A Climate Policy Framework: Balancing Policy and Politics

A REPORT OF AN ASPEN INSTITUTE
CLIMATE CHANGE POLICY DIALOGUE
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FOREWORD

The United States remains divided about the necessity of action on climate change, whether any action should be voluntary or mandatory, the depth and timing of needed cuts in emissions of greenhouse gases, and the structure of a national policy to reduce such emissions. This division has to date resulted in the absence of significant action at the national level. Nevertheless, many participants in the debate, whether supporters or opponents of mandatory action now, believe that such action will be taken sooner or later and that advance work to design effective policies is in the interest of all.

In this uncertain environment, the Aspen Institute, in collaboration with the Pew Center on Global Climate Change, invited a group of interested and knowledgeable people with diverse backgrounds and views on the issue to a three-day dialogue in November 2003 at the Institute's Wye River Conference Center in Maryland. The focus was not on whether mandatory action should be taken, but rather on what policies would be preferable if Congress were to decide such action is necessary.

The participants were chosen to represent a diverse set of constituencies, but they were invited as individuals and were not asked to speak for their organizations. They were also assured that their participation in this effort to outline an optimal plan did not necessarily indicate their support for mandatory action. The resulting dialogue allowed participants to look at policy questions from new perspectives. An informal atmosphere and a not-for-attribution rule encouraged candid exchanges and creative thinking.

The dialogue was co-chaired by Eileen Claussen, President of the Pew Center on Global Climate Change, and Robert W. Fri, Visiting Scholar and former President of Resources for the Future. Their long experience with the substance and politics of environmental policy and their gentle but focused approach in guiding the discussion was largely responsible for the broad areas of consensus described in the co-chairs' summary report that follows. Although the participants were not asked to agree with the exact wording of this report, the co-chairs believe the items of agreement they have noted are an accurate reflection of the meeting, and all participants have had the opportunity to review the draft and to ensure that points of agreement are not overstated.

The starting point for the dialogue was the May 2003 report, *Designing a Mandatory Greenhouse Gas Reduction Program*, commissioned by the Pew Center and written by Robert Nordhaus and Kyle Danish of Van Ness Feldman P.C. The executive summary of their paper, six additional papers commissioned for this dialogue, and the foreword and executive summary of another relevant and timely paper published by the Pew Center, are included in this volume. Some concepts mentioned but not discussed in detail in the Co-chairs' summary report are explained more fully in these papers.

All Aspen Institute dialogues rely on the assistance of many people for their success. This was no exception. The Institute wishes to thank Eileen Claussen, Bob Fri, Bob Nordhaus, Kyle Danish, and Vicki Arroyo not only for their contributions as co-chairs or authors of discussion papers but also for their invaluable assistance in designing the agenda and framing the issues for discussion. David Harrison, Neil Sampson, Neil Strachan, and Naomi Peña also contributed to the substantive underpinnings of the meeting with their discussion papers, and Sally Ericsson and Nikki Roy were very helpful in identifying participants. Katrin Thomas planned and implemented the administrative arrangements for the meeting with her usual efficiency, conscientiousness, and good humor.

The Institute is also very grateful to The Energy Foundation and the UN Foundation for their financial support for the project, and to AEP, Exelon, Rio Tinto, and Toyota corporations for their assistance for printing and distributing this report. Without their generosity and commitment to our work, this dialogue could not have occurred.

Finally, we are grateful to all the participants, whose dedication to the cause of good public policy led them to devote a beautiful Fall weekend to this effort, whose political experience and knowledge of the issues ensured credibility, and whose collegiality and focus on results led them to the productive outcome reflected in this report.

John A. Riggs
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A CLIMATE POLICY FRAMEWORK: BALANCING POLICY AND POLITICS*

Eileen Claussen and Robert W. Fri

What is the preferred framework for a domestic policy to reduce greenhouse gas emissions? The approach most likely to achieve environmental results? To be administratively feasible and cost effective? To gain political acceptance?

A diverse group of stakeholders considering these questions at the Aspen Institute Climate Change Policy Dialogue reached convergence on several fundamental elements of such a program. These include which sectors, gases, and sources should be covered and the nature of the program itself: an initially modest but subsequently declining absolute emissions cap on large sources, a cap on transportation fuel suppliers coupled with CO_2-based automobile efficiency standards, and tradable efficiency standards and offsets. It is a framework, not a fully developed policy; a starting point rather than a final product. But we believe it can be helpful to those seeking to balance policy and politics, environmental effectiveness and cost, efficiency and equity.

This summary reflects our understanding, as co-chairs, of the conclusions and the agreements reached, and of the factors that influenced them. Participants in the dialogue were asked to discuss policy options for a U.S. mandatory greenhouse gas program that could be implemented if and when the nation decides a program is necessary. For purposes of the dialogue, they were asked to put aside questions about whether such a program should be implemented and about the

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* Eileen Claussen is President of the Pew Center on Global Climate Change. Robert W. Fri is Visiting Scholar and former President of Resources for the Future.

scientific evidence supporting the need for such a program. Rather, the focus of this effort was to determine what – if any – agreement could be reached regarding key design features of a domestic greenhouse gas reduction program. While the emphasis was on development of a U.S. program, participants were mindful of the global nature of the climate change issue and the need for any domestic program to be compatible with the emerging international system.

This dialogue grew out of *Designing a Mandatory Greenhouse Gas Reduction Program*, a May 2003 paper commissioned by the Pew Center on Global Climate Change and authored by Robert Nordhaus and Kyle Danish. Program design options evaluated in that study include various cap-and-trade approaches, greenhouse gas taxes, and a "sectoral hybrid" program combining efficiency standards with a cap-and-trade for large emissions sources. The authors of that report established criteria for evaluating program design options and drew some conclusions about program viability under their criteria.

Participants in the Aspen dialogue were provided the Nordhaus/Danish report and several other background papers to inform their discussions. These additional papers include six commissioned for this workshop and one summary of a new Pew Center report on technology policy.

Participants discussed important aspects of design, including program approaches, key design variables, and the criteria for assessing options in making their own determination about a potentially viable program. In doing so, they arrived at general agreement on the principal elements of a U.S. greenhouse gas reduction program, the "Climate Policy Framework", which we describe below.

Criteria and Principles

In assessing the criteria that should be used to evaluate a proposal for a mandatory program addressing climate change, the Aspen group began with the Nordhaus and Danish criteria:

1. Environmental effectiveness: How effective is the program in meeting its emissions reduction target?
2. Cost effectiveness: Will the program design allow cost-effective compliance?
3. Administrative feasibility: Can the program be administered and does it minimize administrative and transaction costs?

4. Distributional equity: Is the burden of compliance with the program fairly apportioned?
5. Political acceptability: Are there elements of program design that affect its political acceptability?

Dialogue participants believed Nordhaus and Danish identified important evaluation criteria, but raised some additional points. For example, there was strong agreement that a mandatory domestic policy would only succeed if it were combined with a push for technology development because of the need to drive fundamental changes in our energy system and fossil-fuel based economy. To this end, the Aspen group added a sixth criterion to the original set: Ability to provide a platform for technology development and diffusion.

On the subject of costs, participants emphasized concerns about the distribution of costs, and about competitiveness in some industries. There was a widespread feeling that these issues were even more important politically than absolute cost considerations. Several aspects of the competitiveness issue were considered important:

1. Avoiding actions that would disadvantage U.S. business or perhaps drive manufacturing offshore (where energy prices may be lower due to lack of climate policy or other reasons);
2. Disadvantaging one sector of the economy disproportionately; and
3. Creating opportunities for U.S. business to develop and market technological innovations that can be exported.

While any government program of this scale requires some degree of complexity, there was a plea to keep administrative feasibility in mind. “Simple but firm” was one participant’s view of a desirable program trait. In addition, the program’s ability to adapt to changing circumstances and incorporate new information was identified as an important element of political acceptability, administrative feasibility, and environmental effectiveness.

Finally, while some degree of compliance with all criteria would likely be necessary for a successful U.S. program, there was broad agreement that the paramount concern for a workable program is political acceptability. Indeed, without political acceptability, the most well-designed, theoretical program will never get off the ground.

As the discussion of criteria proceeded, a set of principles that would guide the discussion began to emerge. For example, consideration of environmental effectiveness and distributional equity generated discussion about the need for broad program coverage (across multiple sources, sectors, and gases, and to include the use of sinks). However, recognizing the limits of our ability to treat all gases and sinks in ways that can be monitored and are verifiable, the participants agreed that while broad coverage and maximum flexibility would be an important principle from both an environmental and equity perspective, nothing should be included until it was clear that it could be monitored and counted.

There was agreement that the environmental effectiveness of a mandatory program should be measured not so much by the extent of emission reductions achieved in the short term but rather by the program's success in encouraging firms and households to start investing in technologies to realize deeper reductions in the longer term. Accordingly, while there was broad agreement that program coverage should be wide, there was also consensus that phasing of actual reduction targets would be important, and that a modest start would be preferable. This would send a signal that reducing greenhouse gases was national policy. Deeper cuts could occur later, as technology evolves and capital stock turns over in response to early market signals generated by the policy.

With these criteria and principles in mind, the group developed its favored approach.

The Framework

In keeping with the desire to address as many sectors of the economy as possible, while recognizing that one size does not fit all, the preferred program design was a hybrid – combining elements of cap-and-trade with efficiency standards that allow for trading. While the group came to consensus rather quickly on the desirability of a hybrid approach, the details emerged only after lengthy discussion and through work of subgroups charged with making recommendations on certain program elements to the group as a whole.

The broad outline of the approach is as follows:

1. A cap-and-trade system covering large point sources of both CO_2 and non-CO_2 GHG emissions, with an initially modest and subsequently declining cap.

2. Coverage of transportation-related emissions through two mechanisms:
   a) Inclusion of upstream suppliers of transportation fuels in the cap-and-trade program;
   b) Fleet efficiency standards for automobile manufacturers, expressed in CO_2 equivalents that are also tradable.
3. Inclusion of appliances and other large energy-using products through efficiency standards and trading.
4. Use of carbon sinks and international trading as offsets to the fullest extent possible, considering monitoring and verification capabilities.
5. Programs to support technology development – providing an assured source of long-term funding generated through taxes, auction revenues, or another mechanism, with support going to both public and private R&D and deployment.

Each of these items is discussed in greater detail below.

Cap-and-Trade System for Large Point Sources

Dialogue participants recommended a program requiring large point sources of greenhouse gas emissions (e.g., electric utilities, manufacturers) to meet a modest but declining cap through a program that includes flexibility through trading and offsets. This would achieve modest near-term reductions in GHG emissions while providing incentives for the development and diffusion of technology that will lead to significant reductions in the longer term. Background papers presented various approaches to developing a target (absolute, rate-based, indexed) but the group quickly settled on an absolute target of a modest – but unspecified – reduction level, with further cuts phased in over time.

Allocation issues were more contentious. Because there are clear winners and losers from various allocation schemes, it was harder to reach agreement. Participants noted that allocation will essentially be a political exercise, one for which Congress is especially well-suited. Having said that, the participants discussed one approach as a potential way to deal with allocation considerations. This approach involves distributing the majority of permits (95%) through grandfathering in the initial allocation.

The method for grandfathering – historical emissions or output-based – was hotly debated by interested parties. Those wanting output-based allocations – i.e., allocations based on a facility's historical output of electricity or other products, rather than its GHG emissions – argued that firms should be rewarded for past investment in efficiency and the use of relatively lower-emitting or zero-emitting technologies (e.g., natural gas, hydroelectric, renewables, or nuclear power). Others believe that the permits should go to firms who will need them most at the outset, so they can afford to cover increased fuel costs and invest in new technologies and fuels. One proposal was to grandfather on an output basis, but make the allocation fuel-specific without allocation of allowances to non-emitting sources.

Because of regional variability in fuels and the challenges in defining a fair allocation at the national level, a proposal was made to allocate permits to the states (based on grandfathered emissions) and allow them to determine in-state allocation. Drawing an analogy to existing air programs managed at the state level, some believed such an approach had precedent and could effectively address some practical concerns and political obstacles. Others remained unconvinced that Congress would find such an approach more politically salable or would delegate this responsibility.

Discussion about the fate of the remaining 5% of the permits was animated. There was general acceptance of the need for this set aside (and possibly a small additional fraction) to cover new entrants and to generate funds to support transition programs, R&D, and/or to help offset increased costs to consumers. The group was unsure, however, of the best vehicle for distributing these permits. Options discussed were auctions or use of a fiduciary body (similar to one proposed in S. 139, The Climate Stewardship Act), but the group did not reach consensus on which could best provide the desired market liquidity or be most easily administered.

The allocation concept advanced by the group was presumed to be an initial allocation that could potentially be adjusted over time (e.g., decreasing the grandfathered proportion). There was also a broad sense that Congress has a variety of workable allocation options from which to choose.

The participants also discussed two tools designed to address "cost certainty concerns", i.e., that a cap-and-trade system will result in unacceptable uncertainty about compliance costs. These tools are: (1) a safety valve policy, which would release as many additional permits as firms require if the trading price reaches a pre-determined threshold; and (2) a circuit-breaker policy, which would postpone a scheduled reduction in the overall cap if permit prices reached a predetermined level. Concerns were raised about the potential market-distorting effect of the safety valve and related detrimental effects on price discovery and investment. Administrative feasibility of the circuit breaker's ever-declining target was questioned.

Some felt that a safety valve or circuit breaker might make the program more politically palatable, while others noted that political opposition often relates more to relative cost and distributional issues than to permit prices per se. Said one participant, " I don't care what it costs, as long as we're competitive." Many participants seemed to feel that a well-designed program – one that gradually phases in deeper reductions over time and provides maximum flexibility in meeting targets – would address cost concerns without some of the drawbacks associated with these devices.

Finally, penalties were thought to be necessary to promote compliance, and the penalty structure used in the Acid Rain program was considered by many to be a useful model.

Transportation

The transportation sector provided the greatest challenge to dialogue participants. Generating roughly one-third of U.S. emissions, the sector is a growing contributor to greenhouse gas emissions and one that cannot be ignored. Yet it was recognized that political and practical obstacles exist to curbing the growth in these emissions.

The dialogue produced a two-pronged approach to addressing transportation sector emissions. Some previous proposals have dealt with transportation emissions entirely through allocation to the fuel provider. However, that approach decouples the allowance holding from one of the principal abatement opportunities available – namely improvement in vehicle efficiency. Thus the suggested approach to transportation distributes allowances to both the fuel provider and the vehicle manufacturer. Vehicle manufacturers' allowances would be based on expected vehicle lifetime emissions in CO_2 equivalents, encouraging investment in both alternative fuels (e.g. biofuels) and in vehicle efficiency measures. This dual approach would not only signal a future (and increasing) carbon constraint on fuel but also a program to promote vehicle efficiency and thus provide consumers with the means to adapt.

The first element is a cap applicable to fuel suppliers with an opportunity to trade in the cap-and-trade program covering large sources. While the group acknowledged that the kind of modest initial cap envisioned in this dialogue would produce only a small increase in gasoline price, with little likely corresponding impact on consumer behavior, participants felt it important to address both automobile fuel and design. A cap covering fuel suppliers would also modestly affect other forms of transportation such as aviation, rail, barges, and motor freight.

With regard to automobile efficiency standards, the second element of the transportation program, the group would include a single efficiency standard for both automobiles and light trucks/SUVs. Existing CAFE standards would be converted into a CO_2-equivalent credit system, with the credits tradable into the cap-and-trade program. In establishing requirements for this sector, the group recognized the need for different starting points for different automakers and yet acknowledged the need for convergence of requirements over time. Such a policy would also serve to drive technology improvements by all manufacturers.

While specific targets and timetables were not determined, a general principle was enunciated that the program should avoid penalizing any companies at the start. Efforts of those who invested early and have exceeded the CAFE standard should be recognized (e.g., through credit allocation) while adequate time is provided for other firms to catch up, recognizing the time needed to develop and market new automobiles.

In order to maintain the integrity of a national emissions cap, a program that awards credits to automakers for fuel economy improvements needs to draw those credits from elsewhere in the cap-and-trade system. One suggestion was that credits be reduced on a pro rata basis from all sectors. Alternatively, credits could come from the upstream motor fuel suppliers.

Other Products

In addition to automobiles, products such as appliances and lighting drive much of the residential and commercial demand for electricity and should be included in efforts to address climate change. Motors are also a significant factor in demand. Where possible, efficiency standards should be extended and converted to a tradable CO_2 credit system, that could be used in conjunction with the cap-and-trade program as described above. By creating incentives for continued reductions, firms would be encouraged to invest in new, more efficient, technology.

Standards for buildings and building materials were also briefly discussed. While most building codes apply at the local or state level, federal government programs could develop best practices and create incentives for incorporating materials that enhance efficiency or promote renewables.

Other (Non-CO_2) Gases, Sinks and International Trading

As discussed in the large source cap-and-trade program description, dialogue participants believed that a broad approach covering all greenhouse gases (i.e., CO_2, CH_4, SF_6, PFCs, HFCs, N_2O) was preferable. Thus, large sources of these gases would be covered under the cap-and-trade program. Emissions from other activities could be included as offsets, where monitoring is feasible and the scale sufficient. For some number of more diffuse or less quantifiable activities, incentive or traditional control techniques were preferred (e.g., best practices, phase-outs, subsidies, etc.). The initial choices should be revisited from time to time, however, because an increasing number of techniques should likely be included in the cap-and-trade or offset system as we learn more.

There was a fairly broad consensus that increased flexibility for meeting the established cap using credits from off-system emission reductions of other greenhouse gases, from carbon sinks, and from international trading would be helpful in addressing economic and political concerns and could be done in a manner that would not compromise environmental effectiveness.

First, land-use related carbon sequestration projects offer an important opportunity to slow accumulation of greenhouse gases in the atmosphere while transitioning to lower emitting fuels and technologies. Opportunities to store carbon in forests or soils vary in size, measurability, and rate-of-return. Projects with a larger rate of return and more certainty of the carbon sequestered were thought to provide the best offset opportunities. Examples of currently available offset opportunities include afforestation and energy plantations. Other efforts may currently be more diffuse or raise monitoring issues. As with some sources of non-CO_2 gases, a spectrum of approaches may be warranted.

For international land-use projects, questions about fungibility and verifiability were raised. Ultimately, the goal would be to have the domestic system link successfully with a coherent and sound international trading scheme. In the shorter term, a domestic system could recognize credits accepted by sanctioned trading programs or approved through the Clean Development Mechanism. One option offered, but not fully discussed, was that credits for sinks could be time limited (e.g., to the first phase of the program), but not discounted or held to a certain percentage of allowable credits.

There was general agreement that for all these categories (non-CO_2 gases not covered in the initial cap-and-trade system, land-based sequestration, and international offsets) that where reductions are real, quantifiable, and verifiable, credits should be allowed into the system unfettered. Some participants noted, however, that to win political support aimed at driving domestic mitigation efforts, limits to the use of offsets may need to be incorporated into a program. For source categories of limited size or monitoring capability, other programs such as controls, incentives, education, or discounted offsets may be most appropriate. As experience and technological proficiency is gained, practices could move from the incentive/standards category to offsets.

Technology Policy

Whatever the short-term reduction policy, the group found that it should be supplemented by research and efforts to promote a transition to new fuels and technologies. There was discussion of the need to secure reliable, sustained funding for technology R&D and to support diffusion of GHG-friendly technologies. This should include both policies to bring nearer term technologies to the market and to encourage longer term paradigm shifts such as hydrogen or carbon capture and storage. In addition to general tax revenues, two funding options were discussed in some detail: (1) regulatory surcharges on transmission lines and pipelines; and (2) revenues from allowance auctions (recognizing that there was not support for auction of allowances other than 5%), whether implemented by the government or by a fiduciary body. There was no consensus on which source was preferable and some objection to using surcharges. Whatever the source, however, there was support for using such funds to aid both public and private sector research efforts.

Finally, the influence of other government policies and incentives on climate policy was noted. Actions the government takes on energy and transportation policy can create barriers to or opportunities for addressing climate change. Natural gas supplies are critical to a transition to a lower carbon economy. Incentives in the transportation sector to build roads or expand public transit have an impact on the ability to address rising GHG emissions. The relationship of climate policy to the broader domestic policy agenda needs to be understood and addressed.

Conclusion

The Climate Policy Framework described here is suggested by participants in the Aspen Institute dialogue as a viable design option for a domestic program to reduce greenhouse gas emissions. Developed in broad-brush, it represents a starting point for further dialogue regarding more specific design features.

While all details of program design were not articulated or agreed upon, and there was no attempt to recommend levels of emissions reductions or dates, it is noteworthy that a varied group of people from different sectors and constituencies reached substantial agreement on a framework for program design — an initially modest but subsequently declining absolute emissions cap on large sources and transportation fuel suppliers, supplemented by tradable efficiency standards and offsets, and coupled with a long-term commitment to technology development and diffusion — and on which sectors, gases, and sources should be covered.

We believe the results of this dialogue provide a hearty basis for further discussion among additional stakeholders, analysts, and policymakers.

DESIGNING A MANDATORY GREENHOUSE GAS REDUCTION PROGRAM FOR THE U.S.*

Robert R. Nordhaus and Kyle W. Danish

Executive Summary

This report identifies issues that must be addressed in the design of a mandatory, domestic greenhouse gas (GHG) reduction program. Three options are specifically evaluated: (1) cap-and-trade programs, (2) GHG taxes, and (3) a "sectoral hybrid" program that combines efficiency standards for automobiles and consumer products with a cap-and-trade program applicable to large GHG emission sources.

Criteria for Evaluating Options

In order to compare various approaches to GHG reductions, each option is evaluated using the following criteria:

- ***Environmental Effectiveness:*** How effective is the program in meeting its emissions reduction target?
- ***Cost-Effectiveness:*** Will the program design permit cost-effective compliance?
- ***Administrative Feasibility:*** Can the program be administered effectively and does it minimize administrative and transaction costs?

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* Robert R. Nordhaus is a Member, and Kyle W. Danish an Associate, of Van Ness Feldman, P.C., Washington, DC. This report, prepared for the Pew Center on Global Climate Change and published in May 2003, is available in full at http://www.pewclimate.org/global-warming-in-depth/all_reports/

- ***Distributional Equity:*** Are the burdens of compliance fairly apportioned?
- ***Political Acceptability:*** Are there elements of the program's design that affect its political acceptability?

Analysis of Options

1. Cap-and-Trade Programs

A conventional cap-and-trade program establishes an economy-wide or sectoral "cap" on emissions (in terms of tons per year or other compliance period), and allocates or auctions tradable "allowances" (the right to emit a ton of greenhouse gases) to GHG emission sources or fuel distributors. The total number of allowances is equal to the cap. A "downstream" cap-and-trade program applies to sources of GHG emissions and requires them to surrender allowances equal to their emissions. An "upstream" program applies to fuel suppliers and requires them to surrender allowances equivalent to the carbon content of fossil fuels they distribute. The primary focus of a cap-and-trade program would be on sources of emissions that can be readily measured and monitored; these include almost all sources of carbon dioxide (CO_2) emissions from fossil-fuel combustion as well as many sources of other GHG emissions. Sources not amenable to regulation through a cap-and-trade program can be covered on an "opt in" or project basis or addressed through supplemental regulation. Four major issues should be considered in the design of such a cap-and-trade program:

- ***Flexibility:*** To what extent can firms satisfy their obligations by purchasing allowances (either from within or outside the United States), by sequestering carbon, by controlling greenhouse gases other than CO_2, or by banking or borrowing allowances?
- ***Downstream vs. Upstream:*** Does the program regulate firms that emit greenhouse gases ("downstream") or does it regulate their fuel suppliers ("upstream")?
- ***Allowance Allocation:*** Does the program distribute free allowances to firms affected by GHG regulation, does it auction them to the highest bidder, or is some combination of approaches involved? If free allowances are distributed, what allocation formula is used? If allowances are auctioned, how are the revenues used? How might the allocation process change over time?
- ***Cost Cap:*** Does the program incorporate a "safety valve" in which additional allowances are made available at a pre-set price?

Evaluation of the Cap-and-Trade Approach

Upstream cap-and-trade. An economy-wide upstream cap-and-trade program would be environmentally effective, could attain cost-effective compliance if it incorporates flexibility measures, and would be administratively feasible. Its distributional consequences would depend on how allowances were allocated and, if auctioned, how the auction revenues were recycled back into the economy. These allocation and recycling decisions can also affect overall compliance costs, because some methods of allocating allowances may be less economically efficient than an auction, and according to some economists, using auction revenues to reduce "distortionary" taxes on capital or labor can reduce the net costs of the program. Finally, because an economy-wide upstream cap-and-trade program will drive up the cost of gasoline and home heating fuels, it is likely to present a political challenge.

All-source downstream cap-and-trade. An economy-wide downstream cap-and-trade program – because it implies the regulation of literally millions of individual GHG sources, including cars and homes – would be difficult and costly to administer, and therefore is not a viable prospect for a domestic GHG regulatory program.

Large-source downstream cap-and-trade. A large-source downstream program (i.e., one applicable only to electricity generators and large industrial sources of greenhouse gases) is administratively feasible and could be environmentally effective with respect to the sectors it covered. To be fully effective, however, such an approach would have to be coupled with a program to cover other sectors. A large-source downstream program might be more acceptable politically than an upstream economy-wide program because it would not result in price increases for gasoline and home heating fuels (though it still would result in price increases for electricity).

2. GHG Tax

A GHG tax is a tax on emissions of greenhouse gases or on the carbon content of fossil fuel. Many of the design issues discussed in connection with cap-and-trade programs are also present – though in somewhat different form – in the design of a GHG tax.

Evaluation of the GHG Tax Approach

An upstream GHG tax program could be environmentally effective, but would not provide certainty in meeting a particular emissions target. It would allow for adoption of least-cost mitigation strategies, would offer cost certainty, and would be administratively feasible. The ultimate distributional consequences of a GHG tax would depend on how policy-makers distributed revenues from the tax. Again, according to some economists, using revenues from allowance auctions or emissions taxes to reduce "distortionary" taxes can reduce the net costs of the program. However, political acceptability is likely to be a major obstacle, since the GHG tax combines both new taxes and fuel price increases. A GHG tax could have better prospects as a part of a larger tax reform effort.

3. Sectoral Hybrid Programs (Product Efficiency Standards Plus Large Source Cap-and-Trade)

One way to increase the environmental effectiveness and cost-effectiveness of a domestic program that relies on a large-source downstream cap-and-trade policy is to regulate uncapped sectors through product efficiency standards. Such a "sectoral hybrid" program would combine a large source cap-and-trade program with product efficiency standards. The product efficiency standard component would be similar to current automobile and appliance efficiency standards, and would be designed to limit GHG emissions from new automobiles and consumer products.

Issues in designing the product efficiency standards component of the sectoral hybrid include: the scope of the program (which products are regulated); the extent to which standards are made "tradable" (i.e., whether manufacturers can trade between product lines within the firm, with other manufacturers, or with facilities regulated under the cap-and-trade program); and whether the program "caps" projected lifetime emissions from use of the product ("capped tradable standards").

Evaluation of the Sectoral Hybrid Approach

A sectoral hybrid program consisting of a large-source downstream program coupled with product efficiency standards would be more environmentally effective than a downstream program alone (or standards alone), because standards could address emissions from sources (such as automobiles and appliances) that could not feasibly be covered by the downstream cap-and-trade program. Building on existing standards programs, such a hybrid program could attain coverage of about 80 percent of U.S. energy-related CO_2 emissions. However, product efficiency standards would not address the intensity of product use or the replacement rate of new products for old, less-efficient products. A hybrid program would be a more costly means of achieving any particular emissions target than an economy-wide upstream cap-and-trade or tax program, though making the standards “tradable” would reduce the disparity. Incorporating tradable standards would present significant administrative challenges, however, because of the need to prevent double-counting of emission reductions and the technical issues in setting and revising standards. Finally, a sectoral hybrid program may score better on political acceptability because it constrains domestic GHG emissions while largely shielding consumers from fuel price increases.

Summary of Analysis

The paper’s analysis would argue against an economy-wide downstream cap-and-trade program (as unadministrable), a stand-alone large-source cap-and-trade program (as incomplete), and a GHG tax program (as unviable politically, unless coupled with structured tax reform). The paper’s analysis indicates that at least two major alternatives appear to be feasible: (1) an economy-wide upstream cap-and-trade program, or (2) a sectoral hybrid program under which product efficiency standards complement a large-source downstream cap-and-trade program.

The first alternative (a comprehensive upstream cap-and-trade program) may be the best one if it can be put in place. However, U.S. energy policy experience over the past three decades suggests that putting it in place may be extraordinarily difficult. Even in times of most compelling national circumstances, such as the 1973 Arab oil embargo, Congress was unwilling to use energy price increases to rein in consumer demand. The second alternative – a sectoral hybrid program – may be all that can be implemented in the near term. If policy-makers take that course, careful attention will have to be given to minimizing economic costs and administrative complexity, and assuring that the program can be effectively enforced.

ADDRESSING THE COSTS OF CLIMATE CHANGE MITIGATION*

Vicki Arroyo and Neil Strachan

I. Introduction

Cost considerations are critical in the development of any mandatory program to reduce U.S. greenhouse gas (GHG) emissions. First, climate change policies impose costs through the development and introduction of new technologies, and through required changes in production by firms and in behavior of individuals. Climate change mitigation policies can also produce benefits, including stimulation of innovation, reduced emissions of traditional air pollutants, and improved energy security. Effective strategies to reduce mitigation costs are also essential for political agreement and to ensure that climate targets are achieved in practice.

This paper frames policies to reduce GHG emissions in terms of cost-effectiveness analysis, and only considers market impacts. Cost-effectiveness analysis takes a stated GHG reduction goal and compares policy approaches to meet this goal at the lowest cost. Although this paper does not cover the benefits of climate change mitigation policies, particularly in terms of avoiding non-market impacts, considerable work continues to be done to accurately depict and account for these impacts and consider these in conjunction with the costs of mitigation.[1]

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* By Vicki Arroyo and Neil Strachan of the Pew Center on Global Climate Change. This paper draws heavily from a paper entitled Addressing Cost: The Political Economics of Climate Change by Joseph Aldy, Richard Baron, and Laurence Tubiana in the Pew Center on Global Climate Change's Beyond Kyoto series of reports. It was synthesized and changed to reflect a domestic U.S. focus for presentation at this Aspen workshop.

II. Key Cost Issues

An important backdrop to any discussions of crafting climate policy is the issue of timing: how much cost to incur now for future benefits and how to deal with limitations to our understanding of the mechanisms and impacts of human-induced climate change?[2] Any U.S. policy effort should provide for phased implementation in order to manage costs and incorporate new information.

With this overall milieu as a backdrop, policy-makers must consider three critical dimensions of cost to shape an effective national program to mitigate GHG emissions. The first is *aggregate* or *absolute cost*: that is, the cost implications for the U.S. economy as a whole. In fact, much of the economic analysis of climate change policy has taken a macro-economic perspective with results expressed in terms of losses or gains in U.S. gross domestic product (GDP). The second cost dimension is *relative cost*: that is, the distribution of cost (and possible benefits) between industrial sectors, different states or countries. The third cost dimension is *cost certainty*: that is, how confidently mitigation costs can be anticipated. The attractiveness of a national mandatory policy to reduce GHGs will hinge in part on its capacity to minimize concerns about these three critical dimensions: aggregate cost, relative cost and cost certainty.

A. Absolute Cost

The overall cost of GHG mitigation hinges largely on the stringency of the goal – which is a function of its magnitude, its timing, and the cost-effectiveness of the measures chosen to meet it. At the national level, the projected cost is most often analyzed and expressed as a change in GDP (although other measures of economic welfare [e.g., household consumption or employment] are also important for policy).

Absolute costs are best minimized by allowing flexibility as to where, when, and what type of mitigation action is taken. To minimize costs, abatement should occur where it is cheapest. Since changes in the climate reflect GHG concentrations (the long-term accumulation of emissions), the precise timing of emissions reductions can also be flexible. Several gases contribute significantly to warming – carbon dioxide (CO_2), methane, nitrous oxide, and a range of industrial gases (perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride). As these non-

CO_2 GHGs are more potent in warming terms[3] than CO_2 and have historically had no explicit price signal to minimize their use, considerable cost effective reductions exist[4], (CO_2 represents over 80% of U.S. GHG emissions, however, so an effective strategy must target both CO_2 and non-CO_2 emissions alike). In addition, a ton of CO_2 permanently sequestered in biological or geological processes yields the same climate benefit as abating a ton of CO_2 emissions, so a cost minimizing policy should include sequestration. Finally, if a reduction target is announced in advance, firms have more time to formulate and implement a cost-effective abatement strategy.

B. Relative Cost

In assessing the political acceptability of a U.S. GHG mitigation policy, aggregate cost may ultimately be less critical than relative cost – the distribution of costs. While the issue of relative cost in the U.S. is often portrayed as one of competitiveness among states (or countries), it operates principally at the sectoral level, arising when a sector faces climate-related costs different from those of its competitors in other sectors or geographical areas. Even if the impact on overall competitiveness is minimal, the concentration of costs in particular sectors (often concentrated in a few states), and resulting concern over competitive disadvantage is a powerful obstacle to the U.S. taking on a mandatory reduction target.

Relative cost issues arise across different dimensions. First, even if two states or sectors have comparable commitments to reduce emissions, variations in their underlying economic and energy structures and in their implementation strategies may yield significant differences in the relative cost of compliance. A second set of competitiveness concerns arises between U.S. industrial firms and competitor firms in developing countries that have not taken on a comparable commitment. Relative costs influence not only the political viability of a climate change mitigation policy, but also its environmental effectiveness. This is usually illustrated by the notion of emissions leakage; for example, under a GHG constraint with associated higher energy costs, some energy-intensive industries could locate new plants or shift existing production overseas.[5]

Finally, the distribution of costs within the U.S. could significantly influence its willingness to adopt a national GHG reduction policy. Fossil fuel energy producers, energy-intensive industries, and workers in these industries are likely to bear a larger share of the burden of an emissions mitigation policy. In contrast, suppliers of energy-efficient and renewable energy technologies, or forestry and agricultural firms that engage in carbon sequestration may benefit from such a policy. The effectiveness of these various actors in influencing the U.S.'s climate change policy can determine in part the path the U.S. will follow. The design of a national mitigation program can ease or exacerbate relative costs, but it is unlikely that there exists an approach that would preserve the current market status of the most heavily carbon-exposed industries.[6]

C. Cost Certainty

A third, and related, issue that complicates the design of GHG mitigation policy is cost certainty. Economic models rely heavily on assumptions about key drivers[7] to overcome key uncertainties, and as such provide a range of costs of GHG reductions[8], and insights into where the actual cost will lie in this range. Long-term emissions forecasts reflect uncertainties over population growth, economic output, energy endowments and their prices, technological change, and land use activities – not to mention geopolitical changes.[9] Uncertainties over future emissions trends are important because the level of effort required to meet a given target must be measured from a presumed baseline of "business as usual" emissions growth.

There are significant uncertainties as well over the likely social and economic responses to a given GHG mitigation policy. For instance, the costs will depend in large part on how easily consumers and producers can substitute away from carbon-intensive activities. The more flexible and responsive firms and consumers are, the lower the costs.[10] The rates of technological change and diffusion are also critical, and difficult to predict. Assigning a price to GHG emissions stimulates the development and diffusion of lower emitting technologies.

Certainty is also crucial to firms that must implement the GHG reductions. Firms would prefer to delay investing resources that are largely irrecoverable (for example, large energy equipment that has lifetimes of years or decades), and to gain new information that can allow for a better-informed decision in the future. [11] However, the magnitude of these investments under more or less stringent policies must be weighed against irreversibilities from the impacts of various degrees of climate change, including the very real possibility of loss of species or destruction of cultures in at-risk geographic locations.[12] The pre-announcement of policy would help to reduce the costs associated with taking action.

Reducing the uncertainty in costs of meeting a given GHG mitigation target will contribute greatly to the political acceptability of such a policy and the likelihood of compliance.

III. Cost Comparison of Policy Options

A. Emissions Trading

A tradable emissions allowance program is a quantity-based mechanism that can ensure that all emissions sources and sectors face the same marginal cost of reduction. This is achieved through purchase of low-cost credits or banking of early abatement. The SO_2 Acid Rain program has demonstrated that cost-effective reductions can be achieved in practice.

An abundant literature supports the cost-minimization advantage of GHG trading.[13] In practice, savings may be diminished by imperfect information, transaction costs in setting up trades between firms, and any lost mitigation opportunities from the omission of various sectors, technologies, greenhouse gases or international offsets from the trading program. Despite these limitations, it is widely agreed that emissions trading is among the most effective means of minimizing the aggregate cost of GHG reductions.

Emissions trading also helps address relative cost. By ensuring that all sources have access to the same least-cost abatement opportunities, emissions trading reduces the competitive disadvantages that sources may face. This also reduces leakage by lowering incentives to relocate. In addition, certain design features of a U.S. trading system can help address relative cost impacts. For example, allocating emissions permits to adversely affected industries can alleviate much of the impacts on these carbon intensive sectors.[14] Another option is to recycle revenues from auctioning some or all emissions allowances to finance transition assistance for workers and communities dependent on energy-intensive industries, provide compensation for consumers facing increased energy prices, or to offset existing taxes on labor or capital inputs. In fact, if the existing taxes are economically inefficient, the emissions trading system may result in a “double dividend,” yielding both emissions reductions and economic savings.

One concern with a quantity-based emission trading system is that if it is designed inflexibly, then supply side constraints and external economic factors can lead to spikes in the price of permits, with resulting negative impacts on both the trading scheme and the economy.[15] The next section discusses some options to hedge against cost uncertainty.

B. Variations on Emissions Trading

An emissions trading variant that may offer greater cost certainty would incorporate a "safety valve" mechanism to insure against unexpectedly high costs. This works through the release of as many additional permits as required when the trading prices reaches a predetermined threshold. This option would effectively put a ceiling on the price of traded allowances and thus provide an upper limit on the marginal cost of compliance. To act as an insurance mechanism, the safety valve price should be set well above the predicted marginal cost of complying with a policy's emissions commitments. However, if the safety valve price is set too low – i.e., well below the forecast cost of the quantity target – it could effectively convert the emissions trading system into a tax-based emissions regime, which would provide less incentive for R&D and technological diffusion and may not meet environmental objectives.

Another mechanism designed to reduce cost uncertainty in an emissions trading scheme is a "circuit breaker." This works by relaxing the overall cap in the trading scheme when the permit price reaches a predetermined level. For example, if the emissions cap is set to decline by 1% per year, if the circuit breaker is triggered for that year, the cap would stay constant, allowing additional permits to enter the system. When the permit price dropped below the threshold, the tightening of the overall cap would resume once more. A circuit breaker would provide an insurance mechanism against excessive cost, but to a lesser extent than a safety valve, as the permit price could still rise considerably, even with a relaxed overall cap.

A third option to reduce cost uncertainty is an "indexed" or a "relative" emissions target. This does not set an absolute emissions target at the start of the trading scheme, but instead adjusts the quantity commitment based on measures of economic performance (e.g., GDP) or other potentially relevant indicators (e.g., population).[16] If the U.S. economy grew faster than expected, then the indexing formula would increase the total quantity of emissions allowed. However, since a GDP-based formula includes only one factor influencing the effective stringency of an emissions commitment, it does not eliminate cost variability from other factors (e.g., weather, energy supply, or the rate of technological innovation). Indexing can address another risk raised by setting absolute emissions objectives years in advance, the creation of so-called "hot air" – a quantity target in excess of business-as-usual emissions even in the absence of any abatement efforts.[17] With an indexing approach, if the U.S. economy grows much slower than expected, the total quantity of emissions allowed would be reduced, thereby reducing or eliminating the prospect of a commitment becoming a hot air target.

All of the options discussed above for reducing cost uncertainty in an emissions trading scheme may involve a trade-off against environmental effectiveness.

A final variant of emissions trading is sectoral targets. These can be used to alleviate the relative impacts on different US economic sectors. Under a sectoral targets approach, the emissions cap is set in terms of industry-specific measures (e.g., tons per MWhr or tons per million dollars of output). This can allow a more precise indexing of required effort to reduce emissions. Sectoral targets can also facilitate direct comparison with equivalent sectors in other countries and hence reduce international competitiveness concerns. Sectoral targets can also allow policy-makers to impose more or less stringent targets to various parts of the economy. Although this is likely to introduce artificial inefficiencies into the trading system, in a practical sense, some sectors may be more important for, and amenable to, emissions mitigation in the near term.

Some of these variants on a standard emissions trading scheme can be combined (for example, sectoral commitments could be integrated with a safety valve).

C. Emissions Taxes

While emissions trading systems provide for greater certainty regarding the quantity of emissions reductions, an emissions tax provides greater certainty about the cost of GHG emissions reductions. By equating the marginal cost of emissions across all sectors, an emissions tax can result in least-cost abatement comparable to what would occur in theory under an emissions trading regime.

An emissions tax can thus minimize aggregate costs, and provide certainty on marginal cost, but at the price of uncertainty in emissions abatement and with few options to address the distribution of cost across sectors. As with an emissions trading scheme, revenues from the GHG emissions tax could be used to compensate adversely affected sectors or communities or to offset existing inefficient taxation.

However, governments could effectively circumvent the effect of an emissions tax by reducing other taxes affecting energy-related activities. And finally, political acceptability is likely to be a major obstacle, since the GHG tax combines both new taxes and fuel price increases.

D. Technology and Emissions Standards

An alternative or supplemental approach to emissions trading or emissions taxes could be standards for technologies or for emission rates. Some policy analysts suggest such standards would be much easier to administer and would allow easier evaluation of firms' compliance. However, a technology-based standard for specific sources of emissions, or standards based on emission rates for various processes or products (e.g., automobiles), would not likely compare well with alternative policies in terms of absolute, relative, or predictable costs. Imposing standards, even tailored to specific industries, would not achieve efficient emissions abatement because the technology would be very expensive for some firms and less expensive for others. A national body cannot implement technology standards in a manner that equates marginal costs among all affected firms, as even expert policy-makers cannot perform as well as the private sector under clear market signals. Further, the process of setting standards may risk regulatory capture – policy-makers with the mandate to design standards becoming strongly influenced by interest groups – resulting in greater disparities in abatement effort across industries, hence exacerbating the relative costs of the policy. Last, improving the emission rate of a technology or a process may provide an incentive to use that product more, hence diminishing the overall emissions savings. However, standards are an important potential tool to address energy use in applications where there are many users, and one way to overcome concerns about inflexibility is to design a tradable standards system or to allow for standards to be integrated with an upstream trading program.[18]

Endnotes

1. Avoided impacts from climate change include changes in resource productivity, damages to the human-built environment, human-health impacts, and notably damages to ecosystems, including loss of biodiversity and damage to aquatic ecosystems. Great uncertainties surround physical impacts of climate change, and valuation of these non-market impacts further depends on assessing thresholds (where impacts either accelerate or change course), low probability but high impact events (also known as climate surprises), existing vulnerabilities and the role of adaptation. For further discussion of benefits of GHG mitigation, see Smith J. (2003), *A Synthesis of the Potential Impacts of Climate Change on the United States*, Pew Center on Global Climate Change, Arlington, VA.

2. See Proceedings of Pew Center's Timing Workshop (www.pewclimate.org). October 2001.

3. As expressed in Global Warming Potential or GWP.

4. Expanding the coverage from energy-related CO_2 to all six GHGs lowers the GDP cost by over 30% for the US to meet its Kyoto objective through purely domestic measures. See Reilly J., H. Jacoby, and R. Prinn (2003), *Multi-Gas Contributors to Global Climate Change: Climate Impacts and Mitigation Costs of Non-CO_2 Gases*, Pew Center on Global Climate Change, Arlington, VA.

5. Of course, a host of factors are likely more important for plant location than energy costs -- including proximity to resources, access to markets, the available employment pool and government fiscal policies.

6. The role of existing carbon intensive sectors may hinge on the development of new technology, for example integrated gasification and sequestration technologies would allow coal-fired electricity to maintain market share in a carbon constrained economy.

7. See Weyant J. (2000), *An Introduction into the Economics of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

8. For example, the range of marginal costs – the cost of removing the last ton – to achieve the Kyoto Protocol's targets ranged from less than $20 to more than $200 per ton of carbon. See Weyant J. and J. Hill (1999), *The Costs of the Kyoto Protocol: A Multi-Model Evaluation*, Special Issue of the Energy Journal.

9. An effort to project long-term emission trends yielded six illustrative scenarios, with global CO_2 emissions in 2100 varying by a factor of six and CO_2 concentration levels varying by a factor of two or more. See Nakicenovic, N. et al. (2000), *Summary for Policymakers: IPCC Special Report on Emissions Scenarios*, Intergovernmental Panel on Climate Change.

10. See Jorgenson D., et al (2000), *The Role of Substitution in Understanding the Costs of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

11. See Lempart R. et al (2002), *Capital Cycles and the Timing of Climate Change Policy*, Pew Center on Global Climate Change, Arlington, VA.

12. This favors a far stronger environmental objective. See Arrow K., and A. Fisher (1974), *Environmental Preservation, Uncertainty, and Irreversibility, Quarterly Journal of Economics*, Vol. 88, pp. 312-319.

13. See Edmonds J. et al (1999), *International Emissions Trading and Global Climate Change: Impacts on the Cost of Greenhouse Gas Mitigation*, Pew Center on Global Climate Change, Arlington, VA.

14. See Burtraw D. et al (2002), *The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances*, Discussion Paper 02–15, Resources for the Future, Washington DC.

15. For example in the California RECLAIM program – See Ellerman D., P. Joskow, and D. Harrison (2003), *Emission Trading in the U.S. - Experience, Lessons and Considerations for Greenhouse Gases*, Pew Center on Global Climate Change, Arlington, VA.

16. An example of an intensity target is the U.S. voluntary goal of reducing its ratio of GHG emissions to GDP to 151 million metric tons per million dollars by 2012 (from the 2001 ratio of 183).

17. For example the contraction of the Russian economy following the demise of the Soviet Union has led to considerable amounts of Russian "hot air" credits in the Kyoto trading system.

18. See Nordhaus R. and K. Danish (2003), *Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.*, Pew Center on Global Climate Change, Arlington, VA.

ESTABLISHING A DOMESTIC GHG REDUCTION TARGET: KEY APPROACHES AND CHALLENGES*

Vicki Arroyo and Naomi Peña

I. Introduction

Establishing a domestic target (like setting an international target) is essentially a risk-management decision: policy-makers must evaluate which risks and costs are tolerable based on the available information. This paper examines the types of targets that could emerge under a domestic mandatory greenhouse gas (GHG) reduction effort. In setting a target, several features must be determined, including its structure, the emission sources that will be covered; and the level and speed at which target levels will be reached. Whatever the target, given the evolving nature of our understanding, any policy should be designed to incorporate new information. The following paper explores issues relating to target structure, coverage, and stringency, and identifies implementation challenges.

II. Target Structure

Targets can be structured in various ways: they can be expressed in terms of limits on the quantity of emissions, in terms of limits on emission rates (indexes), or in terms of technology-based standards.

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Absolute Quantity Limits

One approach is to limit the number of tons of GHG emissions that may be released to the atmosphere. A mandatory absolute quantity limit traditionally has been called a "cap." Caps can be set for groups of nations, individual countries, economic sectors, companies, or facilities. The advantages of this approach include simplicity, clarity, and proven effectiveness through successful implementation of the U.S. Acid Rain program. As long as a target set in absolute quantities is adhered to, it also has the advantage of environmental certainty: one knows in advance how many tons of GHGs will be emitted to the atmosphere.

Rate-based Limits

Another approach is to set a limit on the number of tons of GHGs that may be emitted per unit of something, i.e., using an indexed approach. As with the absolute quantity approach, rates or indexes can be set for nations, sectors, companies or facilities. At the national level, a rate-based standard can apply to emissions per capita, per unit of energy used, or can be relative to the gross domestic product (GDP). When GDP or energy is used as the unit, the target is often referred to as an "intensity" or "dynamic" target. When rates are set for sectors, companies, or facilities, emission limits can be set per unit of production, per ton of production, or per dollar of sales. For example, emission rates can be in terms of GHG emissions per ton of aluminum or per refrigerator produced.

Rates are not as easy to understand as absolute quantities and do not provide environmental certainty in the short run. That is, one does not know in advance how many tons of GHGs will be emitted. As the level of production, GDP, or energy used climbs, so will total tons of GHG emitted. Rates do have some advantages, however. For example, rates will be the primary focus of company-level compliance efforts regardless of the structure of targets. Companies will focus on improving emission rates even under absolute quantity systems because there are only three ways to lower total emissions: lower the level of production; change what one produces, or lower the emission rate per unit of production. Companies are very unlikely to want to lower levels of production, and while changes in what a company produces will occur, a fair amount of inertia can be expected, with the result that lowering rates will be a prime focus of emission reduction efforts.

Moreover, it is easier to trade between a rate-based system and both product standards and parts of an economy that are not under mandatory limitations.

Rate-based targets also tend to provide more "cost certainty" than absolute quantity approaches because of the way they are set. Technologies—whether currently widely deployed, emerging, or still in early stages of development—are characterized by emission rates. The near-term costs of these technologies are, at least in general, known. So to set a rate (except for per capita rates) is, in effect, to determine which technologies, with known costs, will have to be used. For example, the United Kingdom set emissions rates for industrial sectors as part of its trading system. Both business as usual (BAU) and "all cost-effective measures" rates were estimated for each participating industrial sector. It was recognized that most companies would not implement all cost-effective measures, and that industrial sectors with stagnant or falling production might be less able to adopt new technologies due to lack of investment capital. Rates were thus set between BAU rates and the rates that would result from implementation of all cost-effective measures with less aggressive rates set in sectors with low or stagnant production.

Technology- and Rate-based Product Standards

Product standards can be set either in terms of specific technologies or in terms of rates. Technology-based standards prescribe specific technologies that must be used. Although previously common in environmental regulation, prescribing technologies is often not an economically efficient way to achieve a goal. By prescribing particular technologies, alternative, more cost-effective means to achieve the same outcome are eliminated from consideration, and there is no incentive to develop new technologies. More flexible approaches that allow for innovative and alternative ways to achieve a goal are more desirable. Rate-based product standards allow such flexibility. At present rate-based product standards usually take the form of setting a limit on the amount of energy that can be used to accomplish a task. Examples of rate-based product standards include: miles per gallon (for cars), kWh per cycle (dishwashers), and Watts per lumen (lights). For the purposes of GHG targets, rate-based product standards could be stated in terms of emissions per task (e.g., per mile, per cycle, or per lumen) rather than in terms of energy.

Comparison of Structures

In the short term, emissions and costs under different target structures would vary. In the longer term, based on the aggressiveness of the reduction targets sought, the different approaches could lead to comparable results. Theoretically, an aggressive rate-based approach could yield comparable results to an absolute quantity cap or technology-forcing standards. Under rate-based limits and product standards, GHG emissions levels (i.e., total tons emitted) would be uncertain, at least in the short term. Under absolute quantity approaches, costs would be uncertain, at least in the short term. In both cases, there is inherent uncertainty in predicting future economic growth. If growth is greater than expected, rate-based approaches would yield higher emissions than expected and absolute-quantity approaches would lead to higher costs. As experience is gained, the rate at which limits are tightened could be adjusted so that costs and emission levels would be more in line with desired outcomes.

III. Covered Sources

In 2000, carbon dioxide (CO_2) accounted for 83% of total U.S. GHG emissions, 96% of which resulted from the combustion of fossil fuels. Methane accounted for 9%, nitrous oxide for 6%, and industrially produced gases for 2% of U.S. GHG emissions. The primary sources of methane emissions are landfills, agriculture, natural gas, and coal mining operations. Agriculture is the primary source of nitrous oxide emissions. When considering emissions by sector, emissions from electricity generation can be allocated to end-users or to the electricity generation sector (see figure).

FIGURE 1: GHG EMISSIONS BY SECTOR
(EMISSIONS FROM ELECTRICITY GENERATION STATED SEPARATELY)

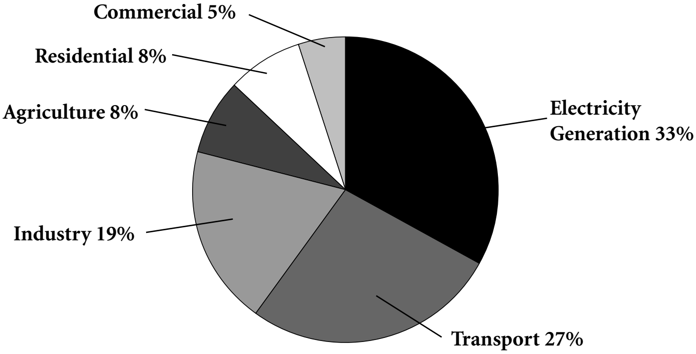
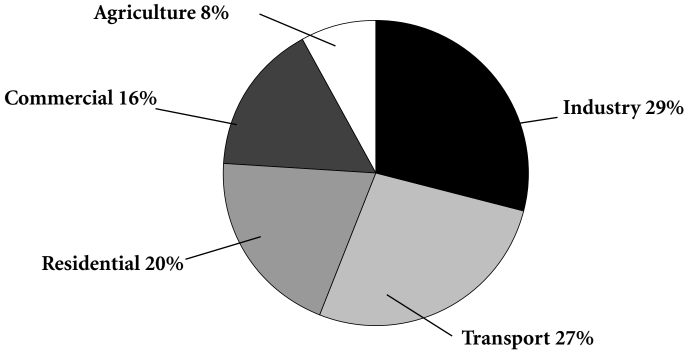


FIGURE 2: GHG EMISSIONS BY SECTOR
(EMISSIONS FROM ELECTRICITY GENERATION ALLOCATED TO END USE)



In order to achieve a national target that reduces GHG emissions, emissions from a number of significant sources must be reduced. As discussed in the Nordhaus and Danish paper, a tax that would affect all sources of carbon dioxide (CO_2) is probably not politically feasible, nor is it administratively feasible to set absolute quantity restrictions on millions of small emission sources. A cap-and-trade program imposing absolute quantity restrictions could more realistically be placed on large point sources, with these restrictions supplemented by product efficiency standards. Moreover, when both rate-based and absolute quantity approaches are considered, a number of other possibilities emerge.

Downstream absolute quantity restrictions may be most suitable for the electric power sector, particularly given the existing reporting requirements under the Acid Rain program. The potential availability of post-combustion capture and storage of waste CO_2 suggests that upstream restrictions on carbon content of fuel for this sector may close off a viable mitigation option. One possible approach would be to begin with caps on emissions from the electric power. Such an approach would vastly simplify issues of ownership of emission reductions. Emissions from buildings and industry are partly from on-site combustion of fuels and other on-site processes and partly due to use of purchased electricity. Reductions in electricity use thus simultaneously reduce building and industry sector emissions and emissions from the electricity sector. (Note: additional policy would still be needed to address important non-CO_2 gases from manufacturing). In concert with these stationary source reductions, transportation emissions could be reduced through a standards-based approach, or through a sector cap.

Certain small sources or sectors (e.g., agriculture) are likely to be exempt under any mandatory limit—whether absolute or rate-based. If the system allows, such exempted sources could sell reductions achieved to sources under restrictions.

IV. Target Stringency and Timing

Target objectives

The objective of a GHG emission reduction program is ultimately to prevent dangerous climate change. To achieve this objective it will be necessary first to stabilize and then to reduce emissions both in the United States and around the world. In the long run, achieving this objective will require the United States and the international community to move to an energy system that is close to emission-free, and to greatly reduce other sources of GHG emissions. The U.S. target should be designed so that the United States is contributing its fair share to the objective. However, the level and timing of U.S. emissions that would satisfy this objective depend on critical assumptions about the connections between atmospheric concentrations and climate impacts, actions taken by other governments, and global population and economic growth. Given the significant uncertainties in assessing what constitutes unacceptably high atmospheric GHG concentrations and the contribution that various countries would make to emissions and emission reductions, defining a domestic target that aims to prevent dangerous climate change would be difficult. Rather than debate what constitutes a "safe" level of concentrations and the necessary U.S. emission reductions, the prudent approach is to get started on a path that would first stabilize and then bend down the emissions path.

Technology and Phasing of Reductions

Given the expected growth in global energy needs, widespread deployment of alternative fuels and technologies with near-zero emissions will be needed over time in the effort to address climate change. Achieving an economy based on very low-emitting energy technologies will require far-reaching, long-term restructuring. Time will be needed for development and deployment of new technologies and for replacement of capital stock. Similarly, the majority of U.S. automobiles rely on an internal combustion engine that runs on gasoline. There are ways to increase the efficiency of these traditional automobiles, and alternatives such as hybrid gas/electric cars are now available. Over time, the ability of the energy production sector to incorporate technologies such as carbon capture and geological sequestration and for automobiles to run on fuel cells or hydrogen will allow for more significant emissions reductions. Interim targets, achievable with existing technologies and at moderate cost, will be useful in defining how quickly reductions can be met. Thus any policy targets would likely involve phased reductions that could be revised over time to achieve the desired reduction trajectory. Such "sequential decision-making under uncertainty" is common for addressing complex and evolving issues (Aldy, Orszag, and Stiglitz, 2001).

In practice, both rates and absolute quantities are used in the process in which GHG emissions limits and timetables are selected. Under a rate-based approach, the absolute quantities (levels) of emissions expected under the selected rates or standards would be calculated—if not by those who set the rates, then certainly by those who wish to evaluate their implications. Emissions levels will be estimated by multiplying rates (i.e., emissions per unit of production, GDP, or energy) by projected production levels, or growth in GDP or energy use. The total emissions that would result from various rates were calculated, and these totals were considered as part of the rate selection process. Under rate-based approaches, if economic growth exceeds expectations of those who have accepted rate limits, emission levels will be higher than expected.

Similarly, absolute quantity targets will be evaluated in terms of the rates they imply. The U.S. Acid Rain (SO_2) program provides an example of how rates are used even in emission limitation systems that use the absolute-quantity approach. The U.S. Acid Rain Program is the "paradigm" absolute quantity approach and allowances to emit were, for the most part, granted for free. To allocate the allowances, the desired emission rate (SO_2 emitted per BTU of input) for each source was multiplied by the average number of BTUs it used in past years (Ellerman at al, 2000).

Costs

The expected cost of achieving targets will be an important consideration. In the short term, as with target levels, costs under different target structures are likely to vary. Over time, costs of reductions will become clearer and new technologies will enter the marketplace, and future targets can be set informed by this experience. Often, estimates of costs prior to regulation are much higher than costs that emerge once regulations are implemented. (Harrington, W. et al 2000).

Projections of economic growth form the basis for setting limits in both absolute quantity and rate-based approaches, but are particularly important for costs under absolute quantity approaches. If economic growth is significantly greater than forecast, achieving the target will be more costly. If costs of compliance are too high, an absolute quantity target may be abandoned or evaded. Conversely, if an absolute quantity limit turns out to have been set too high in relation to the level of economic activity and emissions that actually occur, it will be easy to meet but will fail to restrict emissions and will create "hot air"—emission reductions that can be sold but which do not represent reductions in GHG emissions beyond BAU reductions.

V. Key Implementation Challenges

Measuring, Monitoring, and Compliance

Any mandatory emission reduction system will need a compliance mechanism, which in turn will rely on measurement and monitoring. GHG emissions can be directly measured or can be estimated using formulas based on the amount of fuel or chemicals (inputs) used and the known emission characteristics (i.e., rates of emissions per unit of energy used or per product) of technologies in use. While some large GHG emission sources will use direct measurement, formulas are likely to be used in other cases. Direct measurement does not necessarily provide more accurate results than use of input and technology data, and both absolute quantity and rate-based systems are likely to include sources that will utilize direct monitoring and sources that will use formulas. Technology-based product standards will also rely on formulas, particularly insofar as total annual or lifetime emissions from such products need to be estimated – for example, for trading or to determine compliance with an absolute quantity cap. While self-reporting of measured and formula-derived emissions may be accepted, some system of independent verification would be needed to ensure compliance with any mandatory emission limitation system.

Indirect Emissions, Product Emissions, and Double Counting or "Gratis" Benefits

As long as fossil fuels dominate the energy supply system, any system designed to limit GHG emissions should: (1) encourage large energy users, including electricity users, to become more energy efficient; (2) encourage more energy-efficient products; and (3) avoid double counting or awarding gratis benefits. Meeting these three goals would present difficulties under any system. The Nordhaus and Danish (2003) report explores the difficulty of avoiding double counting when product-use emissions reductions are traded under an absolute quantity target in a sectoral hybrid system. This section goes beyond their analysis to explore, more generally, encouraging emissions reductions while avoiding double counting and gratis awards in both rate-based and absolute-quantity systems.

One issue that will have to be addressed is whether (and if so, how) to include indirect emissions – i.e., the emissions from the building and industrial sectors that result from purchased electricity. As buildings and industries reduce electricity purchases, these indirect emissions will fall, as will direct emissions from electric generators. While these emission reductions are desirable, if an absolute quantity system includes electricity generators as well as the building or industrial sector, ownership or the attribution of credit for such reductions becomes complicated. Determining ownership is critical if trading is to occur. Issues that arise from simultaneous emission reductions can be more easily handled under rate-based targets. Rates could be applied to electric generators, industries, and a full range of products that use energy, including buildings, automobiles, and appliances, without creating ownership issues. Achievement of "better-than-the-rate-limit" can be used to generate tons for trade, analogous to tons available for trading if emissions are below an absolute quantity cap. Consequently, trading can occur under either rate-based or absolute quantity target structures. As in the case of absolute quantity systems, rates can be applied only to selected sectors if desired.

Encouragement of energy-efficient products consists of two components: promoting: (1) products made from materials and components that have lower emission profiles and (2) products that will cause fewer emissions during use. The former are referred to as "embodied" emissions, and the latter as "product-use emissions." It is difficult to define which of the multiple possible claimants should receive credits or incentives for embodied emissions. Product use emissions will also present challenges due to multiple claimants. One possibility not explored in the Nordhaus and Danish (2003) report is granting credit to purchasers of low-emission products. If it was considered administratively infeasible for millions of consumers to buy, sell, and trade credits, the credits could be returned to, or retained by, the retailers or manufacturers – in effect functioning as rebates. This option would stimulate sales of low-emitting products and reward the purchasers. Under a rate-based system, the double counting of product-use emissions described in the Nordhaus-Danish report would not occur because the electricity producer would not receive credits for reductions in energy demand. Finally, the Nordhaus-Danish report mentions that there are no standards for building envelopes. Standards for building envelopes would fit naturally into a rate-based system, thus addressing what has been an elusive goal: reduction of emissions from the building sector.

VI. Conclusions

The choice of a GHG reduction target – how fast and how much to reduce emissions – is largely a political calculation based on the assessment of risks and costs of action and inaction (with all the attendant uncertainties). Beyond this choice of the reduction level itself, the structure of the target will have important implications for administering the domestic system, the timing of imposed economic costs, and achieving compatibility with other trading systems.

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ASSESSING THE FINANCIAL CONSEQUENCES TO FIRMS AND HOUSEHOLDS OF A DOWNSTREAM CAP-AND-TRADE PROGRAM TO REDUCE U.S. GREENHOUSE GAS EMISSIONS*

David Harrison, Jr.

Introduction and Overview

United States policies to reduce carbon dioxide ("CO_2") and other greenhouse gas ("GHG") emissions could have substantial effects on U.S. firms and households.[1] This paper considers the financial effects of a downstream cap-and-trade approach to reducing CO_2 emissions[2], concentrating on the effects of the following three key elements:

1. ***Initial allocations.*** The approach used to distribute initial allocations of the capped total would have major effects on the financial consequences to sectors and firms. In some circumstances, the initial allocation approach also could affect the overall cost-effectiveness and other efficiency considerations of the program.

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2. ***Product market conditions.*** The ultimate effects of a cap-and-trade program on sectors and households also depend upon the extent to which GHG-related costs – including the opportunity cost of using CO_2 allowances to cover emissions – can be passed on to consumers in the form of higher prices (or backward to energy suppliers in the form of lower fuel prices).
3. ***International CO_2 allowance prices.*** Overall financial impacts of a U.S. CO_2 program could be substantially reduced if U.S. firms were able to obtain lower-priced CO_2 allowances abroad. Although most firms would gain financially as buyers, impacts would be more complicated for firms that would be net sellers under a U.S.-only scheme.

II. Initial Allocation

Perhaps no issue has been more contentious in the existing cap-and-trade programs than the allocation of initial allowances. The initial allocation of allowances in a cap-and-trade program confirms valuable property rights and thus it is not surprising that there are considerable differences among participants in recommendations for the appropriate distribution of the allowances. Moreover, in some circumstances the initial allocation approach could affect the overall costs of the program or other "efficiency" considerations. Before discussing the implications of alternative allocation approaches, it is useful to provide a context by considering how a firm would operate under a cap-and-trade program.

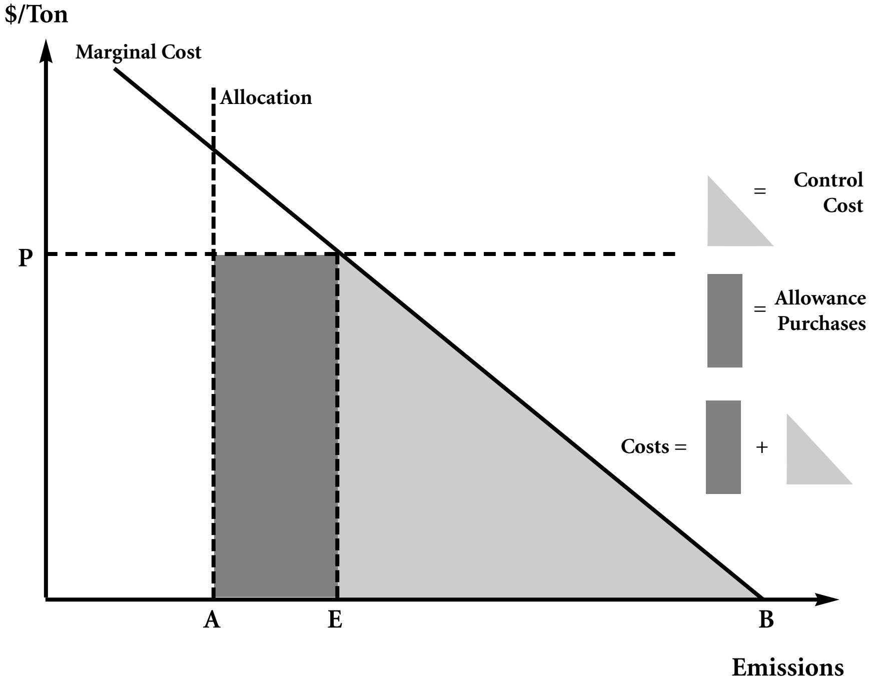
A. Factors Affecting the (Initial) Financial Effects to a Firm of Participating in a CO_2 Allowance Market

Creating a cap-and-trade program for CO_2 (or GHG) emissions means that firms will be participating in a new market – the market for CO_2 allowances. The financial consequences depend largely upon whether a firm is a buyer or a seller of CO_2 allowances, which depends in part on its allocation but also on other factors.

Figure 1 illustrates how a given firm (e.g., oil refinery, electric utility) would be affected by participating in a CO_2 market under a cap-and-trade program. The figure shows the five factors that influence the net costs that the company would bear initially in the CO_2 permit market. (As discussed below, the ultimate effects depend upon how these costs are reflected in product prices.)

- ***Baseline emissions (B).*** This is the level of emissions that the firm's facilities emit under so-called "business-as-usual" (BAU) circumstances, i.e., without limits on CO_2 emissions.
- ***Marginal cost curve.*** This is the curve that shows the marginal cost of reducing the firm's CO_2 emissions (e.g., improving efficiency, substituting low-CO_2 fuels).
- ***Permit price (P).*** This is the expected permit price that the firm would expect to pay (or receive) in the CO_2 allowance market.
- ***Controlled emissions (E).*** This is the level of the firm's emissions after taking into account its optimum controls, i.e., reductions that would cost less than the allowance price. (Note that this optimum depends only on the marginal cost curve and the permit price.)
- ***Allocation (A).*** This is the total number of CO_2 allowances initially allocated by the government to the firm. Note that where all allowances are auctioned, the initial allocation would be zero.

Figure 1: Illustration of Factors Affecting the Financial Impacts of a Firm's Participating in a CO_2 Emissions Market



There are two major implications for financial impacts that follow from these market conditions. First, the *control costs* that the firm would incur do *not* depend upon the allocation; the firm's control costs depend upon its marginal cost curve (i.e., its cost of internal reductions in CO_2 emissions) and the CO_2 permit price. Second, the firm's allocation largely determines whether it will be a buyer or a seller (and how much it will buy or sell) and thus does have a major effect on the financial implications. This figure shows a case in which the allocation (A) is *less* than the firm's controlled emissions (E) and thus the firm *buys* allowance as part of its compliance with its allocated cap. (Note that an auction represents an extreme case in which all participants are buyers and thus all firms pay for allowances to cover *all* of their controlled emissions.)

The financial impacts on the firm would be different if the firm received an allocation (A) *greater* than its controlled emissions (E); in that case, the firm would be able to sell allowances and thus would gain from the CO_2 allowance sales. In essence, the firm would be in another business – the business of "producing" valuable CO_2 allowances. In this case, the net financial impacts of to the firm would be equal to the control costs it incurs minus the revenues it receives for selling its surplus CO_2 allowances.

B. Overview of Major Initial Allocation Approaches

Clearly the procedures used to allocate the total CO_2 cap would have a major effect on the financial consequences to individual sectors and firms. It is useful to distinguish the following three basic alternatives for initially allocating allowances:

1. ***Auction.*** This alternative would involve the U.S. Government auctioning the allowances initially.
2. ***Grandfather.***[3] Under this alternative, allocations would be provided to participants (or others) based upon historical information. For example, allocations to participants in the trading program could be based upon average emission levels in a recent (e.g., 1997–2002) period.
3. ***Update.*** This alternative involves allocating to participants or others based upon information that is updated over time. For example, allocations in 2015 might be based upon activity in 2010, allocations in 2016 based upon 2011 activity, and so on.

Within the second and third categories, there are many additional choices. There are three basic metrics for the allocations: (1) input-based (e.g., tons of fuel input); (2) output-based (e.g., kilowatt-hours of electricity production); and (3) emission-based (e.g., tonnes of CO_2 emissions). There also are choices regarding the years to use for the allocations (e.g., average of recent years, maximum value within recent years) and which sources receive allocations (e.g., only sources regulated under the cap, or those sources and their customers, suppliers, etc.).

Note that it would be possible to combine the various approaches and, indeed, to shift the mix over time. One possibility that has been widely discussed, for example, would be to begin with grandfathered allocations and then transition to a mix of grandfathered and auctioned allowances until at some later point all allowances would be auctioned.

C. General Effects of Alternative Initial Allocation Approaches

It is useful to group criteria for evaluating alternative allocation approaches into two major sets: (1) efficiency considerations, which relate to cost-effectiveness and other societal effects; and (2) distributional considerations, which relate to how different subgroups would be affected. Table 1 lists various elements within these two categories and summarizes qualitative evaluations of the three major alternative allocation approaches. The table includes circles that provide a five-level ranking from best (solid black) to worst (solid white). The following are conclusions from these evaluations.

1. Evaluations Based on Cost-Effectiveness and Other Efficiency Criteria

- Auctions and grandfathering provide the best incentives to minimize compliance costs – that is, they both encourage GHG goals to be met at least cost – assuming that the allowance market is competitive and that there are no pre-existing distortions in the product market.
- Although firms would be allocated allowances for free under grandfathering, the "opportunity cost" of the allowances (i.e., the fact that the allowance can be sold) means that the costs of emissions would be reflected appropriately in product market prices under either grandfathering or auctions.
- Updating is potentially less efficient than either auctioning or grandfathering. The costs of meeting the cap would be greater under updating because

updating both increases administrative (program management) costs and skews the market away from some potential low-cost GHG emissions-reduction measures. In addition, the incentives created by updating could distort product market prices by keeping them "artificially" low, i.e., not reflecting the full costs of "using" allowances.

- Although neither auctions nor grandfathering generally would create "distortions" in product markets, if the product market were distorted by pre-existing policies—for example, if electricity prices were determined by cost-of service ratemaking rather than competitive markets—grandfathering would not necessarily result in minimizing compliance costs because the proper price signals might not necessarily be set.
- The efficiency gains from "recycling" (i.e., using) auction revenues depend upon whether the revenues are used to reduce existing taxes, or instead used to provide transitional assistance to displaced workers or other worthy causes (or simply distributed directly to households as an "environmental dividend")[4].
- The transactions costs of trading generally would not be affected by the choice of allocation approach. Assuming the allocations are clear—and thus participants know their allocation in advance—whether CO_2 allowances are auctioned, grandfathered or distributed with some updating procedure would not affect the costs of buying and selling.

2. *Evaluations Based on Distributional Effects*

The three alternatives would have very different distributional effects.

- Auctioning is likely to harm participating sectors and provides no "stranded cost" relief to producers, unless revenues are recycled directly to the affected firms. On the other hand, auctions tend to be relatively good for consumers and taxpayers, assuming the revenues are recycled in a way that reduces other forms of taxation.
- Grandfathering helps sectors and provides "stranded cost" relief to producers, but is relatively bad for the sectors' consumers and provides no taxpayer gains.
- Updating is less attractive to controlled sectors than grandfathering because it leads to greater compliance costs and lower price increases than grandfathering. (This price effect is explored in the following section on product market effects.) The sector's consumers could benefit, however, due to the lower price increases.

Key

●	Best
◕	Good
◑	Fair
◔	Poor
○	Worst

Table 1: Comparison of Initial Allocation Alternatives

	Efficiency					Distributional			
Allocation Alternative	Compliance Costs	Administrative Costs	Transaction Costs	Product Market Distortions	Tax Distortions	Sector Burden	Stranded Costs	Consumer/ Labor Effects	Taxpayer Effects
1 Auction[1]	●	◕	◕	●	●	○	○	◕	●
2 Grandfathering[2]	●	◕	◕	●	◔	●	●	◔	○
5 Updating	○	◔	◕	○	○	○	◔	●	○

Notes:
1. Auction revenues are assumed to be recycled so as to reduce taxes and to reduce impacts on the affected labor force.
2. Sectors receiving grandfathered allocations are assumed to be competitive or fully deregulated (e.g. electricity is priced on the basis of marginal cost rather than average embedded cost) and thus that the opportunity costs of allowances are reflected in prices to customers. efficiency and distributional impacts would differ if this assumption were not met.

Source: Derived from David Harrison, Jr. and Daniel Radov, *Evaluation of Alternative Initial Allocation Mechanisms in a European Union Greenhouse Gas Emissions Allowance Trading Scheme*, prepared for DG Environment, European Commission, March 2002.

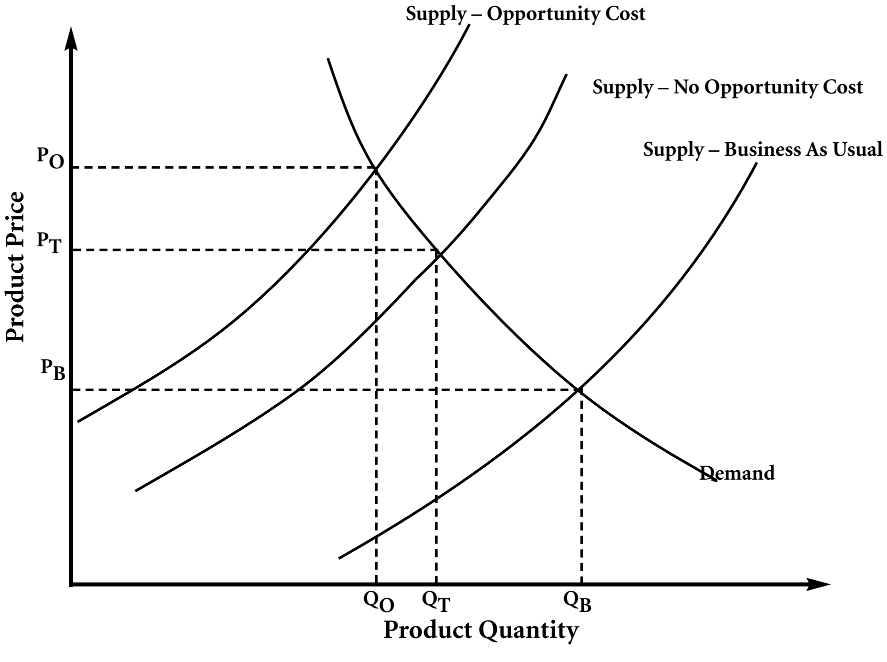
III. Product Market Conditions

The ultimate financial impacts of a U.S. CO_2 cap-and-trade program would also depend upon each firm's product market. In particular, firms and consumers would be affected by two major differences that might exist among product markets:

1. Whether the "opportunity costs" of allowances used to cover CO_2 emissions are reflected in product prices, i.e., passed on to consumers.
2. Whether firms operate in local/national markets, or in international markets largely unaffected by CO_2 concerns.

Figure 2 illustrates how financial impacts on firms and consumers would differ depending upon which cost elements of a CO_2 program would be reflected in product prices. The figure shows initial prices and output levels under "business as usual" conditions, i.e., conditions without a U.S. CO_2 program. Compliance costs to reduce CO_2 emissions will lead to cost increases, which in turn will be reflected in increases in product prices.

Figure 2: Financial Effects for Firms Operating in Local/National Product Markets



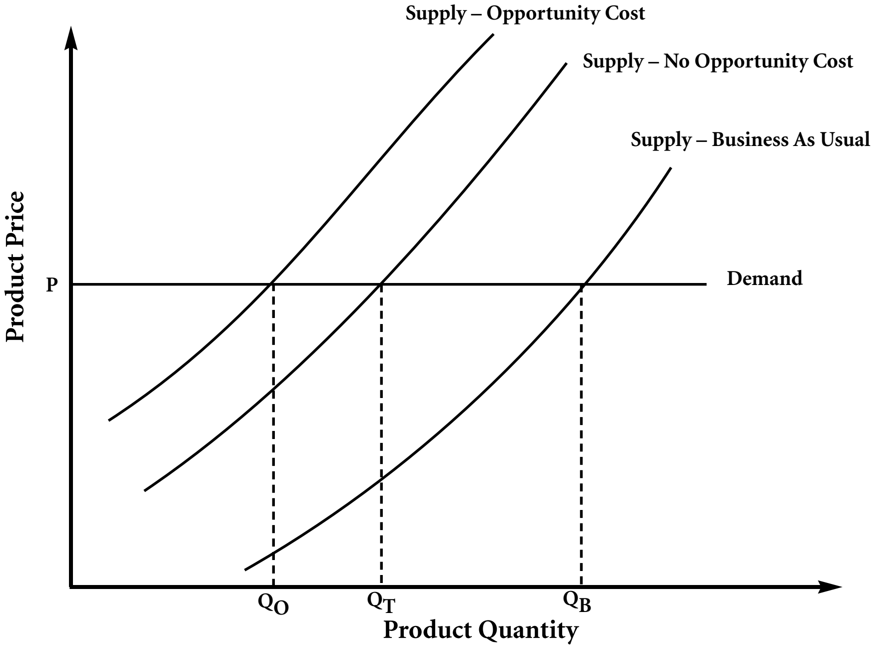
But prices would increase further if prices increase to reflect the fact that firms face a cost when they "use" allowances to cover their remaining CO_2 emissions. In the case of auctioned allowances, these costs are direct; but as noted above, the firm also incurs a cost for using allowances even if it receives the allowances for free. (These costs are referred to as "opportunity costs" because they reflect the opportunity to sell the allowances to other firms, rather than use them.)

Thus, the financial consequences of the CO_2 cap-and-trade program would be different for the firm's shareholders and its consumers depending whether prices reflect "opportunity costs." There are two cases in which the full opportunity costs may not be passed on to customers under a CO_2 cap-and-trade program:

1. ***Regulated prices with grandfathered allocations.*** Firms operating in regulated markets, in which prices are set on the basis of "cost-plus" considerations, may not experience price increases if the "opportunity cost" of grandfathered allowances are not included.
2. ***Updated allocations.*** Under an updating approach, if a firm expanded its output, it also would gain the right to a valuable asset (the right to receive a larger future CO_2 allocation). Thus, the firm would have an incentive to expand current output, resulting in lower product prices.

The financial consequences for firms and consumers also would be affected by the specific market conditions. Of particular interest are firms operating in global markets in which prices are set internationally and where competitors may not face a CO_2 price – examples could include crude oil markets, and to varying degrees the markets for paper, metals, non-metallic building materials and chemicals. In this case, global prices would not necessarily reflect CO_2 compliance costs or opportunity costs. Figure 3 shows the case of a firm operating in an international market with no ability to pass on added costs; in this case, the added costs of CO_2 controls (including the opportunity costs of the use of CO_2 allowances to cover its emissions) would lead only to reductions in output rather than increases in price.

FIGURE 3: FINANCIAL EFFECTS OF CO_2 PROGRAM FOR FIRMS OPERATING IN INTERNATIONAL PRODUCT MARKET



IV. International CO_2 Permit Prices

The financial effects of a U.S. cap-and-trade program would depend importantly on the ability of U.S. participants to trade allowances internationally. International prices for CO_2 allowances would provide an upper limit on the U.S. price – assuming CO_2 allowances in other countries could be purchased by U.S. firms – and thus would limit the overall cost of the program in the U.S. The financial impacts of a possible U.S. CO_2 program thus depend upon the likely international prices for CO_2 allowances, which are highly uncertain. Moreover, although U.S. firms would gain financially as CO_2 allowance buyers from low international prices, the financial effects could be more complicated for firms that would be sellers of CO_2 allowances or that would be recipients of gains from product price increases.

A. Factors Affecting International Prices for CO_2 Allowances

Many factors will influence the likely international CO_2 allowance prices that might be relevant for U.S. firms under a U.S. downstream cap-and-trade program for GHG. These factors include[5]:

- ***Prospects for an international permit market.*** There currently is no single international CO_2 market and there may well be constraints on U.S. participation in the CO_2 markets that are developing (most prominently the European Union Emissions Trading Scheme).[6]
- ***Effects of Russian "hot air" and strategic behavior.*** The Kyoto Protocol gives Russia a critical role with regard to likely international CO_2 prices. In addition to its importance in Kyoto's ratification, the decline in Russia's CO_2 emissions leaves it with substantial "hot air." Russia (and others similarly situated) may withhold CO_2 supply in order to drive the price of CO_2 allowances up.[7]
- ***Availability/cost of potential CDM and sink credits.*** The effective CO_2 price facing U.S. firms would depend upon the cost and availability of credits allowed for in the Kyoto Protocol, particularly the Clean Development Mechanism ("CDM") and sink enhancement.
- ***Level of U.S. cap.*** Given its importance as a source of CO_2 emissions, the level of the U.S. cap (or mandatory CO_2 commitment) will have an important influence on the international demand for CO_2 allowances, and thus on likely international CO_2 prices.

B. Financial Implications of International CO_2 Allowance Prices

Although it is clear that the overall cost of meeting a given U.S. CO_2 cap or commitment would be reduced if U.S. firms had access to potentially lower international CO_2 allowances, the financial impacts could be more complicated for some firms.

- ***Potential sellers under a U.S.-only program.*** Firms that would be net sellers of CO_2 allowances may lose financially if CO_2 prices are lower because of the availability of lower-priced international CO_2 allowances.
- ***Recipients of substantial product price increases.*** Firms that would gain from product price increases linked to CO_2 allowance prices may actually lose financially if CO_2 prices are lower due to lower-prices international CO_2 allowances.

V. Concluding Remarks

These various considerations suggest three general conclusions related to the financial aspects of a downstream cap-and-trade program for U.S. CO_2 and GHG emissions.

1. ***Details matter in assessing financial consequences.*** The financial impacts of such a program on a given firm (or household) will depend upon many specific elements – notably its initial allocation, its opportunities for reducing CO_2 from its facilities, and its opportunities for increasing prices that reflect CO_2 compliance and opportunity costs.
2. ***Most details affect distributional considerations.*** Most of the design elements of a U.S. cap-and-trade program for CO_2 emissions – other than the overall level of the cap – affect the distribution of costs among various groups, rather than the overall costs or administrative feasibility of the program.
3. ***Emissions trading is well suited for controlling CO_2 and other GHG emissions.*** If a decision were made to control U.S. CO_2 emissions, a downstream cap-and-trade program seems well suited as part of the overall program.[8] Such a program could be designed to achieve political feasibility while maximizing environmental effectiveness, cost-effectiveness, administrative feasibility and distributional equity.

Endnotes

1. This paper focuses on financial impacts on firms, because this is often the focus of concerns about political feasibility. Financial impacts on firms ultimately would be translated into impacts on households, both as shareholders and taxpayers (because of the corporate profits tax).

2. The focus on a downstream cap-and-trade approach is due to its prominence in recent policy analyses, including the excellent report that forms the focus for this policy dialog (Robert Nordhaus and Kyle Danish, *Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.*, Pew Center for Global Climate Change, May 2003) and Congressional initiatives (e.g., Mc-Cain-Lieberman) as well as the forthcoming downstream cap-and-trade program being developed for the European Union, the European Union Emissions Trading Scheme ("EU ETS"). Note, however, that although this paper focuses on emissions trading, the framework to assess financial impacts that is developed here can also be applied to taxation approaches; indeed, there are many similarities between a tax approach and emissions trading where emissions allowances are auctioned. This paper draws on the

author's participation in the development of previous emissions trading programs as well as recent work related to the EU ETS, particularly the following documents: David Harrison and Daniel Radov, *Initial Allocation Options for a European Greenhouse Gas Emissions Cap-and-Trade Program*, prepared for the Environment Directorate, European Commission, March 2002; David Harrison, Daniel Radov, et al., *Alternatives for Implementing the UK's National Allocation Plan*, prepared for the UK Department of Environment, Food and Rural Affairs, August 2003.

3. The term "grandfathering" is used to mean the distribution of allowances for free based upon historical information, to distinguish it from the other two forms. Note, however, that "grandfathering" has different meanings in other papers and thus some have avoided its use, distinguishing "free" or "gratis" allocations and "updated" or "non-updated" allocations.

4. There is a rich literature on a possible "double dividend" from the use of auction revenues to reduce distorting taxes. See, for example, Lawrence Goulder, Ian Perry, Robert Williams and Dallas Burtraw, "The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second Best Setting." *Journal of Public Economics*, Vol. 72: 329-360 (1999).

5. Numerous studies consider likely CO_2 prices under various international regimes. For a comprehensive overview of studies evaluating likely prices under the Kyoto Protocol, see John Weyant and Jennifer Hill, "Introduction and Overview," in *The Costs of the Kyoto Protocol: A Multi-Model Evaluation, The Energy Journal, Special Issue*, 1999.

6. The European Union Emissions Trading Scheme ("EU ETS") creates a EU-wide cap-and-trade program for CO_2 emissions and eventually other greenhouse gas emissions. For a brief description of the EU ETS, see David Harrison and Daniel Radov, "Europe Warms to Emissions Trading," *NERA Energy Regulation Brief*, April 2002.

7. Russia's incentive to drive CO_2 prices up, however, would be offset by the adverse effects of higher CO_2 prices on world oil prices, and thus Russia's profits as a major supplier of oil.

8. See A. Denny Ellerman, Paul L. Joskow and David Harrison, Jr., *Emissions Trading in the U.S.: Experience, Lessons and Considerations for Greenhouse Gases*, prepared for the Pew Center on Global Climate Change, May 2003.

THE HYBRID OPTIONS: WHAT IS THE ROLE OF PRODUCT EFFICIENCY STANDARDS UNDER A CAP-AND-TRADE PROGRAM?*

Robert R. Nordhaus

Background

Current federal law includes two major mandatory product efficiency standard programs: one for automobiles, the other for consumer products other than automobiles. Both were established in 1975 under the Energy Policy and Conservation Act (EPCA).[1] Were Congress to enact a cap-and-trade program or other mandatory GHG controls, these product efficiency standards could be retained, modified or eliminated once the mandatory program is implemented. This paper lays out options for integrating these standards with a cap-and-trade program or eliminating them (the "structural options"), describes several mechanisms for accommodating allowance trading between the cap-and-trade sectors and the standards sectors ("intersectoral trading"), and summarizes the cost-effectiveness considerations that may be relevant to choosing different options.

Cap-and-Trade Proposals: As more fully described in the background paper (*Designing a Mandatory Greenhouse Gas Program for the U.S.*[2]) a cap-and-trade program applies either to GHG emitters (in the case of a downstream program) or to sellers of carbon-based fuels (in the case of an upstream program). Tradable allowances would either be allocated to entities impacted by the program or auctioned. The regulated entity would be required to surrender allowances at the end

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of each compliance period equal to its GHG emissions (in the downstream program) or its fuel sales (in the upstream program). A cap-and-trade could apply to the entire economy or to particular sectors.

Existing Product Efficiency Standards: The product efficiency standard program for motor vehicles – known as Corporate Average Fuel Economy or "CAFE" – requires each automobile manufacturer or importer to meet average fuel economy standards for the fleet of new vehicles it manufactures or imports in each model year. These standards are expressed in miles per gallon ("mpg"). Separate, less stringent standards apply for "light-duty trucks" (including sport utility vehicles and minivans) than those that apply to passenger automobiles. The statute applies only to new vehicles and does not regulate in-use consumption of fuel.[3]

The product efficiency program for consumer products other than autos – usually referred to as the "appliance standards program"[4] – includes mandatory energy labeling and energy efficiency standards for a wide range of consumer products, including air conditioners, washers, dryers, kitchen ranges and furnaces. Standards also cover some equipment used in industrial applications, such as industrial motors.[5] The program aims at requiring for each type of consumer product the maximum energy efficiency that is technologically feasible and economically justified. In general, the standards are formulated in terms of either electricity use or fossil fuel use.

An important design issue in any program using product efficiency standards is the inflexibility of conventional product efficiency standards. Conventional product efficiency standards prescribe a uniform emissions limit or technology without regard to the varying circumstances of the regulated firms. Accordingly, reliance on conventional standards would mean forgoing the flexibility benefits of emissions trading. The description of structural options below includes a discussion of means by which "intersectoral trading" (that is, trading between the sectors subject to a cap-and-trade and sectors subject to product standards) can be used to incorporate some of these flexibility benefits into a program that retains product standards.

Also included in the discussion below is a calculation of the CO_2 emissions covered by each option. It is important to note that in these calculations, coverage calculated for certain hybrid options (i.e., those that combine a partial cap-and-trade with standards) is not necessarily equivalent to coverage calculated for an economy-wide cap, because product efficiency standards provide no direct control over in-use emissions. Because of the uncertainty of projections of vehicles miles traveled (VMT) or other measures of intensity of use, actual reductions attributable to product standards may diverge from estimates.

Finally, there are questions of administrative feasibility and political acceptability. These are described in some detail in the background paper, but are not addressed here.[6]

II. Structural Options

Option A: Downstream Sectoral Hybrid

Program design: A downstream sectoral hybrid program would combine a downstream cap-and-trade program for large sources in the electricity and industrial sectors with enhanced product efficiency standards to cover small GHG sources (mainly consumer products and equipment) in the transportation, residential, and building sectors.[7] These standards would regulate energy efficiency or CO_2 emissions of newly-manufactured products used in the transportation sector and in the residential and commercial buildings sector. The key elements of a downstream hybrid program are described in the background paper. (See Box 4 at page 35.)

Coverage: The downstream sectoral hybrid using existing product efficiency standards would cover about 80 percent of CO_2 emissions. It could feasibly cover 95 percent of CO_2 emissions if coverage were expanded to cover commercial building equipment and transportation modes beyond light duty motor vehicles.

Intersectoral Trading: If Option A is chosen, the following alternative approaches can be taken on intersectoral trading:

(i) **Tradable standards** – Tradable standards restore some of the economic benefit that would otherwise be lost by reason of the inflexibility of product efficiency standards. A tradable standards program would use estimates of the average life and use of a product to translate over-compliance with a standard into a stream of emission allowances assigned to particular years.

Conversely, the program would translate a failure to achieve the standard into an annualized deficit of allowances.[8] A tradable standards approach could provide for at least three levels of trading: (1) intra-firm trading, in which a firm could achieve an average level of efficiency across its product lines, instead of being required to meet the standard for each product line; (2) trading among firms subject to standards; and (3) trading between firms subject to standards and firms subject to the cap-and-trade program. However, this last level of trading would be available only to manufacturers of CO_2 emitting products; manufacturers of electric appliances and equipment probably would not be permitted to trade into the cap-and-trade system because of double-counting concerns.

(ii) **Capped tradable standards** – A potential drawback of a tradable standards approach is that it does not ensure that emissions will be limited at any particular level. One way to address this drawback is a capped tradable standards program.[9] Under such an approach, policy-makers would set a cap on the total emissions associated with particular types of newly-manufactured products. To sell products subject to the capped standard, manufacturers would have to obtain and surrender allowances. In other words, it would not be sufficient merely to produce products that met the standard; manufacturers would have to account for the projected emissions associated with each product they sold. A capped tradable standards program would entail resolving a number of design issues, including issues related to allowance allocation, shutdowns, new market entrants, changes in manufacturer market share, and changes in overall level of output.

(iii) **No intersectoral trading** – A hybrid program could also dispense with intersectoral trading entirely. This is the simplest, but most inflexible of the options.

Option B: Upstream Sectoral Hybrid

Program design: Under the upstream sectoral hybrid option, an upstream cap-and-trade program would apply to all distributors of carbon-bearing fuels except to the extent those fuels were used in products subject to efficiency standards. Thus, if product efficiency standards applied to automobiles and consumer products using home heating fuels, then gasoline, home heating oil and residential natural gas would be exempt from upstream allowance requirements. A broader standards program – one that included large trucks and commercial heating equipment – could be linked to broader exclusions from the upstream cap-and-trade program, thus allowing diesel fuel and fuel delivered for use in commercial buildings to be outside the cap-and-trade program.

A variant of this approach would set up a product efficiency standards program, a downstream cap-and-trade for electricity generators and other large stationary sources, and an upstream program applicable to fuel distributed for all uses other than automobile, residential and commercial use and electricity generators.

Coverage: Option B could cover 100 percent of CO_2 emissions.

Intersectoral Trading: Same as for Option A.

Option C: Full Cap-and-Trade, Plus Supplemental Product Efficiency Standards

This hybrid option would layer product efficiency standards on top of the full upstream program, i.e., firms subject to the upstream program would be required to hold allowances for the carbon content of all fuel they distribute to downstream users, even if some of the fuel they deliver is used in products subject to standards.[10] Under this approach the upstream program would have an economy wide cap; the standards would be there to help ensure that efficient products reach the market when consumers need them.

Coverage: Option C could cover 100 percent of CO_2 emissions.

Intersectoral Trading: Because all use of carbon-bearing fuels is covered by the cap-and-trade program, awarding allowances to “overachieving” product manufacturers would result in doublecounting of emissions reductions and arguably undermine the integrity of the cap, absent an offsetting reduction in the cap. Two alternatives are available:

> (i) **No trading** – Manufacturers would not receive allowances for over-compliance, and would not be permitted to remedy under-compliance by purchase of allowances. (This is the approach used in the McCain/Lieberman legislative proposal that the Senate voted on last month.)

(ii) **Trading with cap adjustment** – Manufacturers that over-comply with product efficiency standards are awarded allowances, but an offsetting reduction is made in the allowances allocated to upstream fuel suppliers. (This mechanism was used in the originally introduced version of the McCain/Lieberman legislation in connection with fuel economy standards.)

Option D: Economy-Wide Upstream Cap-and-Trade Program; No Product Efficiency Standards

Program design: Under this option, an economy-wide upstream cap-and-trade program would be implemented and current CAFE and appliance standards programs would be repealed, as no longer necessary or as a political quid pro quo for the imposition of mandatory controls.

Coverage: 100 percent of CO_2 emissions.

Intersectoral Trading: Not applicable.

III. Cost-Effectiveness

Economic studies of the cost-effectiveness or economic efficiency of various GHG regulatory programs have not been at a level of detail that would quantify the differences between the structural options discussed in this paper. However, several observations emerge from these studies: First, the more comprehensive the coverage of a program, the lower the overall economic cost to meet any specific target. Thus, if Option A is limited to existing product efficiency standards, it would cover only 80 percent of U.S. CO_2 emissions, and might be less cost-effective than Options B, C, and D, which could achieve full coverage. Second, a large source cap-and-trade combined with CAFE but without intersectoral trading is a significantly more costly way to attain a particular target than a comprehensive cap-and-trade program alone. However, no analysis has been done of such a program with intersectoral trading. Thus, Option D is likely to be more cost-effective than Option A and B, though intersectoral trading could reduce this cost penalty. Finally, at least one study indicates that a comprehensive cap-and-trade program that retains the current CAFE program is significantly more costly than the cap-and-trade alone. This would indicate that there could be a significant cost penalty associated with Option C as compared to Option D.[11]

Endnotes

1. Energy Policy and Conservation Act of 1975, Pub. L. No. 94-163, 89 Stat. 871 (automobile fuel economy standards are codified as amended at 49 U.S.C. §§ 32,901-32,919 (1994)).

2. Robert R. Nordhaus and Kyle W. Danish, *Designing a Mandatory Greenhouse Gas Program for the U.S.*, Pew Center on Global Climate Change (2003).

3. Compliance with the standard is determined separately for vehicles manufactured in the United States, Canada, or Mexico and those manufactured elsewhere but used in the United States. Special credit is given to electric vehicles and to alternative fuel-capable vehicles.

4. See Energy Policy Conservation Act of 1975, supra note 2, (appliance efficiency standards are codified at 42 U.S.C.A §§6291-6309).

5. For more information on existing energy efficiency standards for commercial and industrial equipment, see *Office of Energy Efficiency and Renewable Technology, U.S. Department of Energy, Building Technolgies Program: Appliances and Commercial Equipment Standards*, available at http://www.eren.doe.gov/buildings/appliance_standards/.

6. See pages 38-41 of the background paper.

7. The Center for Clean Air Policy (CCAP) and the Heinz Center have explored domestic policy designs that would combine a cap-and-trade program with standards for downstream firms. See *CCAP, Options That Include Downstream Sources*, (1998); H. John Heinz Center for Science, Economics, and the Environment, *Designs for Domestic Carbon Emissions Trading* 56-67 (September 1998) (describing "Option III" and "Option IV").

8. For example of tradable standards in the motor vehicle sector, see Box 5, p. 37 of background paper.

9. For descriptions of capped tradable standards approaches, see studies cited in note 8.

10. As used here, the term "consumers subject to standards" encompasses consumers directly subject to standards (e.g., electricity-generators) and consumers using products that are subject to standards (e.g., motorists).

11. A 2002 Congressional Budget Office study assessing options for reducing gasoline consumption concluded that partial coverage of particular sectors would be more expensive than full coverage (under, for example, an upstream cap-and-trade). See *Congressional Budget Office, Reducing Gasoline Consumption. Three Policy Options* (2002), p. 17. Two economists, W. David Montgomery and Anne Smith, have attempted to quantify the costs using various domestic program types to meet a particular national emissions limit. See W. David Montgomery and Anne E. Smith, Charles River Associates, *Interactions Between Domestic Policies and International Permit Trading Regimes* (2000). Montgomery and Smith determined that a pure upstream cap-and-trade program or a carbon tax would result in the lowest social welfare costs. They also found that a program that used standards to limit emissions from certain sectors would result in lower costs than a program that left those sectors entirely unregulated (e.g., a domestic climate policy that relied only on a downstream cap-and-trade program for large sources). They concluded, however, that, a program that relied on conventional standards would be anywhere from 20 to 170 percent more costly than, a pure upstream cap-and-trade program, depending on assumptions about the availability of international trading. While the scenario modeled by Smith and

Montgomery did not involve tradable standards, even a program that relied substantially on tradable standards is likely to be less cost-effective than an upstream cap-and-trade program because of the absence of any incentives to reduce use. A more recent Charles River Associates study reaches similar conclusions. See Smith, Ross & Mongomery, *Implications of Trading Implementation Design for Equity Efficiency Trade-offs in Carbon Permit Allocations* (2002).

INTEGRATING LAND USE, LAND USE CHANGE, AND FORESTRY INTO A MANDATORY NATIONAL GREENHOUSE GAS REDUCTION PROGRAM*

R. Neil Sampson

Introduction

The Nordhaus-Danish paper used as background for the Aspen Dialogue examines three approaches to a mandatory national greenhouse gas reduction program, concluding that two options may be most feasible: a comprehensive upstream cap-and-trade program and a sectoral hybrid program that combines a large-source downstream cap-and-trade program with product efficiency standards. This discussion paper examines policy issues that might arise if land use, land use change, and forestry (LULUCF) practices and projects were incorporated into those options.

LULUCF incorporation into a mandatory national program might take three basically different approaches:

- ***An opt-in market approach***, where emitters can purchase carbon sequestration credits created in LULUCF projects that can help achieve compliance with an emissions cap.
- ***A combination approach*** where opt-in market credits and federal incentives (i.e. subsidies, technical assistance, etc.) are both featured. The market

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credits can help emitters reach individual caps while federal incentives produce sequestration that helps meet national targets, thereby mitigating the reductions needed under the cap program.

- ***A regulatory approach***, where agricultural and forestry producers are brought into the framework of a mandatory economy-wide cap-and-trade program.

The paper focuses on the market and combination approaches, because the regulatory approach would raise exceedingly difficult political and administrative issues. Federal regulation of land use, particularly on private lands, is a politically explosive issue that could reduce the political viability of such a program.

Both the market and combination approaches offer opportunities to expand the political constituency for a national program, take advantage of existing federal and state programs and institutional capacity, achieve targeted GHG reductions, realize many ancillary environmental benefits, and broaden the reach of the national program.

II. Brief Background on LULUCF

With carbon dioxide emissions dominating GHG emissions in the United States, there has been continuing interest in the processes and practices that remove carbon dioxide from the atmosphere and sequester it in stable forms on earth. The most basic process is that of photosynthesis and plant growth, which extracts gaseous carbon dioxide from the air and transforms it into the sugars, cellulose, and other organic compounds that make up plant material and soil organic matter. While much annual plant production is rapidly recycled back to the atmosphere by being eaten, decomposed, or burned within a matter of days or months, some of the carbon compounds are converted into long-lived products such as wood (lasting from decades to centuries in living trees and longer in stable wood products) and soil organic matter (which lasts from a few years to millennia).

Widespread opportunities for increasing carbon sequestration exist in agriculture, where changes in management practices such as reduced tillage or improved crop rotations and nutrient management can build and maintain new carbon stocks in agricultural soils. In forestry, management changes can increase forest growth rates, and extend forest management cycles to produce larger timbers that remain in use longer than the smaller products of young trees. Changes in land use, primarily the conversion of marginal croplands to grass or trees, can provide lasting soil and water conservation benefits as well as carbon sequestration. Growing energy crops such as switchgrass or short-rotation woody crops results, in addition, in industrial feedstocks that can replace fossil fuels.

In addition to carbon sequestration or emission reduction, some LULUCF activities affect other greenhouse gases. Methane is produced by ruminant livestock and manure decomposition, and its emission can be reduced by herd and grazing management, livestock feeding practices, and manure digestors that produce and capture methane for energy production. Nitrous oxide, while a potent GHG emitted from agricultural soil management activities, is difficult to measure or monitor under field conditions, and the scientific uncertainty around the effectiveness of various activities in reducing N_2O emissions may prevent it from being a candidate for inclusion in a national program, at least until more is known about its management.

National policies have recently added carbon sequestration as a purpose in federal conservation and forestry programs like EQIP (Environmental Quality Incentives Program) and FLEP (Forest Land Enhancement Program), administered by the Department of Agriculture. The new program enhancements contained in the Farm Security Act of 2002 (PL 107-171) are now being implemented in the field by USDA agencies. While it is too early to judge results, these efforts build experience in carbon sequestration and add administrative capacity for future national efforts.

In February 2002, President Bush challenged the Department of Energy to develop improvements in the voluntary greenhouse gas reporting system under Section 1605(b) of the Energy Policy Act of 1992. At the same time, the President directed the Secretary of Agriculture, in consultation with DOE and EPA, to develop rules and guidelines for carbon sequestration projects. Drafting is under way, with the target of a new and expanded 1605(b) registry in early 2004. That registry can become a critical component of incorporating LULUCF in a national GHG reduction program.

The prospect of including LULUCF activities as an option in mandatory national or international emissions reduction programs has raised issues that need to be addressed. With the exception of saturation and permanence, these issues are not unique to LULUCF. They include:

- ***Additionality.*** To reduce atmospheric CO_2 levels, the carbon sequestered must be additional to what exists or, under some interpretations, to would have occurred without the practice or project. Different ways of approaching this issue have been proposed, based on the requirements of the program. They include:
  - If the national program requires LULUCF practices to reflect the gains as additional to what would have happened under a "business-as-usual" scenario, it will be necessary to predict future conditions without the project activity. This requires modeling or other methods to construct a logical scenario. This is often called an "absolute quantity" requirement.
  - If the national program requires LULUCF practices to demonstrate increased carbon compared to the existing soil or forest system, an initial measurement (or "baseline") can be established, and future measurements will reflect the additional carbon in the system. The latter method relies on measurements rather than on modeling future events, so will generally enjoy greater credibility.
- ***Leakage.*** The sequestration activity should not result in the shifting of carbon-emitting activities to other lands. Where this occurs, the credit given to the activity should be reduced to reflect a more accurate net impact on the global environment.
- ***Saturation.*** There are limits to the amount of carbon that can be stored sustainably in soil or forest systems. Thus, carbon can be sequestered only until the system "saturates," at which point carbon stocks can be sustained, but additional sequestration will be limited. Depending on the initial carbon condition of the system, the climate, and the practices involved, these time periods range from a few to over 100 years (See Table 1).
- ***Permanence.*** Because the carbon stored in woody vegetation and soils can be re-emitted through changes in management or natural disasters such as wildfires, the accounting system needs to calculate the value of carbon sequestered over different time periods, and/or provide for appropriate debiting of premature losses or emissions.

- ***Monitoring and Verification.*** Credible monitoring and third-party verification can assure both buyers and regulators that claimed amounts of sequestered carbon are, in fact, legitimate. Available scientific methods produce credible results for modest costs.
- ***Measurement and Transparency.*** Because the amount of carbon credits claimed as emission mitigation represents the difference between what is produced and a baseline scenario, prevention of abuse requires that assumptions and calculations be transparent and available for review by observers, buyers, regulators, and independent auditors.

These issues have been widely researched, debated, and analyzed in the literature. The extent to which they will need attention in any future mandatory national program depends largely on how comprehensively they are addressed in the forthcoming 1605(b) enhancements and the associated USDA and DOE policies. That will not be known for a few months, until the enhancements have been finalized and tested. In any case, it seems reasonable to allow time to demonstrate their capacity before moving to new approaches.

III. Incorporating Market-based LULUCF Projects into a Cap-and-Trade System

Policies seeking to incorporate LULUCF into a cap-and-trade system will need to provide for flexible means of meeting the cap, as discussed in the background paper. If regulated firms can choose least-cost options for meeting their target, and purchasing allowances from LULUCF projects is an option, the stage will be set. Such inclusion may raise some policy issues for consideration, such as:

Will allowing regulated firms to purchase carbon credits from LULUCF projects reduce the environmental effect of the national program? This does not appear to be a problem if the construction of national targets and the rules on additionality (see above) are consistent. This can be achieved by taking the on-going and natural changes in agricultural soils and forest growth into account as part of the national target-setting exercise. If that is done, any project changes will reflect real environmental gains against the target.

Will additional administrative or institutional capacity be required if LULUCF credits are incorporated into a national cap-and-trade program? Some additional capacity may be required, but it appears that today's agencies and programs can do most, if not all, that is needed. The capacity includes:

- The enhanced 1605(b) program and agency guidelines. It is too early to tell if these will provide the necessary capacity, but that is clearly the policy intent.
- USDA, state, and local agencies can provide technical assistance to landowners so that project plans and practices meet national criteria. (Budgets constrain, however.)
- Emerging private organizations can create market opportunities (such as trading exchanges) and accumulator services (to assemble projects into "portfolios" that provide sufficient quantities to appeal to regulated firms and increase stability due to the diversity of projects and risks within each portfolio). Organizations such as the Chicago Climate Exchange, CO_2e, the National Carbon Offset Coalition, and others are working in these areas. Many credible consulting firms are capable of doing monitoring and verification.

Thus most, if not all, of the needed pieces for a national program to supply carbon credits on a market exchange are now in operation, at least in fledgling stage. What are not available are potential buyers. A mandatory cap-and-trade program could create such buyers, and the emerging market would then establish real experience in supply, demand, and price. Until that market is established, estimates as to how effectively market-based LULUCF projects could contribute to national goals, or where they would fit in the emerging spectrum of approaches to reducing GHG emissions, are largely speculative.

IV. Incorporating LULUCF into a Hybrid Program

While the role of LULUCF projects in the cap-and-trade portion of a hybrid program could be the same as described above, it is possible to supplement projects with non-regulatory programs such as those contained in the 2002 Farm Bill.

Under this scenario, the national reduction goal could be addressed by three related efforts: 1) a downstream cap-and-trade program for large sources in the electricity and industrial sectors; 2) enhanced product efficiency standards for small GHG sources; and 3) expanded national efforts to increase carbon sequestration and renewable energy production on agricultural and forest lands.

Increasing USDA focus on expanding carbon sequestration and renewable energy production would have several effects, including:

- It would offer landowners a wider range of choice. They could establish and maintain practices such as reduced cultivation and accept a modest per-acre cost-share payment that would be based on a conservative estimate of carbon impact.
- If they desired, landowners could go beyond the federal program and install more intensive practices under a project plan, undertake the necessary measurements, monitoring, and legal transfers, and sell credits into a trading system. This has raised some charges of "double-payment" where a landowner receives cost-sharing for a water quality or erosion control practice, then sells the associated carbon credits on the market. Current USDA policy, however, maintains that the amount of cost-share reflects only the public conservation benefits and is not intended to cover carbon values. Current payment rates are clearly inadequate to cover the costs of installing the monitoring, verification, and legal transfers involved in qualifying a project-based carbon credit.
- It could bring a broader political constituency into the development of the national program. If a national GHG reduction program threatens higher energy costs for agriculture and forest producers but also offers new income opportunities for them, they might support the tradeoff.
- It would strengthen sustainability and environmental performance in the rural sector.

TABLE 1. POTENTIAL EFFECT OF SELECTED CONSERVATION PRACTICES ON CARBON SEQUESTRATION OR EMISSIONS REDUCTIONS

Conservation Practice	Potential GHG Effect (tC/ac/yr)*	Duration of carbon sequestration before saturation (assumes continuity)
Improved Cropping Systems	0.04 to 0.12	15–50 years (depends on initial condition as well as crops, inputs & climate)
Cropland to Grassland	0.03 to 0.45	10–25 years (same as above)
Intercropping	0.1 to 0.4 (?)	Not estimated
Conservation Tillage	0.15 to 0.25	5–15 years (same as above)
Windbreaks & Shelterbelts	0.25 to 0.7	30–70 years
Improved Forest Management	0.1 to 1.4	If wood products are included, saturation may not occur; otherwise 20-100 years.
Energy Crops	1.3 to 1.5	If grown sustainably and used to offset fossil energy, saturation should not occur.
Riparian Forest Buffers	1 to 3 (?)	50–100 years
Cropland to Forest	0.5 to 2.6	50–100 years
Drainage, Wetland Restoration	????	Not estimated
Improved Fire Management (emissions reduction)	????	Not estimated

Sources: Lal et al. 1998; Kimble et al. 2002; Sampson et al. 2000

* Any associated changes in inorganic carbon compounds or emissions of methane or nitrous oxide are not included.

(?) – Indicates that these practices have little research in the U.S. upon which to make estimates.

???? – Indicates that these practices may have both positive and negative effects on GHG balances.

V. Potential Impact of Including LULUCF in a Mandatory National GHG Reduction Program

As noted above, until there are serious buyers in a GHG trading market, it is difficult to estimate the market share that could be filled by LULUCF practices and projects. At the same time, there is little doubt that the potential in improving land management practices in agriculture and forestry is significant. U.S cropland soils currently sequester about 20 million metric tons of carbon (MMTC) per year and have an estimated potential to sequester 60-150 MMTC more (Pew Center (undated)). Kimble et al. (2002) estimate that forest soils (both public and private) could, under a variety of management and land conversion practices, sequester from 49 to 186 million metric tons of carbon per year, while the amount of carbon sequestered in wood would be four to six times as much as that sequestered in the soil. From a national point of view, achieving any significant amount of this potential could make a major contribution to greenhouse gas mitigation. In terms of individual practices, Table 1 illustrates the potential of different agricultural and forestry activities to sequester carbon.

Some other potential impacts include:

- ***Enhanced environmental quality.*** Improving agricultural and forest lands through well-designed carbon sequestration activities has the effect of improving soil quality, increasing vegetative cover, reducing soil erosion and downstream water pollution as well as air pollution, and improving wildlife habitat. Those benefits accrue largely to the public rather than to the landowner.
- ***Contributing to rural sustainability.*** Private landowners need revenue to support agricultural or forestry businesses. Where markets are lacking, or prices too low, those businesses fail and the land, in many cases, is converted to development. As rural businesses fail, supporting infrastructure shrinks, putting added pressure on remaining farms and forests. If carbon sequestration or renewable energy can provide new revenue streams, they may help retain rural landscapes and economies.
- ***Buffering cost inflation in the national program.*** While there is not enough experience in marketing LULUCF carbon credits to provide solid evidence, experience to date suggests that the combination of establishment and maintenance costs to the landowner, the transaction costs needed to measure, monitor, verify, and register project credits for the market, and the trading costs incurred will produce an entry level price of something in the range of \$2.50 to \$5.00 per tonne of CO_2 sequestered. If that is true, regulated firms should adopt technological and efficiency improvements until the entry costs are reached. Once prices draw LULUCF credits into the market, however, there appears to be a large potential supply. If that is the case, prices could stabilize somewhere around the market entry price (\$2.50-\$5.00 per tonne) for those credits.

- ***Increasing political complexity.*** Incorporating LULUCF projects as an option in a national mandatory program will involve different Congressional committees, different federal Departments, and different political constituencies. While that could broaden support for a comprehensive program, it could also make it more difficult to achieve policy consensus.

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LINKING A U.S. FEDERAL CLIMATE PROGRAM WITH INTERNATIONAL AND SUB-FEDERAL CLIMATE PROGRAMS*

Kyle W. Danish

Introduction

A key consideration in developing a federal mandatory greenhouse gas (GHG) reduction program is the compatibility of that program with: (1) climate programs in other countries and (2) with pre-existing U.S. local, state, or regional (hereinafter "sub-federal") programs.

Promoting compatibility of a U.S. climate program with programs in other countries is critical for a number of reasons. In the near-term, establishing at least some links between a U.S. program and other countries' programs could allow firms regulated in the U.S. to take advantage of a global emissions trading market. Numerous studies suggest global emissions trading would result in dramatic cost savings. In addition, program linkage could be particularly valuable for companies with facilities in many countries; such multi-national companies would benefit from compatible regulatory frameworks and the ability to shift emission reduction credits among their various entities.

Overall compatibility will be even more important over the long-term. No country acting alone will be able to achieve the emission reductions needed to

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* Kyle W. Danish is an Associate at Van Ness Feldman, P.C., Washington, D.C. This paper draws some parts of its analysis from Daniel Bodansky, "Linking U.S. and International Climate Change Strategies," Pew Center on Global Climate Change (April 2002). See also Erik Haites and Fiona Mullins, "Linking Greenhouse Gas Emission Trading Systems," International Emissions Trading Association, International Energy Association, and EPRI (October 2002).

meet the ultimate objective of stabilizing atmospheric concentrations of greenhouse gases at non-dangerous levels. Some cooperation among major emitters eventually will be necessary. If a U.S. program diverges substantially from other countries' programs from the beginning, it will be more difficult to achieve needed levels of cooperation over the long-term.

The importance of compatibility between a federal program and sub-federal programs comes from the fact that a number of sub-federal programs are in existence or under development. Designing a federal program in such a way as to integrate pre-existing sub-federal programs will lower overall compliance costs and increase political acceptability.

What follows is a review of emerging international and sub-federal climate programs and an analysis of key design considerations in integrating a US federal program with those programs. This paper assumes that the US program is based, at least in part, on an emissions trading system.

II. COMPATIBILITY WITH FOREIGN PROGRAMS

A. Existing and Emerging International Programs

Currently, most industrialized countries are preparing for compliance with the Kyoto Protocol. Canada and Japan are both working on domestic programs that are likely to involve emissions trading at least to some extent. In addition, the European Union has committed to the establishment of an EU-wide Emissions Trading System ("EU ETS"). The first phase of the program will run from 2005-2007 and cover five sectors, comprising 12-14,000 installations. The EU also is working on a directive authorizing regulated entities to use permits acquired from non-EU countries through the Kyoto "flexibility mechanisms" – i.e., Joint Implementation and the Clean Development Mechanism ("CDM").

Developing countries are not subject to emissions limits under the Kyoto Protocol. However, a number of developing country and Eastern European governments are preparing Joint Implementation and CDM projects.

The Kyoto Protocol cannot enter into force under international law without ratification by Russia. Currently, Russia's ratification is in doubt. Even if the Kyoto

Protocol fails to enter into force, however, it seems practically certain that many countries will move forward with climate programs. With or without the Protocol, linking the various national and regional programs with one another – and with a possible future U.S. program – will present significant policy challenges.

B. "Informal" Trading Between a US Program and Foreign Climate Programs

In their current forms, the Kyoto Protocol and the EU ETS are silent on trading with non-party countries. Assuming that, in the short-term, it is not likely that these programs will be amended in such a way as to formally integrate a U.S. program, are there nevertheless options for trading between these programs and a U.S. program?

Purchases of Foreign Reductions by U.S. Firms. Nothing in the Kyoto Protocol or in the EU Emissions Trading System prohibits sales of Kyoto or EU permits[1] to non-parties. A U.S. federal climate program could allow regulated firms to purchase permits from other countries and use them for compliance purposes in the U.S. program. Formal links with the other programs would not be necessary. If the U.S. program were more stringent than other programs or if mitigation costs were lower in other countries, U.S. firms could benefit from purchasing the rights to less expensive reductions outside our borders.

In addition, the U.S. program could have a mechanism that would certify and award permits for emission reduction projects financed by U.S. firms in countries not subject to emissions limits under the Kyoto or EU programs (i.e., developing countries and Eastern European countries.)

The U.S. program would have to address the risk of "double-counting," i.e., the risk that the same permit would be used for compliance purposes in the U.S. program and in the foreign program from which it was acquired. To address this risk, the U.S. program could require evidence that the foreign permit has been "cancelled" in the other program. For example, under the Kyoto Protocol, a government or company could sell rights to some of its Kyoto permits to a U.S. firm by putting those permits into its "cancellation account" – thereby taking them out of circulation in the Kyoto system. The U.S. firm then could provide the U.S. government with evidence that it has acquired the rights to the cancelled Kyoto permits.

Sales of U.S. Permits to Foreign Firms. Some firms subject to a U.S. climate program will generate surplus permits and might want to sell those permits to foreign buyers. However, in their current form, neither the Kyoto Protocol nor the EU Emissions Trading System allows permits from non-Kyoto countries to be used for compliance.

Short of an amendment, are there ways in U.S. firms could sell their surplus permits to foreign buyers in programs that do not recognize U.S. permits? One option would be to establish a mechanism that would allow trades between the U.S. and foreign program, while ensuring that the net flow of permits from the foreign program to the U.S. is positive. An example of such a "gateway" can be found in the United Kingdom's trading program. In the U.K. program, some firms are subject to a quantity-based emissions target (referred to an "Absolute" target) and some firms are subject to an intensity target (referred to as a "Relative" target.) Trades between the two sectors are regulated by the gateway. The gateway will not 'open' to a trade from the Relative to the Absolute Sector unless and until it is matched by at least an equivalent transfer going the other direction.

C. Linking National Programs Into an Integrated Global Market

The above informal strategies could be useful in the shorter term, during which amendments to the Kyoto Protocol or the EU Emissions Trading System might not be feasible. Over time, however, there could be more opportunity for and greater interest in designing national programs to promote formal linkages. A truly integrated global emissions trading market would offer far greater efficiencies than could be obtained through informal and relatively constrained cross-program trading.

As discussed in the Nordhaus/Danish paper, establishing a national emissions trading program involves quite a number of design issues. By contrast, relatively few design elements must be coordinated to link different emissions trading programs. These include: (1) commonly-defined permits and (2) compatible systems for tracking trades of the commodity between programs. For certain other design elements, coordination is not required but is likely to be desirable because of environmental, economic, and equity implications. These elements are: (1) comparably stringent emissions targets; (2) comparably rigorous emissions monitoring and reporting systems; and (3) comparably stringent compliance systems.[2]

- ***Commonly-defined permits.*** In order to have trading between one or more programs, it is necessary to have one or more commonly-defined permits. For example, the linked programs could transact in a permit that authorizes emission of one ton of carbon dioxide-equivalent greenhouse gases. By contrast, if Country A establishes permits in such "absolute" terms while Country B establishes permits in terms of emissions per unit output (i.e., an "intensity" or "indexed" target), the permits issued under the two programs would not be fully interchangeable.
- ***Compatible Systems for Tracking Trades.*** Another necessary element of an integrated international system is compatibility between each country's registry for tracking holdings and transfers of permits. Inter-linked registries help avoid the problem of "double-counting" discussed above.
- ***Comparably Stringent Emissions Targets.*** In theory, so long as two countries have programs with commonly-defined permits and compatible tracking systems, there are no concrete obstacles to linkage. However, it is unlikely that Country A will support linkage with Country B if Country B's program is substantially less stringent than that of Country A. One reason for reluctance could be concerns about environmental effectiveness. However, equity might also be concern. Linkage could result in a substantial outflow of funds from Country A to Country B as firms subject to Country A's more stringent controls purchase surplus permits from firms that find themselves easily over-complying with Country B's relatively less stringent program.
- ***Comparably Rigorous GHG Emissions Monitoring and Reporting Systems.*** Again, comparability of monitoring and reporting systems is not required for linkage. However, if Country A perceives Country B's systems to be unreliable or inadequate, Country A might be reluctant to pursue integration.
- ***Comparably Stringent Compliance Systems.*** Similarly, Country A and Country B could have compatible systems and comparably stringent emissions targets – however, if Country A has a much stronger compliance regime than Country B, Country A might determine that integration is unjustified on environmental or equitable grounds.

III. Compatibility with Sub-Federal Programs

A. Existing and Emerging Sub-Federal Programs

A number of states, localities, and regions are developing their own climate policies. Many of these policies are taking the form of incentive programs or voluntary emissions reporting registries. However, in some cases, governments are developing mandatory reduction programs. For example, the states of Massachusetts, New Hampshire, Oregon, and the city of Seattle have established regulatory limits on carbon dioxide emissions by power plants. In addition, the State of California has passed a law directing its air regulatory agency to promulgate limits on carbon dioxide emissions by motor vehicles.

Work also has begun on a greenhouse gas cap-and-trade program for the Northeast. The governors of New York, Connecticut, Vermont, New Hampshire, Delaware, Maine, New Jersey, Pennsylvania, Massachusetts and Rhode Island have agreed to develop a regional program by April 2005.

These programs reflect a range of approaches to emissions targets, including both "absolute" or "quantity-based" targets and "indexed" or "intensity" targets.[3] In addition, each of these regulatory programs also contemplates that regulated firms will be able to meet their obligations at least in part through emissions trading.

B. Integrating Sub-Federal Programs: Issues and Options

There are precedents for integrating a pre-existing sub-federal program into a federal program. One example is the Ozone Transport Commission program, which was developed by states in the Northeast and later folded into the federal NOx SIP Call program. In general, relatively seamless integration of pre-existing sub-federal programs into a federal program has the benefits of making the federal program more politically acceptable, lowering its administrative costs, and reducing its impact on the economy.

Possible integration policies include: (1) authorizing, if feasible, the use of banked permits from the sub-federal program in the federal program; (2) ensuring that firms that already have made reductions under the sub-federal program are not penalized under the new federal program; and (3) evaluating the possibility of awarding "credit for early action" to firms regulated under the sub-federal program. This is not an exhaustive list.

Use of Banked Sub-Federal Permits in Federal Program. Because most of the existing and emerging sub-federal programs contemplate emissions trading, one option would be to allow firms regulated under those programs to use their surplus permits in the federal program. Allowing use of sub-federal permits in the federal program would increase the political acceptability of the federal program to those firms. In addition, if the regulated firms have sufficient advance notice, they would be more likely to develop a cost-effective compliance plan.

This policy option raises some of the same issues discussed above in relation to the integration of different national programs, e.g., interchangeability of permits. If the federal program issues permits based on "absolute" targets, it might be infeasible for the program to recognize sub-federal permits based on "intensity" targets, absent the development of some acceptable conversion process.

In addition, policy-makers would have to take into account the relative stringency of the pre-existing program(s). If the new federal program were flooded with surplus permits from pre-existing program(s), the effect could be a deflation of the federal program's emissions objective. In addition, the policy might be perceived inequitable; some might conclude that the policy actually affords firms regulated under the less stringent pre-existing program an unearned advantage.

Baseline Protection. An important integration consideration is ensuring that firms regulated under pre-existing programs are not penalized for implementing early reductions. This could happen if the federal program established a cap-and-trade system and allocated allowances to regulated firms on the basis of their emissions in a year after the year that the sub-federal program imposed emission limits. Under such a scenario, firms regulated under the sub-federal program would receive fewer allowances than they would have if they had not been subject to regulation.

There are number of means by which the federal program could avoid this result (and still incorporate emissions trading). First, it could set a baseline year that pre-dates the start of the pre-existing program. Second, it could set a different baseline just for the firms subject to the pre-existing program. Alternatively, it could allocate allowances by a method unrelated to historic emissions levels, e.g., through an auction.

Credit for Early Action. Another option for treatment of firms regulated under pre-existing sub-federal programs is not only to afford them baseline protection but also to provide them credit for their reductions. However, credit for early action is a concept usually discussed as a means of encouraging companies to undertake voluntary action – i.e., the credit is there to induce reductions that would not otherwise occur under business-as-usual circumstances.[4] In this case, however, the firms would have implemented the reductions because they were required to do so.

Integrating Co-Existing Sub-Federal Programs. The above discussion focuses on the case of a sub-federal program that sunsets prior to the establishment of the federal program. Some states, however, might be interested in implementing a climate program that co-exists with the federal program, e.g., a state program that imposes deeper emission reduction requirements. If the state program regulates the same firms regulated by the federal program, and the federal program involves an emissions trading system, it is not likely that the state program could lead to additional emission reductions in the aggregate. The reason is that firms forced to achieve additional reductions under the state program would thereby generate additional allowances under the federal program. The firms could trade these allowances to firms in other states, allowing them to increase their emissions. On the other hand, if the state program regulates firms outside the coverage of the federal program, it might generate emissions reductions that would not otherwise occur under the federal program.

Endnotes

1. For purposes of convenience, the term "permits" is used hereafter to refer to the range of permits, allowances, credits, or other rights that could be established in a climate program.

2. Certain other elements are important in the design of a domestic emissions trading program, but need not be coordinated in order to link programs, including: (1) whether to regulate upstream or downstream; (2) allowance allocation methods; and (3) coverage respecting sectors and gases. Note, however, that a country's choice of allowance allocation methods could create competitiveness issues that might present political obstacles to linkage – for example, if a country opted to use allowance allocations essentially to subsidize an industry that competes in a global market.

3. For example, both Massachusetts and New Hampshire have programs that limit CO_2 emissions by in-state power plants and allow trading. However, the target for the Massachusetts program is an indexed target (1800lbs CO_2/MWh), while the target for the New Hampshire program is an absolute or quantity-based target (return to 1990 emissions levels).

4. For an introduction to the concept of credit for early action and analysis of different options, see Robert R. Nordhaus and Stephen C. Fotis, "Early Action Crediting and Climate Change: an Analysis of Early Action Crediting Proposals," Pew Center on Global Climate Change (1999).

U.S. TECHNOLOGY AND INNOVATION POLICIES: LESSONS FOR CLIMATE CHANGE*

John A. Alic, David C. Mowery, and Edward S. Rubin

FOREWORD

Eileen Claussen, President, Pew Center on Global Climate Change

New technologies for electric power generation, transportation, industry, and consumer products are expected to play a major role in efforts to reduce the greenhouse gas (GHG) emissions that contribute to global climate change. Yet technological change on this scale cannot happen overnight. Government policies will be instrumental in encouraging more rapid development and adoption of technology. In the United States—long a leader in innovation—well-crafted policies that encourage the development, deployment, and diffusion of new technologies will be essential complements to other GHG-reduction policies.

The Pew Center commissioned this report to examine U.S. experience with technology and innovation policies—both successes and failures—and to draw lessons for future applications, including efforts to address climate change. The authors found that because innovation is a complex, iterative process, different policy tools can be employed as catalysts at various phases (e.g., invention, adoption, diffusion). They also discuss the roles that intellectual property protection and

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regulatory policies play in driving innovation, and examine programs such as the Defense Advanced Research Project Agency (an innovative force in information technology), as well as public-private collaborations such as the Partnership for a New Generation of Vehicles, to glean lessons for climate change policy. The insights revealed are clear:

- A balanced policy portfolio must support not only R&D, but also promote diffusion of knowledge and deployment of new technologies: R&D, by itself, is not enough.
- Support for education and training should supplement research funding.
- "Non-technology policies" provide critical signposts for prospective innovators by indicating technological directions likely to be favored by future markets.
- Policy-makers should channel funds for technology development and diffusion through multiple agencies and programs, because competition contributes to policy success.
- Public-private partnerships can foster helpful, ongoing collaborations.
- Effective programs require insulation from short-term political pressures.
- Policy-makers must be prepared to tolerate some "failures" (i.e., investments that do not pay off), and learn from them as private sector entrepreneurs do.
- In light of the inherent uncertainty in innovation processes, government policies should generally support a suite of options rather than a specific technology or design.

Technology policies, while important, cannot by themselves achieve the GHG reductions necessary to mitigate climate change. Rather, they should be part of a comprehensive approach that includes "non-technology policies," such as a GHG cap-and-trade program. The authors and the Pew Center thank Bob Friedman, Ken Flamm, David Hart, and Ev Ehrlich for commenting on previous report drafts.

EXECUTIVE SUMMARY

Large-scale reductions in the greenhouse gases (GHGs) that contribute to global climate change can only be achieved through widespread development and adoption of new technologies. In the United States, energy consumption is the dominant source of GHG emissions. Most of these emissions consist of carbon dioxide (CO_2), which accounts for approximately 84 percent of total GHG emissions. Although other GHGs, such as methane (CH4), have a more powerful effect on global warming per unit of release, CO_2 enters the atmosphere in far greater quantities because it is produced whenever fossil fuels are burned. Thus the technological innovations needed to reduce GHG emissions and eventually stabilize GHG concentrations in the atmosphere are those that can, at reasonable cost: (1) improve the efficiency of energy conversion and utilization so as to reduce the demand for energy; (2) replace high-carbon fossil fuels such as coal and petroleum with lower-carbon or zero-carbon alternatives, such as natural gas, nuclear, and renewable energy (e.g., wind and solar); (3) capture and sequester the CO_2 from fossil fuels before (or after) it enters the atmosphere; and (4) reduce emissions of GHGs other than CO_2 that have significant impacts on global warming.

Although innovation cannot be planned or programmed, and most innovations come from private firms, government policies of many types influence the rate and direction of technological change. This report identifies technology policy tools that have fostered innovation in the past (see summary table below) and draws lessons for GHG abatement. It also briefly discusses other measures such as environmental regulations that would serve to induce innovation.

A Summary of Technology Policy Tools

Direct Government Funding of Research and Development (R&D)

- R&D contracts with private firms (fully-funded or cost-shared).
- R&D contracts and grants with universities.
- Intramural R&D conducted in government laboratories.
- R&D contracts with industry-led consortia or collaborations among two or more of the actors above.

Direct or Indirect Support for Commercialization and Production; Indirect Support for Development

- Patent protection.
- R&D tax credits.
- Tax credits or production subsidies for firms bringing new technologies to market.
- Tax credits or rebates for purchasers of new technologies.
- Government procurement.
- Demonstration projects.

Support for Learning and Diffusion of Knowledge and Technology

- Education and training (technicians, engineers, and scientists; business decision-makers; consumers).
- Codification and diffusion of technical knowledge (screening, interpretation, and validation of R&D results; support for databases).
- Technical standard-setting.*
- Technology and/or industrial extension services.
- Publicity, persuasion, and consumer information (including awards, media campaigns, etc.).

The key lessons of this analysis are supported by a large body of literature in economics and other fields concerning the innovation process, and include the following:

- ***Technological innovation is a complex process involving invention, development, adoption, learning, and diffusion of technology into the marketplace.*** The process is highly iterative, and different policies influence outcomes at different stages.
- ***Gains from new technologies are realized only with widespread adoption, a process that takes considerable time and typically depends on a lengthy sequence of incremental improvements that enhance performance and***

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* Refers only to standards intended to ensure commonality (e.g., driving cycles for comparing automobile fuel economy), or compatibility (e.g., connectors for charging electric vehicle batteries), not to regulatory standards.

reduce costs. For example, several decades passed before gas turbines derived from military jet engines improved in efficiency and reliability to the point that they were cost-effective for electric power generation. Today, gas turbines are the leading technology for new, high-efficiency power plants with low GHG emissions.

- ***Technological learning is the essential step that paces adoption and diffusion. "Learning-by-doing" contributes to reductions in production costs.*** Adopters of new technology contribute to ongoing innovation through "learning-by-using." Widespread adoption accelerates the incremental improvements from learning by both users and producers, further speeding adoption and diffusion.
- ***Technological innovation is a highly uncertain process.*** Because pathways of development cannot be predicted, government policies should support a portfolio of options, rather than a particular technology or design.

Government policies influence technological change at all stages in the innovation process. Lessons learned from U.S. experience with technology policies over the past several decades include the following:

- ***Federal investments contribute to innovation not only through R&D but also through "downstream" adoption and learning.*** Government procurement of jet engines, for example, accelerated the development of gas turbines by providing a (military) market that allowed users and producers to gain experience and learn by using. Likewise, in the early years of computing, defense agencies made indispensable contributions to a technological infrastructure that propelled the industry's rise to global dominance.
- Public-private R&D partnerships have become politically popular because they leverage government funds and promote inter-firm collaboration. ***Partnerships may have particular advantages in fostering vertical collaborations, such as those between suppliers and consumers of energy.***
- Adoption of innovations that originate outside a firm or industry often requires substantial internal investments in R&D and human resources. ***Smaller firms may be less able to absorb innovations without government assistance.***
- Just as competition in markets helps resolve uncertainties and improves economic performance, ***competition within government can improve performance in fostering innovation.*** The messy and often duplicative

structure of U.S. R&D support and related policies creates diversity and pluralism, fostering innovation by encouraging the exploration of many technological alternatives.

- Because processes of innovation and adoption are lengthy and convoluted, ***effective policies and programs require insulation from short-term political pressures.*** Reliable political constituencies have been essential for the development of new technologies in defense, for research in the biomedical sciences, and for agricultural and manufacturing extension. By contrast, technology policies for addressing climate change face a discordant political environment.

Technology policies alone cannot adequately respond to global climate change. They must be complemented by regulatory and/or energy pricing policies that create incentives for innovation and adoption of improved or alternative technologies. Such "non-technology policies" induce technological change, with powerful and pervasive effects. Environmental regulations and energy efficiency standards have fostered innovations that altered the design of many U.S. power plants and all passenger cars over the past several decades. The technological response to climate change will depend critically on environmental and energy policies as well as technology policies. Because climate change is an issue with time horizons of decades to centuries, learning-by-doing and learning-by-using have special salience. Both technology policies and regulatory policies should leave "space" for continuing technological improvements based on future learning. Climate change policy must accommodate uncertainties, not only regarding the course and impacts of climate change itself, but also in the outcomes of innovation

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