reduce to 50% of 1990 level	0.0	0.0	0.0	0.2	0.6	2.0	7.0	11.0	15.0	18.0
Total electricity production										
BAU	13	15	16	17	18	20	21	23	25	26
Stabilize at 2008 level	13	15	15	16	17	18	19	21	22	25
Reduce to 50% of 1990 level	13	15	14	15	16	17	19	21	22	24

Source: Paltsev and others (2007b, 1, 2, 3).
a. See table 3 for details of the scenarios.

FIGURE 2

An Alternative Estimate of Impacts of CO_2 Allowance Prices on Electricity Production



SOURCE: U.S.Energy Information Administration (2006c, 2006e).

eventually declines as CO_2 prices rise at the end of the period and CCS technology becomes increasingly attractive. For an alternative set of predictions of the impacts of various allowance prices (in 2030) on electric power production, see Figure 2 [52]

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 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. Table 8 reports estimates of the added cost for each of the major fuels, including crude oil, gasoline, heating oil, wellhead natural gas, residential natural gas, and utility coal, at sample allowance prices of $25, $50, and $100 per ton of CO_2. 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.

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, in addition to the cost of the crude oil itself. Likewise, the percentage impact on the cost of wellhead natural gas is much greater than that on 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 take place much more gradually than did recent spikes in energy prices (Aldy 2007, 15).

Impacts on Aggregate Costs to the Economy

The cap-and-trade system, like any regulatory initiative, affects the behavior of both individuals and firms, causing reallocation of resources and thereby causing output to grow more slowly than it would in the absence of the policy. Impacts on GDP are measured relative to no policy (BAU), and so the

52. The alternative set of predictions is based on analysis using the NEMS model (U.S. Energy Information Administration 2007).

TABLE 8

Added Cost of Fuels at Various CO_2 Allowance Prices

Units as indicated

Fuel	Average base price (ABP), 2002-06 (2005 dollars)	Added cost[b]					
		Allowance price = $25		Allowance price = $50		Allowance price = $100	
		Dollars	% of ABP	Dollars	% of ABP	Dollars	% of ABP
Crude oil	40/bbl	11.3	28	22.6	57	45.2	113
Gasoline	1.82/gal	0.24	13	0.48	26	0.96	53
Heating oil	1.35/gal	0.27	20	0.54	40	1.08	80
Wellhead natural gas	5.40/mcf[a]	1.38	26	2.76	51	5.52	102
Residential natural gas	11.05/mcf	1.39	13	2.78	25	5.56	50
Utility coal	26.70/short ton	51.20	192	102.4	384	204.8	767

Sources: Paltsev and others (2007a) and author's calculations.
a. mcf, million cubic feet.
b. Does not include adjustment for the effects of cap-and-trade policies on producer prices; see table 6.

TABLE 9

GDP and Welfare Impacts Under Illustrative Scenarios

Percent except where stated otherwise

Impact and scenario[a]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Change in GDP from BAU										
Stabilize at 2008 level	0	0	-0.22	-0.38	-0.55	-0.68	-0.33	-0.29	-0.36	-0.28
Reduce to 50% of 1990 level	0	0	-0.51	-0.79	-0.67	-0.56	-1.18	-1.00	-0.61	-0.48
Change in welfare from BAU										
Stabilize at 2008 level	0	0	-0.01	-0.13	-0.36	-0.45	-0.19	-0.12	-0.24	-0.18
Reduce to 50% of 1990 level	0	0	-0.04	-0.32	-0.69	-1.08	-0.77	-0.92	-1.28	-1.45
Memoranda:										
GDP under BAU (billions of 2005 dollars)	11,981	14,339	16,921	19,773	22,846	26,459	30,534	34,929	39,530	44,210

Source: Paltsev and others (2007b, 1, 2, 3).
a. See table 3 for details of the scenarios.

TABLE 10

Potential Revenue from CO_2 Allowance Auctions Under Illustrative Scenarios

Units as indicated

Scenario[a]	2015	2020	2025	2030	2035	2040	2045	2050
Stabilize at 2008 level								
Auction revenue								
Billions of 2005 dollars 2005$	119	145	177	216	264	322	390	473
Percent of total non-CO_2 federal tax revenue	6	6	6	7	7	8	8	9
Potential tax reduction for family of four (dollars)	1,490	1,730	2,050	2,410	2,860	3,400	4,020	4,770
Reduce to 50% of 1990 level								
Auction revenue								
Billions of dollars	269	301	332	361	386	404	410	404
Percent of total non-CO_2 federal tax revenue	14	13	13	12	11	10	9	8
Potential tax reduction for family of four (dollars)	3,360	3,610	3,820	4,030	4,180	4,260	4,230	4,060

Source: Author's calculations using data in Paltsev and others (2007b, 2, 3, 5, 6).
a. See table 3 for details of the scenarios.

reductions in GDP do not indicate that output would be below current levels, but rather that output would be lower than what would otherwise be expected.[53]

Consistent with findings from other studies, the analysis indicates significant but affordable impacts on GDP: reductions below BAU are generally less than 0.5 percent in each year of the program for the less aggressive cap trajectory and range up to 1 percent in each year for the more aggressive policy (Table 9).[54] These impacts on GDP by 2050 are equivalent to average annual GDP growth of 2.895 percent and 2.891 percent under the two cap trajectories, compared with 2.901 percent in the BAU case.[55]

Potential Revenue from CO_2 Allowance Auctions

How much revenue would the auctioning of allowances generate under the proposal? If all allowances were auctioned, potential auction revenue under the less aggressive program would be $119 billion a year in 2015, increasing to $473 billion by 2050; it would range from $269 billion in 2015 to $404 billion in 2050 under the more aggressive policy (Table 10). Revenue rises more slowly under the more aggressive policy because although allowance prices increase over time, the quantity of allowances auctioned equals the quantity of capped emissions, which decreases over time.

53. The EPPA model predicts that GDP (in 2005 dollars) will increase from 2005 to 2050 in the BAU case from $12.0 trillion to $44.2 trillion, or by 269 percent. The model predicts that GDP will increase over those years under the two cap-and-trade scenarios to $44.1 trillion (268 percent) and $44.0 trillion (267 percent).

54. Given the monotonic increases in CO_2 allowance prices over the entire time period, continuous increases in GDP impacts might be expected, but the costs are driven both by the 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.

55. A more comprehensive measure of aggregate cost is 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: the less ambitious policy causes annual welfare losses of less than 0.5 percent by 2050, and the more ambitious policy causes losses of up to 1.5 percent (Table 9).

To place these numbers in context, Table 10 also reports the potential tax reduction per family of four if all auction revenue were used to reduce other taxes.[56] Under the less aggressive policy, taxes are potentially reduced by $1,490 per family in 2015, rising to $4,770 in 2050. Under the more aggressive policy, the potential tax reduction increases from $3,360 in 2015 to $4,260 in 2040 and then decreases to $4,060 in 2050. The reason for the rise and fall is that, again, although the CO_2 emissions price increases consistently throughout the period, the number of allowances to be auctioned decreases as emissions are brought down.

By its construction, the EPPA model as employed in Paltsev and others (2007a, 2007b) cannot be used to examine quantitatively the cost savings associated with using auction revenue 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 percent if all auction revenue were used to lower taxes on capital, and by 9 percent if auction revenue were used to cut taxes on labor (Gurgel et al. 2007).[57]

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 CO_2 allowance prices compare with estimates of marginal benefits for what some analysts have indicated would be efficient policies. For example, one recent estimate suggests an optimal (efficient) allowance price (or tax) of approximately $10 per ton of CO_2 in 2015, rising to about $23 per ton in 2050 (Nordhaus 2007). This price path lies well below even that associated with the less aggressive of the two illustrative cap trajectories considered above.

More broadly, over one hundred estimates of the marginal damages of CO_2 emissions from twenty-eight published studies were analyzed, with the result that the median marginal benefit (marginal damage avoided) estimate was approximately $4 per ton of CO_2, the mean was about $25 per ton, and the 95th percentile of the highly right-skewed distribution was approximately $95 per ton (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).

Distributional Impacts

Although the aggregate impacts on economic output and welfare are relatively small, the impacts on particular sectors or groups of people can be quite large. Regardless of how allowances are distributed, most of the cost of the program will be borne by consumers, who will face higher prices of products, including electricity and gasoline, for 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, and 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 gradual phasing in of the policy provides more time for firms and people to adapt.

56. In keeping with Paltsev (2007a), these calculations divide annual auction revenue by the anticipated number of households nationwide, which is simply anticipated population divided by four.

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

The cost impacts can be regressive, because lower-income households typically spend a larger share of their income on energy products than do 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 revenue is used.

Effects on Industry

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

Variation in a cap's economic impacts on different 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 counterintuitive. Coal production will be the most affected because coal is the most carbon-intensive fuel, and opportunities exist for electric power 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 CO_2 emissions, it is uncertain whether a cap would increase or reduce the output and profitability of natural gas producers (U.S. Energy Information Administration 2003, 2006c).[58]

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 the quantity of natural gas demanded, but demand may increase because natural gas is the least carbon-intensive fossil fuel, leading users to switch to it. However, as the price of natural gas has increased considerably in recent years, so, too, has the cost of achieving emissions reductions through fuel switching. The cost of natural gas for electric power generation was little more than twice that of an equivalent amount of coal (on an energy content basis) in 1999 but rose to more than five times the cost of coal in 2005 (U.S. Energy Information Administration 2007).

Of course, the impacts on coal producers and other industries depend on the stringency of the emissions cap—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 only slow the expansion of even the most affected industries, lessening transition costs as workers, communities, and regions adjust.[59]

Among firms that consume fossil fuels and electricity, energy- and emissions-intensive industries will likely suffer the severest impacts (Bovenberg and Goulder 2003; Smith, Ross, and Montgomery 2002; U.S. Energy Information Administration 2003; Jorgensen et al. 2000). Some of the hardest-hit industries will be petroleum refiners and manufacturers of chemicals, primary metals, and paper.[60] Among industries experiencing similar increases in costs, the impacts will be greatest in those globally competitive industries that are least able to pass through higher costs. Also, some of the most

58. There will likely be positive distributional impacts on non-fossil fuel producers of energy, including nuclear and renewable electric power generators.
59. For example, an analysis of the National Commission on Energy Policy's (2004) proposed cap estimated that coal production would continue to grow through at least 2025, although at a slower rate than it would without a climate policy (U.S. Energy Information Administration 2005).
60. These industries accounted for two-thirds of manufacturing sector CO_2 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).

economically affected industries may be relatively small, even with respect to their contribution to aggregate CO_2 emissions.[61] Finally, average industry-level impacts may obscure significant variation in firm-level impacts within an industry. The electric power sector is an important example.

Effects on the Electric Power Sector

Regional variation in the impact on electric power generators will be greater than in many other sectors because of regional differences in the fuels used, physical limits on interregional electricity trading, and state regulation of electricity markets. Increases in the cost of power generation will depend on the carbon intensity of a region's power output, which varies widely across the country. For example, Washington State, which has abundant hydroelectric power, emitted only 0.15 ton of CO_2 per megawatt-hour in 2005, while Indiana, which largely depends on coal-fired generation, emitted 0.94 ton 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 generating costs are passed through to consumer rates differs fundamentally between states under traditional cost-of-service regulation and those with restructured electricity markets.[62] Under cost-of-service regulation, rates reflect the average cost of all power generation necessary to meet demand. Therefore 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 generating costs. As a result, consumers effectively bear all of the costs that a cap initially imposes on generators, whereas the generators, for the most part, fully recover their compliance costs through higher rates. (They do experience some other impacts, such as reduced electricity sales.) Two-thirds of U.S. electric power generation and more than three-quarters of coal-fired generation are located in states with cost-of-service regulation.[63]

In restructured markets, in contrast, rates are based on wholesale electricity prices, which under typical conditions are determined by the incremental cost of the most expensive power generated to meet demand. In these markets, therefore, rate increases from a cap will depend on the cap's effect on the marginal cost of generation, not on total costs, and regardless of how allowances have been allocated. This marginal cost of electric power typically varies less across the country than does average 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.

Whereas generators subject to cost-of-service regulation will generally fully recover their increased costs under any climate policy, a cap-and-trade system's effect on their 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 that have no allowance costs, such as nonemitting renewable plants and nuclear plants, 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-fired generators, some of the cap's costs will be offset by increased electricity prices.

61. For example, lime manufacturing accounts for less than 1 percent of fuel-related manufacturing emissions, but it may incur one of the greatest percentage increases in costs (Morgenstern et al. 2002; U.S. Energy Information Administration 2002).
62. This description of regulated and restructured markets simplifies many of the institutional differences that will affect the pass-through of allowance costs.
63. Coal accounted for 61 percent of total power generation in cost-of-service regions in 2004, but for only 35 percent of generation in restructured markets.

Effects on Household Expenditure and Income

Although 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 expenditure on energy and other goods and services, but also through changes in labor income (including job losses) and investment income that arise indirectly from impacts on firms. Low-income households tend to spend a larger share of their income on energy-intensive (including carbon-intensive) goods and services than do high-income households. As a result, higher fuel prices will likely have a regressive effect: expenditure will increase by a greater percentage of household income for low-income than for high-income households. However, this effect may not be very large (Dinan 2007) and may be counterbalanced by the fact that the adverse impacts on investment returns will fall most heavily on high-income households.

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 expenditure 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 for inflation. In addition, by reducing economic activity and thereby the tax base, a cap reduces government tax receipts. The federal government may choose to 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 revenue from those firms that manage to raise their profits under the cap-and-trade system.

Regional Variation in Impacts

Many of the effects of a CO_2 emissions cap, including impacts on the cost of using fossil fuels, will be similar nationwide. However, these impacts will vary significantly across regions because of differences in electricity rate impacts, in the intensity of energy use, and other factors. For example, one study found that an economy-wide cap imposing an allowance price of \$10 per ton of CO_2 would increase average annual household energy expenditure 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 economic activity and employment may vary more dramatically across regions than its impact on household energy expenditure, for several reasons. First, regional economies vary greatly in their reliance on the industrial sectors most likely to be adversely affected by a cap. Second, the factors affecting the impacts on a particular industry are quite varied, including the industry's energy intensity, the carbon intensity of the fuels 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 fifteen times that in other states (Abt 2005).

Illustrative Numerical Distribution of Costs

The EPPA analysis used here to estimate the costs of the proposed cap-and-trade system (Paltsev et al. 2007a) does not yield numerical estimates of the distribution of costs under the two policies. Instead, for illustrative purposes, Table 11 reports 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 on 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 revenue are not included. As discussed below, allocation arrangements can be designed to offset the costs to particular sectors.

TABLE 11

Illustrative Distribution of Private Costs of a Cap-and-Trade System[a]

Percent

Item		Share of total
Cost to fossil fuel producers (coal, oil, natural gas)		3.6
Increase in business and industry expenditure		54.7
Of which:		
For primary energy	28.8	
For electricity	25.9	
Cost to fossil fuel-fired electric power generators		6.9
Increase in household expenditure		34.7
Of which:		
For primary energy	21.5	
For electricity	13.1	
Total		100.0

Source: National Commission on Energy Policy (2007a)

a. Results are adopted from the first proposal from the National Commission on Energy Policy (2007a) and refer to the theoretical distribution of net private costs if all allowances are auctioned and none of the revenue is recycled. In other words, the potential offsetting effects of free distribution of allowances or of using revenue to cut taxes or otherwise return revenue to businesses or individuals are not included. Percentages may not sum to totals because of rounding.

Recalling that the distribution of the program's cost burden is largely independent of the point of regulation, Table 11 illustrates several general points. First, the cost burden to fossil fuel producers as a group represents a relatively small share of the total burden—less than 4 percent in this example—because most of the costs are passed forward. For the same reason, fossil fuel-fired electric power generators bear a relatively small share of the burden, about 7 percent in this case. Business and industry bear 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 expenditure amounts to about 55 percent of the total cost burden. The remaining roughly 35 percent of costs are borne by households in increased expenditure for primary energy (22 percent of the total) and electricity (13 percent). In truth, the final household share of the cost burden is likely to exceed 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).[64]

Distributional Impacts of the Allowance Allocation

The half of allowances that are auctioned initially under the proposed program would generate revenue that could 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 distributed for free should decline over time, falling to zero twenty-five years into the program. Over time the private sector, including industries with long-lived

64. 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 in the oil and gas sector, and 4 percent for electric and gas utilities. These losses, however, would be widely dispersed among investors.

TABLE 12

Revenue from CO_2 Allowances and Aggregate Costs Under Illustrative Scenarios
Billions of 2005 dollars

Scenario[a]	2015	2020	2025	2030	2035	2040	2045	2050
Stabilize at 2008 level								
Potential auction revenue	119	145	177	216	264	322	390	473
Total economic cost	37	75	126	180	101	101	142	124
Reduce to 50% of 1990 level								
Potential auction revenue	269	301	332	361	386	404	410	404
Total economic cost	86	156	153	148	360	349	241	212

Source: Author's calculations using data in tables 9 and 10.
a. See table 3 for details of the scenarios.

capital assets, would adjust to the program's restrictions, reducing the justification for free distribution.

The aggregate value of allowances would far exceed the total cost burden to the economy: it would be two to three times greater than the total cost 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 compensating the most burdened sectors and individuals.

With some important exceptions, in competitive markets the benefits of free distribution of allowances will generally accrue only to their recipients. Although free allocation will increase the recipients' profitability or wealth, it generally will not benefit the consumers, suppliers, or employees of those recipients. Hence, although the cost burden can be expected to ripple through the economy, as explained above, the benefits of free distribution of allowances will not. 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 distributed for free to meet compensation objectives.

On the other hand, in cost-of-service-regulated markets, utilities pass allowance costs on to consumers in the form of higher rates, so that consumers are likely to be the ultimate beneficiaries from free allowances.[65] Thus free allocations to these utilities will reduce the rate impact on consumers by reducing the net cost of the policy for the utilities.

65. In the case of the SO_2 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 revenue from allowance sales).

IV. Comparison of the Cap-and-Trade Proposal with Alternative Proposals

The alternatives to the cap-and-trade approach most frequently considered by policymakers fall within the general category of standards-based policies (also often called conventional regulatory approaches, or command-and-control regulation because they dictate the adoption of particular measures or set source-specific emissions limits). In addition, among economists and other policy analysts, there has been considerable discussion of the use of carbon taxes. This section compares these two approaches with the cap-and-trade approach.

Standards-Based Policies

Technology or performance standards are often proposed as a means of achieving emissions reductions. Examples include efficiency standards for appliances, vehicle fuel-economy standards, best available control technology standards, and renewable portfolio standards for electric power generators. Standards could serve as either substitutes for or complements to a cap-and-trade system. For example, instead of including vehicle emissions under a cap, as proposed here, emissions 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 (see, for example, National Commission on Energy Policy 2004). This section compares standards with cap-and-trade with regard to environmental effectiveness, cost-effectiveness, and distributional equity.

Environmental Effectiveness

Because of practical limitations, most standards to address CO_2 emissions would target energy use or emissions rates from new capital equipment only, such as appliances, cars, or electric power plants. Retrofitting equipment to increase efficiency or reduce CO_2 emissions is usually impractical. The fact that standards would not affect existing equipment limits the opportunity for near-term emissions reductions. It also makes the level and timing of those reductions dependent on the rate of capital stock turnover and therefore difficult to predict.

Moreover, by increasing the cost of new capital stock but not the cost of using the existing capital stock, standards on new sources have the perverse effect of creating incentives to delay replacement of existing stock, which can significantly delay the achievement of emissions reductions (Stavins 2006). The New Source Review regulations are a prominent example of this effect.[66] In addition, the tendency with standards (and taxes) for legislators to grant exemptions to address distributional issues weakens their environmental effectiveness (and drives up costs), whereas distributional battles over the allowance allocation in a cap-and-trade system neither raise the overall cost of the program nor affect its climate impacts. More broadly, if standards are applied for selective purposes but under the umbrella of an economy-wide CO_2 cap-and-trade system, the standards will offer no additional CO_2 benefits as long as the cap-and-trade system is binding.

Cost-Effectiveness

Compared with a well-designed cap-and-trade system, standards-based approaches are less cost-effective.[67] How much less cost-effective they are depends on several factors. First, because of administrative limitations a standards-based approach can cover fewer sources than an upstream, broad-based cap-and-trade system. For example, standards cannot practically target all types of energy-consuming

66. The incentives for delay 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).

67. In theory, standards are potentially more cost-effective when the measurement and monitoring of actual emissions or fuel use is particularly costly compared with the measurement and monitoring that standards could require.

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 emissions reductions.

Second, standards may fail to target all the determinants of emissions even from the covered sources. Consequently, they may miss many types of potentially cost-effective emissions 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 stocks 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 without the standards. However, this rebound effect leads to an increase in emissions that partly offsets the reductions achieved by standards.

Third, standards often impose uniform requirements on all entities using a given type of equipment or operating a given type of facility, even though these entities may face very different costs of reducing emissions (Newell and Stavins 2003). Important sources of this variation include variation in how intensively different firms or households use the regulated equipment, 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 power generation is carbon-intensive (such as that from coal plants in the Midwest) or not (such as that from hydroelectric facilities in the Northwest). Although policymakers could in principle lower the overall cost of standards by targeting them to reflect the myriad different circumstances of affected sources, such efforts are administratively infeasible.[68]

Compared with market-based policies, standards yield weaker incentives for the development of new emissions reduction technologies. For example, unlike market-based policies, standards for energy consumption by air conditioners would not provide clear or certain rewards for the development of air conditioners that are more efficient than the standards require. 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 emissions targets must be met, pursuit of a standards-based approach would require continual adjustments to the standards, at a significant administrative cost, to ensure that responsibilities for emissions reduction continue to be distributed across regulated sources in a reasonably cost-effective manner. By contrast, under a cap-and-trade system, only the emissions cap need 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 emissions reductions.

Standards have also been proposed as complements to market-based policies. But would this have any effect on total emissions reduction costs? On the one hand, standards may needlessly restrict the flexibility that allows market-based policies to minimize the cost of achieving emissions targets. For example, air conditioner standards would require consumers to purchase more expensive, efficient

68. Some of the cost disadvantages associated with standards can be reduced through careful design, including providing firms with greater compliance flexibility. For example, CAFE standards allow manufacturers to meet fuel efficiency requirements on average across the vehicles they produce. Even so, 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 tradable credits (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 producers.

equipment, whether or not they use the equipment enough to justify the increased cost. In contrast, a market-based policy would 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 under the umbrella of an economy-wide CO_2 cap-and-trade system, they offer no additional benefit as long as the cap-and-trade system is binding. But, depending upon the nature of the standard and its associated costs, its application can drive up aggregate costs.[69]

On the other hand, as also indicated above, a cap-and-trade (or carbon tax) policy may fail to address some market failures affecting the development and adoption of less emissions-intensive technologies. Consumers may lack sufficient information to properly evaluate energy-efficiency investment alternatives; for example, they may lack information about the full life-cycle costs of alternative product models.[70] Simply increasing the cost of emitting greenhouse gases will not address the 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 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. 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 include programs that promote research and development or the provision of information.

Distributional Impacts of Standards

The distributional consequences of standards depend on the specific standards being implemented and the 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 emissions reductions and investments required by the standards, whereas market-based policies also impose costs associated with the remaining emissions.[71] 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 the initial allocation decisions or the redistribution of tax or auction revenue.

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 CO_2 emissions. However, they differ fundamentally in the way that signal is determined. A carbon tax fixes the price of CO_2 emissions and allows the quantity to adjust in response to the tax. In contrast, a cap-and-trade system fixes the quantity of emissions and allows their price to adjust to ensure that the emissions cap is met.

Environmental Effectiveness, Cost-Effectiveness, and Distributional Impacts

Unlike a cap-and-trade system, a carbon tax does not guarantee achievement of a given emissions target. Individual sources reduce emissions up to the point where it costs less to pay the tax than to reduce emissions further. Given uncertainty regarding emissions reduction costs, that point may lie above or below the policy target. However, be-

69. For an examination of how to merge CAFE standards cost-effectively with a cap-and-trade system by allowing trading between the two programs, see Ellerman, Jacoby, and Zimmerman (2006).

70. For a more complete discussion of the types of market failure that may make additional complementary policies desirable, see Jaffe and others (2005).

71. The costs associated with remaining emissions do not represent true social costs. Rather, they are transfers from those who must pay a tax or purchase allowances from firms that received the allowances for free.

cause a tax limits the costs that firms will incur to achieve further reductions, it provides greater certainty regarding the marginal costs of the policy. By contrast, a cap-and-trade system that establishes rigid annual caps offers less certainty about policy costs precisely because it provides greater certainty about emissions.

Like a cap-and-trade system, a tax can achieve emissions reductions in a cost-effective manner. If a credible commitment is made to keep it in place, a tax, again like a cap-and-trade system, also lowers the long-run cost of achieving emissions reductions by providing incentives for investment in the development and deployment of new technologies.

Either an economy-wide cap-and-trade system or an upstream, economy-wide carbon tax would be more cost-effective than a tax with a narrower scope of coverage. Such a tax would achieve fewer emissions reductions, requiring a higher tax rate to achieve a given level of reductions. Similarly, either a cap or a tax can be imposed either upstream on fuel suppliers or downstream on emissions sources. The administrative costs of an economy-wide tax would be minimized if it were imposed upstream, as a tax on the carbon content of fossil fuels. 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 emissions reductions.[72]

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 the resulting revenue. Moreover, before any use or redistribution of that revenue, the impacts of a tax on affected firms and households are the same as those of a cap-and-trade system with an auction in which the resulting allowance price is identical to the tax. However, a carbon tax and a cap-and-trade system differ in the options they present to mitigate economic impacts. Although a tax creates no allowances to be distributed for free to compensate those affected, policymakers can mitigate a tax's burden by redistributing the tax revenue 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 exemption. Unless the exemptions are tradable, however, their use may erode the cost-effectiveness of the tax if a firm's exemption exceeds its actual emissions. Then the firm has no incentive to undertake emissions reductions, no matter how cost-effective. In contrast, because a firm under a cap-and-trade system can sell any excess allowances, it always has an incentive to reduce emissions, no matter how many allowances it initially received.

Like free allocations of allowances 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 are needed to compensate those not directly subject to the carbon tax. Although tradable tax exemptions and redistribution of tax revenue theoretically provide flexibility to achieve the same distributional outcomes as under a cap-and-trade approach, political and practical considerations may limit what can be done in practice.

Apparent Advantages of a Carbon Tax

An upstream carbon tax, like an upstream cap-and-trade system, could include credits to provide incentives for downstream CCS at electric power generators. Such a tax would appear to have some advantages over an equivalent upstream cap-and-trade system.

First is the simplicity of the carbon tax system: firms would not need to manage and trade allowances, and the government would not need to track allowance transactions and ownership. Experience with

72. 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).

previous cap-and-trade systems, however, indicates that the costs of trading institutions are not great. Whether a meaningful national carbon tax would turn out to be simple in its implementation, however, is an open question. Second, the tax approach avoids the political difficulties related to allocating allowances among economic sectors, but it would create pressure for tax exemptions.

Third, a carbon tax would raise revenue that can be returned to individuals or be used to lower distortionary taxes, finance climate-related programs, fund other government programs, reduce the deficit, or provide assistance to sectors burdened by the policy. Of course, an auction mechanism under a cap-and-trade system can do the same. Particular attention has been given to the use of tax revenue to reduce distortionary taxes and thus the aggregate net costs of the policy. Given that a CO_2 tax of $10 a ton would raise about $50 billion a year—equivalent to more than 7 percent of federal personal income tax revenue—this is an attractive possibility. However, the revenue might be spent on the "wrong" tax cuts or on other government programs whose costs exceed their benefits, 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 price volatility of a cap-and-trade system. Some emissions trading markets have exhibited significant volatility in their early years. In the case of the U.S. NO_X Budget program, prices increased sharply in the presence of uncertainty about whether Maryland, a net supplier, would enter the program on time. Other examples are the RECLAIM program in southern California, where price spikes were linked to flawed design and problems with electricity deregulation, and the EU ETS, which experienced a dramatic price crash when data revealed that allocations had exceeded the BAU level. In principle, such volatility 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; 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.

Apparent Disadvantages of a Carbon Tax

First among the disadvantages of a carbon tax, relative to a cap-and-trade regime, is the stiff 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 more politically feasible in future years with 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 among key stakeholders. Put differently, whereas a tax approach focuses political attention on prices, revenue, and costs, cap-and-trade discussions tend to keep the focus on the environment.

Second, in their simplest 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 firms subject to a tax incur both abatement costs and the cost of tax payments. Under the simplest cap-and-trade system, the regulated sector experiences only abatement costs, since the transfers associated with purchase and sale of allowances remain within the private sector. This straightforward difference between the two approaches can be diminished or even eliminated, however, if either tax revenue recycling or allowance auctioning is adopted.

Third, cap-and-trade approaches leave the 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 activity 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 program's costs, as more and more sources are exempted from the program at the expense of environmental effectiveness. Instead a cap-and-trade system leads to battles over the allowance allocation, but these neither raise overall cost nor affect the climate impacts. Some observers seem to worry about the propensity of the political process under a cap-and-trade system to compensate sectors (through free allowance allocations) that successfully claim unfair burdens. But a carbon tax is sensitive to the same pressures and may be expected to succumb in ways that are ultimately more dangerous.

Fourth, as already noted, a carbon tax provides greater certainty over costs at the expense of much less certainty about emissions levels. Most climate policy proposals call 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 would be uncertain, mainly because of variations in economic conditions. More broadly, the flexibility of cap-and-trade means that it can replicate virtually all of the key aspects of a tax, for example by auctioning allowances and adopting a cost containment mechanism.

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 CO_2 emissions).

Potential Convergence Between Cap-and-Trade and a Carbon Tax

Despite their differences in specific implementations, the carbon tax and cap-and-trade have much in common. Both are market-based instruments, able to achieve goals cost-effectively and provide incentives for technological change to bring costs down in the long term. Either can be used to regulate emissions upstream, at the mine, refinery, or processor, and so more easily bring emissions throughout the economy under their sway. Either can include offsets for uncovered sources and for CCS. And both provide a measure of cost certainty: a tax program through the tax rate itself, and a cap-and-trade system through the proposed flexibility mechanisms.

The remaining differences can begin to fade when various specific implementations of either program are carried out. Hybrid schemes that include features of both systems blur the distinctions between them (Parry and Pizer 2007). In a cap-and-trade system the government can auction allowances, thereby reproducing many of the properties of a tax approach. Likewise, a carbon tax can include rebates and exemptions on some basis other than current emissions. Mechanisms that deal with uncertainty in a cap-and-trade system also bring it close to a tax approach; these can include a cost containment mechanism that caps allowance prices, banking that creates a floor under prices, and borrowing that provides flexibility similar to a tax. To some degree, the choice between taxes and permits can turn out to be a choice of design elements along a policy continuum.

V. Responses to Common Objections

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 reducing CO_2 and other greenhouse gas emissions. This section briefly describes and responds to these objections.

"Cap-and-Trade Is Unethical—It Allows Firms to Buy and Sell the Right to Pollute."

Over the twenty-five years in which market-based instruments have become an accepted part of the environmental regulatory portfolio, the claim that cap-and-trade systems are morally flawed because they allow firms to buy and sell the right to pollute is heard with decreasing frequency. But the argument has been made at least as recently as the late 1990s, and in the specific context of global climate change policy (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. Yet all of these activities result in CO_2 emissions (Gaines 1997).

"Cap-and-Trade Creates Hot Spots of Pollution."

Because greenhouse emissions uniformly mix in the atmosphere, there are no greenhouse gas hot spots. The question is whether allowance trading activity might lead to excessive concentrations of other, localized pollutants whose emissions are correlated with greenhouse gas emissions. This concern has frequently been expressed in California's debate over a proposed cap-and-trade system for greenhouse gases.

A cap-and-trade system for greenhouse gases, however, would not supplant existing local air quality regulations. If a firm's action resulting from an emissions trade violates local regulations for NO_X emissions, for example, that action would still be illegal no matter how many greenhouse gas allowances the firm obtained. A greenhouse gas cap-and-trade system would not interfere with local air quality regulations; only legal trades would be legal.

"Upstream Cap-and-Trade Will Have Minimal Effects on the Transportation Sector."

It is quite true that the greatest share of emissions reductions under cap-and-trade would occur in the electric power sector, followed by the industrial sector, with much smaller percentage reductions in the transportation and other sectors. Given that approximately one-third of U.S. CO_2 emissions from energy consumption come from the transportation sector, this may seem like an opportunity missed for deeper cuts in emissions. But from an economic (that is, cost-effectiveness) perspective, such an outcome could still be both appropriate and desirable, if the reason for the policy is to combat climate change. An upstream cap-and-trade system that provides a uniform price signal for cost-effective emissions reductions economy-wide will lead to those reductions being undertaken wherever they are least costly. The result will almost certainly not be proportionate reductions in emissions from each type of source or each sector. If there are other, non-climate-related reasons, such as oil dependency, for concerns about the use of transportation fuels, those concerns should be addressed through other policies appropriate to the problem (Sandalow 2007).

"It Would Be Better to Begin with Narrow Coverage Across a Few Sectors."

Some have argued that, for political expediency, any cap-and-trade system should start by covering only a few sectors and then broadening coverage over time, rather than imposing an economy-wide system as proposed here. There are several problems with beginning with narrow coverage. First, narrow coverage is inevitably more costly for any given amount of environmental gain, because some of the lowest-cost emissions reduction opportunities are taken off the table. Second, the best way to deal with the political forces that prompt the recommendation for narrow coverage seems to be to begin broad and then go deep (Schmalensee 1998). Resistance from uncovered sectors will only increase as the stringency of policy and the corresponding economic burdens increase—as has been observed in the debates surrounding proposals to expand the sectoral coverage of the European Union's downstream cap-and-trade program.

"A Cap-and-Trade System Will Create Barriers to Entry and Reduce Competition."

It is true, in principle, that incumbent firms could use their emissions allowances strategically to keep new entrants from competing in their product markets. This is why the SO_2 allowance trading program auctions allowances annually so that the government can be a source of allowances of last resort. In fact, there is no evidence from any implemented cap-and-trade system of incumbent firms withholding allowances from the market for strategic purposes. The proposed CO_2 cap-and-trade system includes a large auction of allowances from the very beginning.

"The Experience with RECLAIM and the EU ETS Demonstrates that Extreme Price Volatility is Inherent in Cap-and-Trade Systems."

It is true that a cap-and-trade system (at least one that establishes *rigid* annual caps) offers less certainty about costs, precisely because it provides greater certainty about emissions. But the significant price volatility observed in the RECLAIM program and the EU ETS were associated with particular, problematic design features as well as special circumstances.

The price spike for NO_X allowances observed 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 so facilities have no incentive to install pollution control equipment that would allow them to reduce their current emissions and bank allowances for the future. The result was that during the 2000-01 electricity crisis some units facing high demand were unable to purchase allowances for their emissions, leading to a price spike. Even in the absence of an allowance bank, the crisis would not have resulted in a price spike had a safety valve or some other cost-containment mechanism been available.[73]

In the spring of 2006, when it became clear that the allocation of allowances in the pilot phase of the EU ETS had exceeded emissions, a dramatic fall in allowance prices occurred. The price collapse was due to a combination of the system's design, generous allowance allocations, data problems, and modeling mistakes. It now appears that the European Union may not meet its aggregate target under Kyoto, and some claim that the fault lies with the EU ETS. However, the downstream system covers only 45 percent of European CO_2 emissions, and the failures to reduce emissions are concentrated in the sectors *not* covered by the program.

It is also claimed that the windfall profits of some electric power producers under the EU ETS are evidence of an inherent problem with cap-and-trade. Here, again, the evidence is otherwise. As explained in the online appendix, the program's guidelines called for at least 95 percent of allowances to be distributed for free in the first compliance period,

73. In RECLAIM a safety-valve price of $15,000 a ton had been written into the regulations as a feature that could be made operational. It was *not* operational, however, when the price spike occurred and it was needed.

and most countries distributed 100 percent of their allowances for free. In contrast, the cap-and-trade system proposed here provides for 50 percent of allowances to be auctioned initially, gradually rising to 100 percent after twenty-five years.

"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 CO_2 emissions caused by that production can shift comparative advantage in 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 to the actions of other key nations. In particular, imports of highly carbon-intensive goods from countries that have not taken climate policy actions comparable to those in the United States would be required to hold appropriate quantities of allowances. This would establish a level playing field for domestically produced and imported products, would reduce emissions leakage, and may help induce some key developing countries to join an international agreement.

VI. Summary and Conclusions

The need for a domestic U.S. policy that seriously addresses climate change is increasingly apparent. But a policy that meaningfully reduces emissions of CO_2 and other greenhouse gases will not come cheap: estimated annual costs are on the order of 1 percent of GDP. These high stakes make it critical to identify the most effective, lowest-cost, and most equitable policy at the outset, because any policy design once in place can be difficult to change.

Policy analysts generally agree that the policy most likely to optimize these three criteria will be one based on some form of market-based instrument for reducing emissions: either a cap-and-trade system, based on emissions allowances, or a carbon tax.

This paper has argued that a cap-and-trade system is the better approach for the United States in the short to medium term—and more likely to be politically successful. Besides providing greater certainty about emissions levels, cap-and-trade offers several advantages: an easy means (partial free distribution of allowances) of compensating for the inevitably unequal burdens imposed by climate policy; it is straightforward to harmonize with other countries' climate policies, which are much more likely to employ cap-and-trade than tax approaches; it avoids the current political aversion in the United States to taxes; and it has a history of successful adoption in this country. Given this judgment, the paper has further proposed a specific cap-and-trade system that is scientifically sound, economically rational, and politically feasible.

The proposed system has several key features. It imposes an upstream cap on CO_2 emissions (carbon content is 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 the cost uncertainty that is a potential drawback of a cap-and-trade system; these include provisions for banking and borrowing of allowances, and possibly a cost containment mechanism (such as the sale of additional allowances during severe price spikes, with the revenues dedicated to bringing about additional emissions reductions) 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 phase out gradually over twenty-five years. The auctioned allowances would generate revenue that could be used for a variety of worthwhile public purposes. To increase the program's short-term cost-effectiveness and create long-term incentives for technological development, entities that successfully implement carbon sequestration (biological or underground if feasible) would be eligible for offsets.

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 that maintains 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 are recommended, for example in the area of consumer information.

Like other market-based emissions reduction schemes, the one proposed here reduces compliance costs by offering regulated entities "what, where, and when" flexibility. Rather than mandate specific measures on all sources, it allows emissions to be reduced however, wherever, and, to a great extent, whenever they are least costly. To illustrate the potential cost savings, this paper has reported empirical cost estimates for two hypothetical time trajectories for emissions caps. The first stabilizes CO_2 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 CO_2 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. Average annual GDP growth over 2012-50 would slow to 2.895 percent under the first trajectory and to 2.891 percent under the more stringent one, compared with 2.901 percent under business as usual.

The empirical analysis also generated estimates of the market prices of allowances under both trajectories: the estimated price rises from \$18 per ton of CO_2 in 2015 to \$70 per ton in 2050 under the less aggressive trajectory, and from \$41 per ton in 2015 to \$161 per ton in 2050 under the more aggressive one. Among other effects, the gradual price increase leads not only to reductions in electric power production, but also to dramatic changes in the mix of fuels used to generate electricity. Conventional coal-fired generation drops significantly even under the less aggressive trajectory and disappears completely by 2040 under the more aggressive path.

The proposed system could generate substantial government revenue. If all allowances were auctioned, revenue would rise from an estimated \$119 billion a year in 2015 to \$473 billion by 2050 under the less aggressive trajectory, and from \$269 billion in 2015 to \$404 billion in 2050 under the more aggressive trajectory.

The paper also explored the distributional implications of the proposed program. Illustrative estimates—which do not account for the offsetting effects of possible free allocation of allowances or redistribution of auction revenues—indicate a relatively small burden on fossil fuel producers (about 4 percent of the total), because most of the costs would be passed on to customers. Fossil fuel-fired electricity generators also would bear a relatively small share, about 7 percent, for analogous reasons. Business and industry would bear nearly 30 percent of the total cost burden through their primary energy use, and about 25 percent through their electricity use, for a total of about 55 percent. The remaining roughly 35 percent of costs would be borne by households.

The paper has argued that the details of policy design in addressing climate change matter, even if their implications are not always immediately apparent. For example, although the point of regulation (upstream, midstream, or downstream) in a cap-and-trade system determines who incurs the initial regulatory costs, the ultimate distribution of burdens is ultimately determined by market forces and will be the same for any point of regulation. Thus the choice of point of regulation in no way prevents policymakers from allocating allowances to whomever they choose. This shows that well-informed policy design can mitigate the trade-offs between cost-effectiveness and distributional goals.

Finally, in interpreting the estimates presented in this paper, it is essential to realize that the global-commons nature of climate change makes it impossible to associate any specific U.S. domestic policy directly and unequivocally with progress toward a particular climate target, whether stated in terms of atmospheric greenhouse gas concentrations, changes in temperatures, or damages avoided. The impact of any U.S. policy will ultimately depend upon the actions of other nations around the world. Without an effective and compelling 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 establishing U.S. climate policy should be to establish international credibility and lead other countries to take action. For this it is essential that the United States be perceived as taking on an equitable share of the burden. The proposal presented in this paper offers a way for the United States to demonstrate its commitment to an international solution while making its own real contribution to combating climate change.

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