MIT Joint Program on the Science and Policy of Global Change

Emissions Trading to Reduce Greenhouse Gas Emissions in the United States: *The McCain-Lieberman Proposal*

Sergey Paltsev, John M. Reilly, Henry D. Jacoby, A. Denny Ellerman and Kok Hou Tay

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The MIT Joint Program on the Science and Policy of Global Change is an organization for research, independent policy analysis, and public education in global environmental change. It seeks to provide leadership in understanding scientific, economic, and ecological aspects of this difficult issue, and combining them into policy assessments that serve the needs of ongoing national and international discussions. To this end, the Program brings together an interdisciplinary group from two established research centers at MIT: the Center for Global Change Science (CGCS) and the Center for Energy and Environmental Policy Research (CEEPR). These two centers bridge many key areas of the needed intellectual work, and additional essential areas are covered by other MIT departments, by collaboration with the Ecosystems Center of the Marine Biology Laboratory (MBL) at Woods Hole, and by short- and long-term visitors to the Program. The Program involves sponsorship and active participation by industry, government, and non-profit organizations.

To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

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Abstract

The Climate Stewardship Act of 2003 (S. 139) is the most detailed effort to date to design an economy-wide cap-and-trade system for U.S. greenhouse gas emissions reductions. The Act caps sectors at their 2000 emissions in Phase I of the program, running from 2010 to 2015, and then to their 1990 emissions in Phase II starting 2016. There is a strong incentive for banking of allowances, raising the costs in Phase I to achieve savings in Phase II. Use of credits from outside the capped sectors could significantly reduce the cost of the program, even though limited to 15% and 10% of Phase I and II allowances respectively. These credits may come from CO_2 sequestration in soils and forests, reductions in emissions from uncapped sectors, allowances acquired from foreign emissions trading systems, and from a special incentive program for automobile manufacturers. The 15% and 10% limits increase the incentive for banking and could prevent full use of cost-effective reductions from the uncapped sectors. Moreover, some of the potential credits might contribute little or no real climate benefit, particularly if care is not taken in defining those from forest and soil CO_2 sequestration. Analysis using the MIT Emissions Prediction and Policy Analysis model shows that costs over the two Phases of the program could vary substantially, depending on normal uncertainty in economic and emissions growth, and the details of credit system implementation.

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1. INTRODUCTION

The Climate Stewardship Act of 2003 (S. 139) is a plan to cap U.S. greenhouse gas emissions, proposed by Senators McCain (Rep., Arizona) and Lieberman (Dem., Connecticut). The Act would almost certainly be amended and modified in various ways were it to make it through the legislative process. Still, the current version provides specific targets and timetables that are subject to quantitative assessment. Here we present an analysis of the Act, with a focus on its program for "market driven reductions in greenhouse gas emissions" as described in Title III of the Staff Working Draft dated 9 January 2003. Titles I and II cover provisions on climate change research and related activities and for developing a national greenhouse gas database. While these are important topics, complementary to Title III, we do not address them. There are also many features of Title III that are not amenable to quantitative analysis, at least with the modeling tools at our disposal. Moreover, our analysis is primarily an aggregate economic analysis. We do not examine the legal or regulatory implications of the Act, the specific regulatory, monitoring, and enforcement requirements, or the economic implications for specific entities or sectors of the economy.

We begin with a broad overview of the proposed legislation, highlighting features of the greenhouse gas emissions cap-and-trade system envisioned in the Act. We next describe our analysis approach—in particular how we have approximated features of the Act within our MIT Emissions Projection and Policy Analysis (EPPA) model. We then proceed with a set of scenarios intended to demonstrate the effects of key provisions, and the inevitable uncertainties in such projections. Whether the Act ultimately succeeds or not, it represents the most detailed effort to date to design an economy-wide cap-and-trade system for greenhouse gas emissions reductions in the United States. As a result the drafters of the Act have had to deal with the many issues that arise in implementing such a system. It also provides a challenge for economic modeling to realistically capture key implementation issues.

2. PROVISIONS OF THE CLIMATE STEWARDSHIP ACT OF 2003

The Act creates its system of market driven reductions by imposing an emissions cap with tradeable allowances. Under such a system a given number of allowances are issued, and each entity covered by the cap must, at the end of some accounting period, possess allowances at least equal to its emissions. In making the allowances tradeable, an entity may choose to reduce its emissions to the level of allowances it has received, it may obtain more allowances from the pool of those that have not been used by other entities, or it may reduce emissions below its allowances. If the cap is binding, a market will develop that makes it reasonably straightforward for an entity to purchase allowances to cover its emissions, or to sell any allowances it does not need. The main example of such a system is the one covering SO_2 emissions under Title IV of the Clean Air Act Amendments of 1990. That program has demonstrated that such an allowance trading system can work effectively. In almost all quarters the SO_2 trading program has been considered a success, exceeding original expectations (see Ellerman *et al.*, 2000).

In moving from broad concept to a real emissions trading system several design decisions immediately arise. What emissions are covered, and when does the cap become effective? Which entities will need to hold allowances? Where and how will emissions be monitored? How will allowances be distributed, and what limitations or rules determine how they may be used? For example, can they be banked for future use, and can firms borrow against future allowances? Can credits be generated outside the system and applied against emissions from capped sources? The Climate Stewardship Act of 2003 addresses each of these issues, as discussed below.

2.1 What emissions are covered by the cap-and-trade system?

In its greenhouse gas coverage, the proposed system is consistent with the Kyoto Protocol. It includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), and it uses the IPCC's recommended global warming potential indices (GWPs) to convert emissions of different gases into carbon dioxide equivalents. With regard to sectors of the economy, households and agriculture are specifically exempt. All other sectors are covered, including utilities and the industrial, commercial, transportation, and public (Federal, State, and local government) sectors. A further exception is provided for entities that emit less than 10,000 tons of greenhouse gases measured in carbon dioxide equivalents (CO_2-e). For practical purposes this limit would exempt the commercial sector but would capture most large industrial sources. While these provisions exclude many potential entities (millions of households and farms and tens of thousands of businesses) the fact that most emissions are from a relatively smaller number of large sources means that the cap would likely cover 90% of carbon dioxide emissions and about 80% of all greenhouse gas emissions, according to the Environmental Protection Agency's Greenhouse Gas Inventory for the year 2000 (US EPA, 2002).

A major reason the Act covers such a large fraction of emissions is that it makes certain entities responsible for their "indirect" emissions. The most important of these are petroleum refiners or importers selling petroleum products for use in transportation. Without this provision emissions from automobiles and trucking would be largely exempt. Transportation was responsible for nearly 27% of U.S. CO_2 emissions in 2000 by EPA estimates (US EPA, 2002), and fuel use has been growing more rapidly in transportation than in other sectors. The provision on indirect emissions also applies to hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride where producers or importers of these substances must hold an allowance for every ton of carbon dioxide equivalent that will eventually result from their release.

It is worthwhile to note what else is not included under the proposed cap. Carbon sources and sinks from forests and agriculture are not accounted for under the cap, but sinks can enter as credit offsets. In principle, large land owners such as forest companies or government agencies that own land (*e.g.*, the Forest Service, Interior Department, and Defense Department) could be assigned a reference level of net emissions from land use sources and brought under the cap, but this is not a feature of the Act although forest companies whose other greenhouse gas emissions exceeded the 10,000-ton limit are included. In calculating emissions for these entities, the intent of the Act appears to be to exclude emissions of CO_2 from forest harvesting itself because the gross emissions from land use change are not included in the EPA inventory, which is the basis of the emissions cap set in the Act. Land use carbon emissions are entered in the EPA inventory as a net amount, which for the U.S. in 2000 was a sink of 902 million metric tons of CO_2 (US EPA, 2002).

Other radiatively important substances (tropospheric ozone and its precursors and aerosols) are also not included either under the cap or as a potential source of credits, because there currently exists no ready way to compare these substances with CO_2. Their inclusion in a cap-and-trade system would require a solution to science and policy questions that have so far stymied development of a GWP-like index for them (see, *e.g.*, Reilly *et al.*, 2003). The two most important non-CO_2 gases (methane and nitrous oxide) are included in principle, but in practice many of these sources are below the 10,000-ton limit, or are from agriculture, which is specifically excluded from the cap. Large landfills are a potentially large methane source, but they are already controlled under recent amendments to the U.S. Clean Air Act for reasons unrelated to climate. Except for emissions related to fossil fuel production, then, the largest portion of non-CO_2 greenhouse gases can only enter under the crediting provisions of the Act.

2.2 What is an entity?

One of the more challenging aspects of the proposed legislation is the definition of an "entity." The term suggests that a company would need to add up all of the emissions at all of its facilities, whereas the terms "establishment," "plant," or "facility" would more likely be taken to apply to a single building, factory, or plant complex at a contiguous site. The entity designation thus would bring more emissions under the cap than an "establishment" designation, but how much more is not easy to determine given the limits of available data and the difficulty in determining the exact boundaries of an entity. Notably, firms with vehicle fleets or that directly emit HFCs, PFCs, or SF_6, would not be required, we assume, to have allowances for these emissions (and they would not be tallied in determining the 10,000-ton limit) as the intent is to control these indirectly at the point of production or import.

If the entity is a corporate firm, then whether its emissions total up to 10,000 tons CO_2-e or not may depend on how the business is structured. Starbucks, or McDonalds, for example, might each be considered a single entity, but some of the retail establishments that carry their names are part of the corporation while others are franchises operating under license. It seems likely that such franchises would be considered as separate entities. Other corporate structures, such as joint ventures, could raise similar issues. Which entity is responsible for space conditioning emissions may depend on whether the space is owned or leased, and who purchases fuel under the terms of any lease. Inclusion of the public sector raises issues of definition as well. Is the Federal government or each state government a single entity, or are departments, agencies, legislative, judicial, and educational systems (*e.g.*, state university systems) each separate entities? These issues are unlikely to be completely resolved unless and until actual implementation occurs. For the bulk of U.S. emissions these distinctions may not matter very much. But establishing which entities are subject to the cap would involve a considerable burden for corporations and the regulating agency.

The Act recognizes that entities might have an incentive to restructure themselves to remain under the 10,000-ton limit, and prohibits companies from doing so. This provision may prevent obvious ploys to stay under the limit. But companies are continually making decisions about the structure of their organizations, and it would seem nearly impossible to determine whether staying below this limit was a factor in any particular decision. For example, growing and persistent costs of meeting a target could tilt the balance in an electric market from a central-grid utility to micro-turbines generating combined heat and power that would then be small enough to be exempt. A central utility may not be involved in these small-scale investments, and might actually lose market as a result. Thus leakage from the cap might result not from specific actions by covered entities but as the result of competitive forces created in part by the exclusion. Whether such leakage is likely, or could become significant under some situations, is a subject for further evaluation, and would need to be monitored over time.

2.3 What is the cap and when does it become effective?

The intent of the Act is that, during a Phase I of implementation, the aggregate cap for covered entities will be the total of their 2000 emissions, with the cap dropping to the total of their 1990 emissions in Phase II. Phase I runs from January 1, 2010, to December 31, 2015, and the Act specifies an annual cap of 5896 million metric tons CO_2-e *less* the calendar-year 2000 emissions of non-covered entities. For Phase II (January 1, 2016 onward) the cap is 5123 million metric tons CO_2-e *less* calendar-year 1990 emissions of non-covered entities. The caps of 5896 and 5123 million metric tons are based on the U.S. inventory of greenhouse gases (US EPA, 2002, Table ES-4) and represent U.S. emissions of greenhouse gases, less the exempt sectors (households and agriculture) and less emissions from U.S. territories. The exact numerical cap depends on a determination of the non-covered entities and their emissions in 2000 and 1990. Its calculation will require the estimation of historical figures for the years 2000 and 1990, once entities are defined.

The apparent intent of the Act in setting Phase II limits (which the Kyoto Protocol does not do) is to provide guidance to entities of what to expect after Phase I. Section 336 of Title III requires the Undersecretary of Commerce for Oceans and Atmosphere to evaluate the adequacy of the target at least every two years, and report the findings to Congress. In our reading, this leaves open the possibility that even the Phase II cap could be altered, if it was deemed inadequate upon further consideration. However, by specifying specific numerical targets the intent of the Act also appears to be to hold to them unless compelling evidence emerges of a need for change. Also, evaluations of adequacy of the target would help in the formulation of targets for a Phase III of the program.

2.4 Where and how will emissions be monitored, and which specific entities will need to hold allowances?

In discussions of potential carbon cap-and-trade programs, the pros and cons of upstream versus downstream programs have been argued extensively. Because there are limited options for removing carbon at the point of combustion, the main exception being carbon capture and sequestration at power plants, an upstream system (requiring allowances when the fuel is produced, imported or refined) would not, it is generally believed, foreclose many reduction options. Fuel producers would roll the cost of acquiring allowances into fuel product prices and these higher prices for fuels, reflecting their carbon content, would cause energy consumers to conserve or to switch to energy sources with lower carbon emissions.

An upstream system is typically seen as preferable for reasons of administrative and transaction costs. The number of producers and importers that would need to be considered in an upstream system probably numbers only a few thousand, whereas a complete downstream system could require each of millions of households to turn in allowances with each energy purchase, as would tens of thousands of commercial and industrial energy users.

The Climate Stewardship Act of 2003 envisions a mixed upstream and downstream system, referred to as “indirect” and “direct” emissions, but it is mostly downstream. It is upstream only for emissions from transportation fuels and HFCs, PFCs, and SF_6, but downstream for all emissions from other refined oil products, natural gas, and coal. By its exemption of households, farms and small sources, the Act avoids the potential transactions costs of requiring tens of millions of energy users to each comply separately. Of course, if an upstream system for natural gas and other oil products were proposed instead, all of these millions of exempted energy users would fall under the cap automatically. This convenient feature is imposed only for transportation, since refiners and importers must hold allowances for transport fuels even if their direct emissions are less than 10,000 tons. This mixed downstream/upstream division can create many problems. For example, it requires refiners to separately identify transportation and non-transportation fuels, and creates the possibility that downstream users may purchase fuel oil and use it as diesel fuel, since there is little substantive difference between them.

The Act anticipates that in some cases (*e.g.*, electric utilities) there will be direct measurement of CO_2 from flue gases, but recognizes that other methods will be needed to deal with some sources. Carbon coefficients will be required for different fuels, as is the case in constructing the national inventory. These estimates would then be applied to quantities of purchased fuel to determine emissions.

2.5 How will allowances be distributed?

Two broad approaches are available for distributing allowances under a cap-and-trade system: (1) free distribution, also called "grandfathering" when distributed to incumbent emitting facilities as is usually the case; and (2) auctioning by some agency of the Federal government that receives the revenue.

All existing cap-and-trade programs to date have allocated allowances free of charge to incumbent emitters, typically based on past activity levels (not emissions). For instance, allowances for the SO_2 trading program are allocated according to average annual fossil-fuel heat input in 1985-87 multiplied by a specified "allowed" emission rate. While free allocation is sometimes justified as a form of compensation to those most adversely affected by the measure, many other considerations intrude, such as earlier abatement action and various notions of fairness. Moreover, the cost incidence of a greenhouse gas constraint may fall downstream or upstream from the entity that actually is required to hold allowances. For example, under the proposed Act electric utilities are required to hold allowances. But, the incidence of any costs directly borne by utilities will be divided between shareholders of the utilities, consumers of electric power, and industries that supply utilities (particularly coal producers). As a result, various proposals have been made to allocate allowances (freely) to parties other than incumbent emitters, who would then sell the allowances to those required to hold them for compliance purposes.

Auctioning avoids the problem of directly allocating allowances, although in reality the problem is only removed one stage since the auction revenues will be used in some manner. The main reason for the attention given to auctioning, particularly in the economic literature, has been the possibility of obtaining a "double dividend" by using the auction revenue to reduce distortionary taxes on labor and capital (Goulder, 1995; Bovenberg, 1999; Bovenberg and Goulder, 2003). These benefits might arise because existing taxes discourage the supply of labor and capital, thereby lowering income and economic activity. Various studies have indicated that the use of auction revenue to offset taxes on wages or capital could partially (or in some cases when reductions from reference are small, completely) offset the economy-wide costs of the greenhouse gas reduction program (Babiker *et al.*, 2003). Underlying this proposal is the idea that:

(1) there is need for Federal government revenue at some given level; (2) existing taxes discourage "good" activity, namely, the supply of labor and capital; and (3) while environmental taxes or their auction equivalent will discourage "bad" activity. Because much of this literature imagines a reduction in existing taxes while Federal spending remains constant, the implicit assumption is that the current level of Federal revenue is the desirable one. The correct level of Federal spending is open to continuing debate, however, and decisions on the use of a revenue stream from allowance auctions would almost inevitably take place in the context of the broader debate on the proper level of Federal spending and the appropriate structure of taxation. These issues are well beyond the scope of this paper, but they are not irrelevant to the economic consequences of the Act.

The Act describes a complex allowance allocation involving a mix of free allocation and auctioning. In the first step of the process the Secretary of Commerce would make a division between allowances to be auctioned by a newly created Climate Change Credit Corporation (CCCC) and those to be distributed without charge by the Environmental Protection Agency. After transferring those to be auctioned to the CCCC, the remaining allowances would be divided among early action claimants and incumbents. The Act lays out a process by which entities could receive allowances for reductions in emissions achieved prior to Phase I, and these entities would have first claim on allowances allocated to the EPA Administrator. Any remaining allowances would be distributed at the discretion of the EPA Administrator with some guidance in the Act on what factors to consider. Considering the discretion of Executive Branch agencies and the influence of firm behavior before the start of Phase I, a very wide range of allocations could result from this process. If the Secretary of Commerce retains few allowances for auction and few early action allowances are claimed or allowed by entities, the EPA Administrator could have a large number to allocate in some manner to the affected entities. But, there is nothing to prevent all of the Phase I allowances to be claimed by early action and the auction, such that few or none were left for distribution at the discretion of the EPA Administrator.

Except for possible "double dividend" effects, the exact distribution of allowances likely would matter little from an economic efficiency standpoint. Thus the inability to predict the allocation does not directly affect our ability to conduct an aggregate economic analysis. Individual entities have much at stake, of course, in how the allowances are distributed.

Three elements of the allocation mechanism are worth pointing out for their effects on the efficiency and effectiveness of the proposed system. First, any allowances allocated for "early action" are deducted from the Phase I's 5896-million metric tons CO_2-e *less* emissions of non-covered entities. Early-action allowances thus only affect how much of the fixed target each entity receives and do not loosen the Phase I (or II) target in any way. Allowances awarded for early action can be used like any other allowances. In contrast, registries for early action have sometimes been envisioned as a bank of allowances that would apply over and above a specified future target. If that were the case, generous interpretation of early action could create a bank that would make the target much looser.

Second, early action credits may result in some environment benefit prior to the formal start of Phase I, as entities reduce below what their reference emissions would otherwise have been in those years. The real benefit may never be known because the result depends on the extent to which the rules defining these early action allowances can ensure real reductions. The language of the Act indicates that an historical peak, apparently chosen by the entity but subject to review by EPA, will be the reference. This procedure favors allocating early action allowances to entities whose emissions for one reason or another might have declined anyway. The total number of allowances thus allocated (or claimed) will likely be an overestimate of the real reductions occurring prior to Phase I. It could also be argued that this provision discourages entities from avoiding emissions reductions prior to Phase I, in hopes of getting a larger allocation.

Third, the decision to auction a certain share of the total target could influence the macroeconomic costs through the “double dividend” effect. Although use of the auction proceeds to reduce labor and capital taxes directly seems to be precluded by the organization of the CCCC, the allocation of some portion of auction revenues to the Treasury, to compensate for reduced tax revenue due to the reduced economic activity resulting from the emission restrictions, could indirectly have the same effect by avoiding a compensatory increase of taxes on labor or capital. Only a general basis for the Commerce Secretary’s decision is given, principally to reduce the costs borne by consumers. The Act does not instruct the Secretary to consider these “double dividend” effects, in contrast to transition assistance and various subsidies to encourage energy efficiency and thereby reduce the cost incidence of the greenhouse gas emission restriction on consumers. The Act specifies that 20% of the auction revenue for 2010 should be used for transition assistance to dislocated workers and communities, with the amount to be phased out at 2% per year thereafter. The language of the Act clearly suggests efforts such as making energy efficient appliances affordable to consumers. The Act also allows the Secretary to preferentially treat those consumers least able to afford the increased costs. Thus, with little guidance as to whether 10% or 90% of allowances will be auctioned, and a variety of objectives for the revenues raised, there is little basis for assessing the macroeconomic effects of any revenues it might yield.

2.6 What limitations or rules exist regarding how allowances may be used?

The Act allows unlimited banking (holding allowances for future periods), limited borrowing (using future reductions to offset current emissions), and prohibits the CCCC from retiring unused allowances. The borrowing provision is limited to specific entities that undertake a long-lived capital investment to reduce emissions. An example might be an electric utility that retrofits carbon capture and sequestration equipment on a coal-fired power plant. Borrowing may be useful for some entities, but in aggregate, as we will see in the following sections, the economic incentive is likely to be toward net banking. The prohibition on retiring allowances prevents the CCCC from unilaterally lowering the number of allowances available, but little other guidance is given. The CCCC “shall buy and sell tradeable allowances whether allocated to it..., or obtained by purchase, trade, or donation from other entities.” It is not required to sell all of the allowances it holds in any specific period—*i.e.*, while it could not retire Phase I allowances, it appears that nothing would prohibit the Corporation from holding some of the allowances for sale in future phases of the program.

It is not obvious what motivation the CCCC would have to purchase allowances. It is not directed to try to maximize its revenue in any period, or over time, nor is it instructed to play a role in “stabilizing” allowance prices. It thus seems to have a mandate to auction all allowances soon after it receives them. A more active role in the market would need to stem from a set of goals developed by the Corporation board itself. Our presumption for the quantitative analysis that follows is that it would play a passive role, auctioning the allowances it receives in Phase I (and future Phases) well before Phase I (or subsequent Phases) end, allowing private market participants to bank or trade among themselves as the economics dictate.

2.7 What if any provisions apply to sources not covered by the cap-and-trade system, and can credits be generated outside the system and applied against emissions from capped sources?

Under the Act all exempt sectors and sources can create credits applicable against the emissions cap. Credits can be derived from both CO_2 and non-CO_2 greenhouse gas reductions from exempt sources; credits can be gained from forest and agricultural sinks for carbon; and credits can be obtained from a foreign cap-and-trade system.

At this point, parties to the Kyoto Protocol, specifically the European Union (EU), seem the more likely nations to have some form of cap-and-trade system. In the quantitative analysis below, we evaluate the possible linking of the U.S. cap-and-trade system with a non-U.S. system. As stated in the Act, the foreign system would have to be certified by the Secretary of Commerce. Two considerations are likely to apply: integrity and comparable effort. The most basic requirement is that the system with which trade is to be established possess sufficient integrity in terms of monitoring, compliance, and enforcement that a foreign allowance used for compliance in the U.S. will ensure a ton of greenhouse gas emissions reduction. The trickier consideration is likely to be whether trade should be allowed with a cap-and-trade system in a country that is believed not to be making a comparable effort towards reducing greenhouse gas emissions, even if its trading system possessed the requisite integrity. While trading with such a partner would reduce costs for the U.S. and result in no greater emissions than would occur otherwise, recognition would also confer the benefits of trade on the other party and thereby reward it for not adopting a more ambitious target. While comparability of effort will undoubtedly be a consideration, the criteria for establishing comparability are not obvious. For instance, should the same effort be expected of China or India as might be expected of Europe?

Also, whether trade with a certified non-U.S. system would lead to lower prices in the U.S., as seems to be commonly assumed, is not obvious. The most likely candidate, the proposed EU system, provides a good example. It is easy to create low-price scenarios for the EU system, and commensurately little effort by sources located within EU member states, due to a liberal treatment of excess allowances held by East European accession countries or Russia and of credits from the Clean Development Mechanism. But, on the other hand, the acceptability of these off-system credits is currently a matter of debate within Europe precisely because a liberal acceptance of the Kyoto mechanisms would result in little emission reduction effort within the current 15 EU member states. It is possible to envisage a situation, as is done by some participants in the proposed system, in which few off-system credits are accepted and the large sources now included in the trading system are made to bear a disproportionate share of the burden of meeting the Kyoto targets. The emissions price could be higher than the price in the U.S. system, and U.S. prices would rise as a result of international permit trade.

The availability of credits from exempt sources and from sinks within the U.S. raises similar problems in that the key to potential supply is the determination of a reference point from which credits are to be calculated. In the case of exempt sectors and entities, this reference must be established for each entity. Moreover, entities may choose whether or not to participate. Those entities whose reference point is relatively high compared to what their emissions would have been in the absence of the credit system clearly have an incentive to participate, but the credits may not represent real reductions. The credit system also exacerbates problems of leakage. One forest landholder may plant trees to sequester carbon, rather than harvest timber, and thereby claim credits. To fill the supply for timber, however, another forest-land holder may increase its harvesting, increasing CO_2 emissions.

Even more problematic for sink credits is the fact that, in the year 2000, *net* terrestrial CO_2 sinks in the U.S. were 902 million metric tons. One way to think about the net sink for the U.S. is that it is the total of all uptake of CO_2 in forests and on farmland (the gross sink) *less* emissions of CO_2 from forest harvesting or other land use. The current U.S. inventory approach does not estimate the annual gross sink and annual emissions but instead considers the change in the total stock of carbon, an equally valid way to estimate the net sink for the U.S. as whole (see EPA, 2002). In a credit system, however, any entity whose land is a sink might claim credit for it, whereas those entities whose land use resulted in emissions of CO_2 could choose not to participate in the credit system.[1]

[1] Suppose there were three entities in a country we will call Forestland. Entity 1 sequesters 2000 tons of CO_2, Entity 2 sequesters 500 tons of CO_2, and Entity 3 harvests forests and causes emissions of 2000 ton of CO_2. Net carbon sequestration for Forestland is 2000+500-2000=500. But, with crediting rather than capping, if the reference point for calculating credits was 0 net emissions, then Entities 1 and 2 could register for 2500 credits, 2000 more than the net sequestration of the entire country, and Entity 3 would have no incentive to register its emissions.

The total uptake of only those entities with sinks is likely to considerably larger than the net sink for the total U.S. The reference level for each entity from which credits for sequestration were calculated would thus need to include a specific estimate of each entity's likely sequestration in a business-as-usual scenario, and credits could only be earned for reductions beyond these amounts if the system is to avoid crediting a large number of "no reduction" credits.

The Act restricts the amount of credits that can be used to no more than 15% of any entity's allowances in Phase I, dropping to 10% in Phase II. If the crediting system was thus very loose, there is an ultimate limit on credits flowing into the system. While the percentages are enforced entity-by-entity, with a well-developed market these constraints should readily translate to an aggregate limit. That is, entities could readily swap credits for allowances such that no entity was above the 15% limit individually, and on aggregate the 15% limit was not exceeded.

Another provision of the Act would allocate credits to automobile manufacturers who improve fuel efficiency of their vehicle fleet beyond that required by the Corporate Average Fuel Economy (CAFE) standards. To receive credits automobile manufactures would need to exceed the fleet average CAFE fuel economy standards by 20%. If they exceeded the limits by only 10% or 15% they would receive no credit. If they exceeded by 20% then they would receive credits for savings related to the entire improvement. There is thus a highly discontinuous marginal benefit of exceeding the standard by exactly 20%, and then a lower but nearly constant marginal benefit for exceeding the limit by more than that percentage. An improvement in fuel efficiency would save carbon emissions over the entire life of the car. The Act assigns the Secretary of Transportation the task of arriving at a method for estimating the number of credits applicable if the 20% improvement in fuel-efficiency is met. This provision, combined with inclusion of transportation fuel in the cap-and-trade system, creates a double incentive for reducing fuel use in automobiles. Although marginal costs would still be equalized within the trading system once established, marginal costs would not be equalized with respect to the status quo ante since more abatement would be obtained from the transportation sector than would occur without this subsidy to improved fuel efficiency.

We have not been able to model this credit process directly within the EPPA model. At this point, there is little basis, of which we are aware, to estimate automobile manufacturer and consumer response to a financial incentive to increase fuel efficiency of vehicles. It may make sense for some automobile manufacturers to exceed the CAFE limit for their fleet, but not for others. What we have done, instead, is to estimate an economic incentive per vehicle in an imagined manufacturer's fleet. This involves making some assumptions about how the Secretary of Transportation would credit reductions. We have followed the following approach for estimating the value of the credit:

$$CreditValue = \sum_{t=0}^{t=CL} \frac{CO_2ePrice_t \times CO_2Savings_t}{(1+r)^t}$$

where t is an index for the year, starting with the first year of the program as year 0, CL is the estimated car life, r is the discount rate, and $CO_2Savings$ are calculated by estimating the gasoline savings obtained with the higher average fleet mileage times the CO_2 emission coefficient for gasoline. We have assumed for simplicity that the lifetime mileage of cars is not affected by the efficiency improvement, although the Dept. of Transportation may wish to make such an estimate.

Given the banking provision, the expectation would be that the CO_2-e price would rise at the discount rate. We can thus substitute the expression $[(1+r)^t \times CO_2ePrice_0]$ for expression $[CO_2ePrice_t]$. With this substitution the $[(1+r)^t]$ term appears in both the denominator and numerator and cancels out of the equation, and the CO_2-e price is just the price in year 0 and can thus be moved outside the summation sign. The expression reduces to simply:

$$CreditValue = CO_2ePrice_0 \sum_{t=0}^{t=CL} CO_2Savings$$

for vehicle fleet savings in the first year of the program. It is that year's CO_2-e price times the summed CO_2 savings over the lifetime of the vehicle fleet sold in that year. In each succeeding year, the formula is simply the CO_2-e price for that year times the estimated accumulated savings. Or, as the Act is written, the Secretary of Transportation would award credits equal to undiscounted estimated cumulative savings over the life of the vehicle, and the automobile manufacturer could sell these into the allowance trading system at the going price (or bank them). It may turn out that the CO_2-e price in reality rises at different rates because of unexpected changes in the economy, but given the banking provision the best estimate is that it will rise at the discount rate, and this assumption eliminates the need to make an explicit forward estimate of the price.

3. THE EMISSIONS PREDICTION AND POLICY ANALYSIS (EPPA) MODEL

To analyze the Act we apply the MIT Emissions Prediction and Policy Analysis (EPPA) Model. It is a recursive-dynamic multi-regional general equilibrium model of the world economy (Babiker *et al.*, 2001). The version of EPPA used here has been updated in a number of ways from the model described in Babiker *et al.* (2001). It includes non-CO_2 greenhouse gases, greater disaggregation in the electric sector, and updated evaluation of economic growth and resource availability (Hyman, 2001; Hyman *et al.*, 2003; McFarland *et al.*, 2003; Reilly *et al.*, 2003).[2] It is

[2] Oil and gas resources were updated to be consistent with a recent USGS re-evaluation (USGS, 2000). The electric sector was revised to include separation of hydroelectricity from other conventional sources based on IEA data (IEA, 2001), reformulation of the backstop renewable electric sector, and addition of a biomass electric generation technology. China's energy and emissions outlook was revised to be consistent with reports of recent trends. Near term economic growth prospects were revised to be consistent with the most recent IMF global outlook, and compared with Babiker *et al.* (2001) energy efficiency trends in developing countries were revised to reflect historical data, which show little or no improvement in the energy intensity of GDP.

built on the GTAP data set, which accommodates a consistent representation of energy markets in physical units as well as detailed accounts of regional production and bilateral trade flows (Hertel, 1997). The version of the model used here has recently been updated to GTAP5-E, with a base year for the model of 1997. GTAP5-E includes the most recent input-output tables for the U.S. From 2000 onward, EPPA is solved recursively at 5-year intervals.

For purposes of this assessment, a significant feature of the model is the inclusion of the cost of abatement of non-CO_2 greenhouse gas emissions (CH_4, N_2O, HFCs, PFCs and SF_6). The cost calculations consider both the emissions mitigation that occurs as a byproduct of actions directed at CO_2, and reductions resulting from gas-specific control measures. Targeted control measures include reductions in the emissions of: CO_2 from the combustion of fossil fuels; the industrial gases that replace CFCs controlled by the Montreal Protocol and produced at aluminum smelters; CH_4 from energy supply and use, landfills, and sewage; and N_2O from chemical production. Limited reduction possibilities from agriculture also are included for control of CH_4 from manure management in large concentrated livestock operations, and N_2O reductions from the improved management of inorganic fertilizer applications. Because of a lack of proven technologies and/or the difficulty of measurement and monitoring we do not consider reductions in process CO_2 from cement production, N_2O from organic nitrogen application and fossil fuel combustion, or CH_4 from ruminant digestion and manure management on small farms. More detail on how abatement costs are represented for these substances is provided in Hyman *et al.* (2003).

Non-energy activities are aggregated to four sectors, as shown in **Table 1**. The energy sector, which contributes to emissions of several of the non-CO_2 gases as well as to CO_2 itself, is modeled in more detail. The synthetic coal gas industry produces a perfect substitute for natural gas. The oil shale industry produces a perfect substitute for refined oil. These “backstop” technologies do not enter over the time periods analyzed here. All electricity generation technologies produce perfectly substitutable electricity except for the “Solar&Wind” technology, which is modeled as producing an imperfect substitute, reflecting its intermittent output. Biomass use is included explicitly in electric generation and is implicit in the fuel demand structure of the model. Among the Annex B countries, the energy efficiency of the electric sector is modeled as improving at a rate of 0.40% to 0.45% per year while non-electric sectors increase in energy efficiency by 1.2% to 1.3% per year.

The regional and sectoral disaggregation also is shown in Table 1. The Kyoto Annex B Parties are aggregated into seven nations or multi-nation groups, including the U.S. Under this EPPA aggregation the countries of the Former Soviet Union (FSU) are taken to represent those economies that are in Annex B and thereby assuming a Kyoto commitment (principally Russia and Ukraine). This aggregation is not exact, but the difference does not have a significant effect on the results for cases considering foreign credits.

Table 1. Countries, Regions, and Sectors in the MIT EPPA General Equilibrium Model

Country or Region	Sectors
Annex B	***Non-Energy***
United States	Agriculture
Canada	Services
Japan	Energy Intensive products
European Union+[a]	Other Industries products
Australia/New Zealand	***Energy***
Former Soviet Union[b]	Coal
Eastern Europe[c]	Crude Oil
Non-Annex B	Natural Gas
India	Electric: Fossil, Nuclear, Hydro, Solar&Wind, Biomass
China	Refined Oil
Indonesia	Synthetic Gas from Coal
Higher Income East Asia[d]	Oil from Shale
Mexico	
Central and South America	
Middle East	
Africa	
Rest of World[e]	

[a] The European Union (EU-15) plus countries of the European Free Trade Area (Norway, Switzerland, Iceland).

[b] Russia and Ukraine, Latvia, Lithuania and Estonia (which are included in Annex B), and Azerbaijan, Armenia, Belarus, Georgia, Kyrgyzstan, Kazakhstan, Moldova, Tajikistan, Turkmenistan, and Uzbekistan which are not. The total carbon-equivalent emissions of these excluded regions were about 20% of those of the FSU in 1995. At COP-7, Kazakhstan, which makes up 5% to 10% of the FSU total ,joined Annex I and indicated its intention to assume an Annex B target.

[c] Includes a number of former Yugoslav republics and Albania not Part of Annex B, which contribute only a small percentage of the overall emissions of the Region.

[d] South Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand.

[e] All countries not included elsewhere: Turkey, and mostly Asian countries.

In this version of EPPA we do not yet have the capability to represent policies that discriminate among economic sectors. We thus approximate the proposed Act as applying to the entire U.S. economy either as a CO_2-only policy or as a full greenhouse gas policy with trading among gases. To minimize the effect on the carbon price of including the sectors excluded in the Act we use a cap equal to economy-wide 2000 CO_2 emissions rather than the cap specified in the Act, as the intent of the Act is clearly to set a target equal to 2000 emissions of covered entities. Direct residential CO_2 emissions were 5.5% of total U.S. greenhouse gas emissions in 2000 and agriculture was 0.7%; commercial CO_2 emissions were 3.5% of total emissions (EPA, 2002, pp. 1-20). Assuming the commercial sector's CO_2 emissions approximates the total of all non-covered entities, the total non-covered CO_2 emissions are about 9.7%. By altering the target to include the 2000 emissions of these sectors, as a first approximation we expect no effect on the CO_2-equivalent price[3] and we

[3] Assuming residential, agriculture, and commercial sector abatement opportunities and emissions growth from 2000 are on average similar to the rest of the economy.

would expect costs in terms of welfare percentage or total dollar cost to be overestimated by the 9.7% (approximately 10%) compared to the cost we would get if we modeled the sectoral exemptions. These omitted sectors, and particularly agriculture, are more important because of their emissions of non-CO_2 greenhouse gases. We structure a case with trading between CO_2 and other greenhouse gases to provide an estimate of how they might affect the cap-and-trade system via reductions of these gases applied as credits. As previously discussed, the Act includes hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, and methane from fossil fuel production under the cap. Thus, by including these only, as if they were credits, likely results in a slight overestimate of the carbon-dioxide equivalent price and the economic cost of the Act.

In subsequent analyses we hope to approximate the specific sectoral exclusions contained in the Act more closely. Given that these are relatively small, and given the other uncertainties, we do not expect that the basic findings will differ substantially from those reported here. Another variation from the Act is that we approximate Phase I as running from 2010 to the end of 2014 (rather than 2015 as in the Act) and we start Phase II in 2015 rather than 2016. We extend the analysis through 2020. We assume that the Annex B Parties are meeting their Kyoto targets using full flexibility of the trading mechanism and we assume that the Kyoto target for the first commitment period remains unchanged (and no new Parties take on targets) through the 2020 horizon of our analysis. While likely not a large factor, there will be trade effects on the U.S. of Annex B Party implementation: by assuming this in all scenarios, including the reference, we can observe more clearly the economic effects on the U.S. of implementing the Act. The exception to this is a case where we assume that Annex B-wide trading does not occur, and the U.S. program links to an EU-wide trading system. Other Parties meet their targets domestically in this case, and again, the Kyoto targets remain unchanged through the 2020 time horizon. To accurately assess the economic impacts on the U.S., we compare the U.S. cost impacts in this case to a reference where each of the Annex B parties meets their targets without trading among the Parties.

4. SCENARIOS AND RESULTS

To better understand the various components of Act we have constructed a set of scenarios designed to show how each of its provisions affect its cost. Among the critical provisions are the tightening of the cap in Phase II of the program, banking, and the various possibilities for credits from outside the capped sectors and limits on their use. A first set of scenarios considers the cap tightening in Phase II and banking. A second set of scenarios examines the possible effects of outside credits. And a final set examines the effects of different assumptions about baseline gross domestic product (GDP) and emissions growth. **Table 2** identifies more specifically how each scenario differs.

Table 2. Summary of Scenario Variants

Scenario	Cap in Phase I	Cap in Phase II	Banking	Source of Credits	Growth Assumption
1	2000 CO_2 emissions	2000 CO_2 emissions	No	None	EIA ref. CO_2 emissions
2	2000 CO_2 emissions	2000 CO_2 emissions	Yes	None	EIA ref. CO_2 emissions
3	2000 CO_2 emissions	1990 CO_2 emissions	No	None	EIA ref. CO_2 emissions
4	2000 CO_2 emissions	1990 CO_2 emissions	Yes	None	EIA ref. CO_2 emissions
5	2000 GHG emissions	1990 GHG emissions	Yes	None	EIA ref. CO_2 emissions
6	2000 CO_2 emissions	1990 CO_2 emissions	No	15%, 10% limits at $0 cost	EIA ref. CO_2 emissions
7	2000 CO_2 emissions	1990 CO_2 emissions	Yes	15%, 10% limits at $0 cost	EIA ref. CO_2 emissions
8	2000 CO_2 emissions	1990 CO_2 emissions	No	Non-CO_2 GHGs as economic	EIA ref. CO_2 emissions
9	2000 CO_2 emissions	1990 CO_2 emissions	Yes	Non-CO_2 GHGs as economic	EIA ref. CO_2 emissions
10	2000 CO_2 emissions	1990 CO_2 emissions	No	EU-wide only Trading System	EIA ref. CO_2 emissions
11	2000 CO_2 emissions	1990 CO_2 emissions	No	Annex B wide Trading System	EIA ref. CO_2 emissions
12	2000 CO_2 emissions	2000 CO_2 emissions	Yes	Non-CO_2 GHGs as economic	EIA ref. CO_2 emissions
13	2000 CO_2 emissions	1990 CO_2 emissions	No	None	Low GDP Growth
14	2000 CO_2 emissions	1990 CO_2 emissions	No	None	High GDP Growth

For the central runs (all those except the variations in GDP and emissions growth) we have benchmarked the EPPA model to produce a reference greenhouse gas (GHG) emissions forecast nearly identical to the Energy Information Administration's (US DOE, 2003) central forecast for the U.S. GDP and emissions growth outside the U.S. remain as in the EPPA reference.

We report results in terms of the price per ton CO_2-e and percentage welfare loss. To avoid any potential confusion when comparing our results to other studies that may report in terms of carbon-equivalent (C-e) we also report prices in C-e in brackets in the tables. These differ by a constant factor (3.67) reflecting the relative molecular weight of CO_2 to C. Choice of CO_2-e or C-e is simply a matter of convention. All values are in 1997 constant dollars. Welfare is measured as equivalent variation, and is equivalent to loss in macroeconomic (personal) consumption. To obtain absolute dollar costs of the welfare loss the percentage can be multiplied by an estimate of U.S. consumption for the years shown. Economists generally prefer welfare loss as the best measure of the real cost to the economy of a policy because it is the most accurate measure of the loss of effective income of households—lost income in terms of households' ability to purchase goods and services. **Table 3** provides the necessary data to place these percentage losses in perspective. A 0.1% welfare loss would be about $69 per household in 2010, rising to $87 per

Table 3. Reference U.S. Consumption, Household Income (in 1997 dollars)

	2000	2010	2015	2020
Private Consumption ($ trillions)	6.3	8.2	9.5	11.1
Aggregate cost of 0.1% loss ($ billions)	6.3	8.2	9.5	11.1
Households (millions)	108[a]	118[b]	123[b]	127[b]
Cost/household of 0.1% loss ($)		69	77	87
Median Household Income ($)	41,000[a]	49,000[b]	55000[b]	61,000[b]

[a] Bureau of Census Data (http://www.census.gov/hhes/income/histinc/h06.html). Household income deflated to 1997 dollars using U.S. GDP implicit price deflator, rounded to nearest 1000.

[b] Estimated using EPPA population and income growth per capita to index 2000 base year Census estimates.

household in 2020. At the same time median household income would rise from $40,000 in 2000 to $49,000 in 2010, and $61,000 in 2020 based on the EPPA forecast for the reference scenario of GDP growth.

For the banking scenarios (2, 4, 5, 7, 9) we show how petroleum product, coal, and gas consumption are affected by the policy. For these same scenarios we report on the potential value of exceeding the CAFE limits by 20% or more, using the approach described previously. In all scenarios, we assume a free distribution of allowances or a lump sum distribution of auction revenues that does not include possible benefits from a recycling of revenue to reduce distortionary taxes on labor or capital.

4.1 Effects of Tightening the Target in Phase II, and Banking

We start with a scenario constructed as if the Phase I targets continued indefinitely. We are thus able to see the effects of tightening the target in Phase II, and how the benefits of banking depend on the future constraint. The results, in terms of the price per ton CO_2-e and percentage welfare loss are given in **Table 4**. Assuming the Phase I target was to remain unchanged in

Table 4. Effects of Banking and Tightening of the Target in Phase II (in 1997 dollars)

		$/ton CO_2-e [$/ton C-e]		
Scenario	**Cost**	**2010**	**2015**	**2020**
(1) Phase I target indefinitely, no banking, CO_2 only	Price	16 [59]	28 [103]	41 [150]
	Welfare Cost (%)	0.05	0.13	0.18
(2) Phase I target indefinitely, banking, CO_2 only	Price	21 [77]	27 [99]	34 [125]
	Welfare Cost (%)	0.09	0.12	0.13
(3) Phase I and II target, no banking, CO_2 only	Price	16 [59]	70 [257]	86 [316]
	Welfare Cost (%)	0.05	0.49	0.59
(4) Phase I and II target, banking, CO_2 only	Price	39 [143]	49 [180]	63 [231]
	Welfare Cost (%)	0.25	0.34	0.40
(5) Phase I and II target, banking, applied to all GHGs	Price	25 [92]	32 [117]	40 [147]
	Welfare Cost (%)	0.14	0.20	0.25

Phase II, through to 2020, and in the absence of banking, we find the CO_2-e price to start at $16 per ton in 2010, rising to $28 in 2015 and then rising more gradually to 2020. (The same prices, stated in $ per ton of C-e are shown in brackets.)

Next we add banking, which we model on the assumption that market participants will bank emissions allowances as long as the expected price is rising more rapidly than an economy-wide rate of return of 5%. The intuition for this equilibrium condition is that an entity faced with the decision to abate and bank in Phase I, would compare the expected return on that abatement investment with the rate of return elsewhere in the economy. If the CO_2-e price were rising more rapidly than 5% per year, abatement investments yield a higher return than the 5% elsewhere in the economy and entities would thus abate and bank more.[4] We have enforced this CO_2-e price banking equilibrium through the 2020 horizon of our model run; examination of post-2020 results suggest some remaining incentive to bank, and therefore if we were to extend the horizon of the model the equilibrium prices for the reported years would be slightly higher.[5]

The results show limited incentive to bank when the target is not tightened in Phase II. The Phase I CO_2-e price rises by $5, and falls slightly compared with the no-banking (scenario 1) case in 2015 and 2020. The benefits of banking in terms of welfare costs are also seen in 2015 and 2020, at the expense of somewhat higher costs in 2010. The welfare costs of these scenarios are small, starting at around 1/10 of 1% and rising slowly.

One of reasons for the low welfare costs of this restriction is that the U.S. is a large importer of crude oil and petroleum products. It thus influences the world oil market, causing world oil prices to fall when oil consumption is restrained through a CO_2 policy. These effects are more pronounced if the developed countries act together to limit oil consumption, and as discussed previously, we have assumed the Kyoto Parties are meeting their Kyoto commitment (unchanged through 2020) using full flexibility of international trading, in all scenarios except scenario 10 where Annex B Parties meet their targets without trading. This policy scenario thus has an oil market effect. But, we compared the welfare costs of the U.S. policy to a reference case where the Kyoto Parties implement the Protocol while the U.S. does nothing. With trading among Annex B Parties, the Kyoto commitment requires very little reduction of CO_2 emissions in 2010, and thus

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[4] Since EPPA is recursive dynamic rather than forward-looking the model does not automatically solve for optimal banking. The results here were numerically approximated by reallocating the target over time to yield the equilibrium condition that the price is rising at the 5% rate of return. Entities will make this choice themselves based on their expectations and perception of risks. Assuming a higher rate of return would tilt the price path to lower prices in the early years, and higher prices in later years—there would be less banking. Assuming a lower rate of return would create more banking, and higher early year prices and lower later year prices.

[5] Given growth in emissions, we would expect the incentive to bank to gradually disappear, if the Phase II cap were extended indefinitely. The specific incentive to bank would depend on what, if any, specific information became available over time on the likely cap beyond Phase II, and on the expectations of entities regarding the resulting costs in these later years.

there is little effect on the oil market and the U.S. Very small effects on the U.S., on the order of 0.01% welfare benefit, occur in 2020 when the Kyoto targets require greater CO_2 reductions among the Parties. Thus, any oil market benefits from the Kyoto Protocol already exist in the reference, and so any further oil market benefits are the result solely of reduced U.S. demand on the world oil market.

Scenarios 3 and 4 in Table 4 show the effect of implementing the Phase II targets, returning to 1990 emissions levels in Phase II. Without banking, the costs are the same in 2010 as in the no banking scenario—it is the exact same constraint for that period—but the costs in 2015 more than quadruple in terms of the CO_2-e price from 2010, and the welfare loss rises to about 1/2 of 1%. The benefits of banking are thus far more substantial, cutting the loss in welfare in the 2015 and 2020 periods by almost 1/3. The CO_2-e price rises in the 2010 period from \$16 to \$39 as a result of banking. For comparison purposes, and to bound the results in terms of inclusion or exclusion of the non-CO_2 greenhouse gases, we include a scenario 5 where the target is expanded to all greenhouse gases. As expected based on previous work, this reduces the costs compared to the equivalent CO_2-only case. We show only the case with banking and with the tightening of the target in Phase II; the magnitude of the effect is similar in other cases.

4.2 The Potential Effects of Outside Credits

As already introduced briefly in early sections, it can be difficult to create a credit system that can efficiently take advantage of low cost reductions from uncapped sources without letting in credits that, in reality, involve no real reduction in emissions or increase in sinks beyond what would have occurred without the credit incentive. If the reference level of emissions (or sinks) from which reductions (or further increases in sinks) are scrutinized very carefully, requiring extensive study and documentation, the process may be so burdensome that few entities find it worthwhile. If simple rules are set then the system may self-select entities that would have reduced their emissions in any case, or it may reflect actions that create leakage. For example, if historical emissions in a year prior to Phase I were specified as the reference, those entities whose emissions may have been declining for other reasons would gets credits for these reductions even though these were not a real reduction from what their reference emissions would have been. Or, entities may make a decision not to expand or to reduce a part of their production activities that have high emissions. But demand for that product is likely to continue to exist, and so other entities with similar production capability, but who have chosen not to seek credits, are likely to expand their production and emissions. These phenomena are minimized in a broad cap-and-trade system because covered entities do not have a choice of whether to participate or not. Some leakage can occur when the cap-and-trade system is not complete (geographically, or covering all entities) but with sufficiently broad coverage this leakage may not be extreme.

Rather than identifying all possible credits from foreign cap-and-trade systems, domestic exempt entities, and sinks in a single scenario, we bracket the possible effects by considering each of these separately, with differing assumptions about how well the credit system might work, and whether it would produce credits that involve additional reductions at some additional real cost to the economy.

In scenarios 6 and 7, reported in **Table 5**, we assume that the credits are generated at no cost; we simply relax the cap by 15% in Phase I and by 10% in Phase II. As noted previously, there was an estimated 902 tons of net CO_2 sequestration in the U.S. in 2000. This was 13% of total U.S. greenhouse gas emissions in 2000 or slightly over 15% of total CO_2 emissions. A crediting system, if it adopted zero sequestration as a reference for any single entity, might well end up with credits from sequestration considerably greater than the estimate of net sequestration; net emitters would not register, and potentially all of gross sequestration could be registered. Sequestration alone could thus completely supply credits up to the 15% and 10% limits at no real cost to the economy and no additional net sequestration. If the 15% and 10% limits are binding (there was excess supply) one might expect the credit price to be near zero, even though there would be a positive price on allowances. Under such circumstance the no-cost sequestration would dominate other costly reductions (from non-CO_2 greenhouse gases or from a foreign trading system) and there would be virtually no incentive to reduce these emissions. Of course, zero cost credits might also be available through the foreign trading system if large quantities of Russian hot air were put on

Table 5. Effects of Credits, Phase I and II Targets, Except as Noted (in 1997 dollars)

		\$/ton CO_2-e [\$/ton C-e]		
Scenario	**Cost**	**2010**	**2015**	**2020**
(6) No Banking, 0-cost credits to 15 and 10% limits	Price	0 [0]	49 [180]	62 [228]
	Welfare Cost (%)	0.00	0.30	0.36
(7) Banking, 0-cost credits to 15 and 10% limits	Price	20 [73]	26 [95]	34 [125]
	Welfare Cost (%)	0.09	0.11	0.13
(8) No banking, non-CO_2 credits as economic	Price	4 [15]	34 [125]	43 [158]
	Welfare Cost (%)	--[a]	0.19	0.22
(9) Banking, non-CO_2 credits as economic	Price	17 [62]	22 [81]	28 [103]
	Welfare Cost (%)	0.07	0.09	0.11
(10) No Banking, CO_2-only, credits from EU trading	Price	17 [62]	47 [172]	54 [198]
	Welfare Cost (%)	0.05	0.46	0.57
(11) No Banking, CO_2-only, credits from Annex B trading	Price	8 [29]	26 [95]	32 [117]
	Welfare Cost (%)	0.05	0.37	0.47
(12) Phase I indefinitely, banking, non-CO_2 credits	Price	8 [29]	10 [37]	13 [48]
	Welfare Cost (%)	0.02	0.02	0.02

[a] Rounds to zero.

offer, or through the domestic exempt sector's credits if reference levels for non-CO_2 reductions were set very generously.

The results for the no banking case (scenario 6) shows that the 15% credit allowance essentially makes the cap non-binding in 2010; that is, in the reference emissions are growing by less than 15%. The tightening of this limit to 10% and continued growth in emissions leads the cap to bind in 2015 and after. Even though the Phase I cap is not binding by itself, under the banking provision entities would abate in Phase I to bank the allowances for later years, as shown in scenario 7. Thus, we end up with a price of $20 per ton CO_2-e in 2010 with banking.

We then considered non-CO_2 greenhouse gases as a source of credits. Here we constrained the non-CO_2 greenhouse gases at the reference emissions in each year and allowed any reductions from this reference to be treated as credits. This is easy to do in a modeling exercise because we can easily produce a scenario with and without a policy constraint. In reality, implementation would require an accurate projection for each entity, and essentially would require forcing each entity into the credit system to avoid leakage. Of course as we have constructed the case the system would operate like allowance trading. It therefore does not capture the extra cost and problems associated with establishing a reference level of emissions from which reductions would be calculated. In evaluating the SO_2 trading system, Ellerman *et al*. (2000) found that the transparency of trading allowances rather than reductions was one the reasons why that system worked well.

These scenarios (8 and 9) show that potential credits from non-CO_2 greenhouse gases are substantial and would exceed the 10% limit in 2015 and later. In these cases, we have not explicitly enforced the limits, but we can compare the result to scenarios 6 and 7 to see whether the limits are exceeded. Since scenario 6 has a zero price, we can see that the non-CO_2 greenhouse gas no-banking scenario 8 has a higher price, and thus has not exceeded the 15% limit. However, in succeeding years the price is lower than in scenario 6, and similarly the banking scenario prices are lower in all years than in scenario 7. Thus, not all of these reductions could, in fact, be credited under the current provisions of the Act. We should note, however, that this result may depend on our simplifying the coverage of the cap-and-trade system. We assumed all non-CO_2 greenhouse gases would enter as credits, whereas methane (some sources, such as from fossil fuel production), and the hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride would in reality fall under the cap. We also considered non-CO_2 greenhouse gas credits under a scenario where the Phase I targets remain through to 2020, with banking. Results are shown for this case under scenario 12 in Table 5, and, to see the specific effect of adding credits, these results can be compared to scenario 2 in Table 4. In this scenario, the initial CO_2-e price is $8/ton and it rises to $13/ton in 2020. The welfare cost rounds to 0.02% in all years, the least costly policy scenario we considered. This is about $15 to $20 per household per year.

Scenarios 10 and 11 consider the possibilities of linking with a foreign trading system. Scenario 10 estimates the effects of linking to an EU-wide trading system. For these purposes we assume a cap-and-trade system covering the entire EU economy, rather than the limited sectoral coverage that is actually being developed. As noted earlier, the problem for analyzing the proposed EU system is that the cap for these sectors has not been specified. Here we assume the EU is meeting its Kyoto target domestically. We have further assumed that other Annex B Parties achieve their Kyoto targets domestically. The interesting result here is that the CO_2-e price falls as a result of trading compared with case 3—the U.S. is an allowance buyer—but we do not see a reduction in welfare costs, instead they increase slightly. One reason is that this case is not directly comparable to scenario 3. The difference is that in scenario 3 the Annex B parties were meeting the target with trading and, as discussed earlier, there was little oil market effect because not much reduction in CO_2 emissions is required. When Parties meet the target without trading there are significant oil market effects, with the world oil prices falling. With lower world oil prices, the U.S. consumed somewhat more oil and therefore it needed to reduce more to meet the cap than in scenario 3.

We ran the directly comparable case, no trading among Annex B parties and no U.S. trade with the EU, to check whether there were indeed gains from international trading if we made a direct comparison. There are slight gains in scenario 10 compared with the welfare losses in that scenario. The gains, however, are of only a few percentage points, far smaller than the gains we observe from the domestic credit systems. The reason is that, in a trading system, the buyer pays the market-clearing price for all allowances, even when the marginal cost of some of the abatement is much less than the market-clearing price. The extra amount above the cost of each unit of abatement is an economic surplus transferred from buyer to seller. With international trading, and the U.S. buying, this economic surplus is lost to the U.S. economy as it is transferred abroad. In the domestic credit system, economic surplus is also paid from allowance purchasers to the credit sellers, but it is a transfer that occurs between domestic parties and so it is not lost from the U.S. economy.

One can also observe the surplus transfer effect in scenario 11. In this case, scenario 3 is directly comparable. In both cases, there is Annex B-wide trading. When the U.S. trades with this system, the allowance price fall substantially. There are welfare benefits but they end up rounding to zero in 2010 and are only 0.12 percentage points in 2015 and 2020. This can be contrasted with the 2015 result in scenario 7 where credits are obtained domestically. Coincidentally it has the same CO_2-e price as scenario 11 in 2015. The welfare gain, compared with scenario 3 in that year from the lower CO_2-e price is 0.38 percentage points.

4.3 Sensitivity to GDP and Emissions Growth Projections

Economic growth (and as a result emissions growth) is variable and uncertain. Over the longer term the U.S. has an average annual growth rate of GDP 3.4% (1959-99) but annual growth rates for a single decade were as low as 2.4% (1972-82) and as high as 4.4% (1959-69).[6] Average growth over a decade can be highly dependent on choice of endpoint. Coincidentally, we can now look back to the year 2000 and see that that was near the peak of a boom cycle: to make up for little growth over the past few years, growth in the remaining part of the decade will need to be more rapid than average. The U.S. Department of Energy's Energy Information Administration (EIA) reference GDP growth projection in the 2003 Energy Outlook averaged 2.9% per year from 2000 to 2010 (US DOE, 2003). For the previous scenarios we have benchmarked growth in the EPPA model to that level, and also adjusted energy efficiency improvements to get similar emissions growth as in the EIA forecast. Costs of a cap-and-trade system are quite sensitive to the baseline projection of growth in emissions. To study this sensitivity we have altered EPPA GDP growth to generate emissions scenarios very similar to the EIA high and low growth emissions scenarios. We then introduce the Phase I and Phase II caps. We do not introduce banking in these scenarios, but based on the previous results the general implications of banking can be easily deduced.

In **Table 6** we present results showing how the economic cost depends on the emissions growth assumptions. In the low growth scenario, both the CO_2-e prices and the percentage loss in economic welfare are 20% to 30% lower compared with the comparable scenario 3 with reference growth in emissions. Of course, with lower growth the absolute level of economic consumption is lower and so the absolute cost is reduced even further. Compared to the costs using reference growth assumptions, the costs with high emissions growth rise by about 20% to 25%, and rise more than that in terms of the percentage welfare cost. In this case, of course, future welfare and consumption are higher because of the rapid GDP growth and so the absolute increase in cost is greater than the increase in the percentage cost. In the end, of course, the economy and consumers would be in much better shape with high economic growth and high mitigation costs than with low economic growth and low mitigation costs. These scenarios indicate, however, how sensitive estimates of the carbon price and welfare costs of a policy are to growth projections.

Other factors also would likely contribute to uncertainty in costs, such as availability of technology, energy prices, and changes in consumers' habits, but in sensitivity analysis, by far

Table 6. Effects of Varying Economic and Emissions Growth in the U.S. (in 1997 dollars)

		\$/ton CO_2-e [\$/ton C-e]		
Scenario	**Cost**	**2010**	**2015**	**2020**
(13) Low growth, no banking, CO_2 only	Price	12 [44]	60 [219]	70 [258]
	Welfare Cost (%)	0.03	0.40	0.44
(14) High growth, no banking, CO_2 only	Price	20 [74]	82 [300]	106 [387]
	Welfare Cost (%)	0.08	0.61	0.77

[6] Calculated from data in the U.S. Economic Report of the President, 2000, Table 308.

the most important factor creating uncertainty in emissions growth within the EPPA model is the rate of economic growth (Webster *et al.*, 2002) and reference emissions, in turn, is one of the most important factors in uncertainty in costs. Also, note that we used high and low GDP growth assumptions assumed in EIA analyses, where they also produce high and low emissions scenarios. However, in the EPPA model altering the GDP growth assumptions produces a much wider range of emissions growth than in the EIA projections. These differences represent structural differences in the modeling systems. We note the difference because, had we instead re-benchmarked EPPA to the high and low emissions growth scenarios of the EIA, the emissions range (and resultant costs) would have been narrower. Ideally, a more complete uncertainty analysis would be conducted to estimate mean and standard errors of the cost estimates.

4.4 Fuel Market Effects

Table 7 shows the effects on petroleum products, coal, and gas consumption in the U.S. as projected in the EPPA model under the policy scenarios given. We provide these estimates for the banking scenarios. The results are consistent with the expected effects of CO_2 and greenhouse gas

Table 7. Effects of the Policy on Fuel Consumption (exajoules)

	Case	2000	2010	2015	2020
Petroleum Products Consumption	Ref	39	44	48	50
	2	39	39	41	42
	4	39	36	37	38
	5	39	38	40	41
	7	39	39	41	42
	9	39	40	42	43
	12	39	42	45	46
Coal Consumption	Ref	24	28	30	34
	2	24	21	21	21
	4	24	19	18	18
	5	24	20	20	21
	7	24	21	21	22
	9	24	22	22	23
	12	24	24	25	27
Gas Consumption	Ref	22	24	26	27
	2	22	23	24	25
	4	22	21	23	24
	5	22	22	23	24
	7	22	23	24	25
	9	22	23	23	25
	12	22	24	25	26

Note: The supplemental data on physical energy flows in GTAP 5.0 are from the International Energy Agency (IEA) Energy Balance Tables, and differs from EIA estimates of energy use. The difference is largest for natural gas and petroleum products. For details on the GTAP use of IEA data, see Dimaranan and McDougal (2002).

mitigation policies. In general, when compared to the reference projections coal use falls the most and natural gas the least, reflecting the relatively high CO_2 emissions from burning coal and relatively lower emissions from gas. Oil is intermediate. While the extra cost of carbon allowances for gas act to reduce consumption of it, there is also a tendency to substitute toward gas and away from coal in the electric sector. We find the net effect of these two factors to be a reduction in gas consumption compared to the reference, but a relatively small one. Compared with year 2000 use of fuels, both oil and gas consumption continue to grow in the policy cases, with the exception being scenario 4. On the other hand, coal use declines by as much as 1/3 (scenario 4). Not surprisingly scenario 4 produces the largest impacts on the fuel markets because this is the case with the tightest caps, and no credits from outside the allowance trading system. If credits are available, not surprisingly, it reduces the effects on fuel markets.

The economic value of this reduction in welfare terms can be estimated by multiplying the drop in the imported oil times the quantity of oil imports. The bounding scenarios are 4 and 12. The oil market benefits are about $2.4 billion in 2010, rising to over $4.0 billion in 2020 in scenario 4. The CO_2-e price is much lower in scenario 12, and thus the oil market effects are only $0.6 billion in 2010 rising to $1.5 billion in 2020.

4.5 The Value of Exceeding CAFE Requirements

Using the approach previously described, we estimated the potential value per vehicle if an automobile manufacturer's fleet were to exceed the CAFE standard by the 20% set out in the Act. We also calculated the marginal benefit of additional 1 mile per gallon (mpg) improvements. For this purpose we assumed average vehicle lifetime mileage for gasoline-powered cars and light trucks as used in the U.S. EPA greenhouse inventory (EPA, 2002, Table D-4). We calculated these values only for the banking scenarios, as the methodology we use assumes banking, and would be inconsistent with the non-banking scenarios. We estimated the value per vehicle sold in 2010. For future years, the value would escalate proportionally with the CO_2-e price, using our method, and assuming future targets were such that banking continued, at least for the vehicle lifetime. As seen in **Table 8**, the incentive per car to exceed the current CAFE limit by 20% ranges from about $200 to $450, and for light trucks the value ranges from about $300 to $670. The marginal value of further exceeding the standard drops to about $30 to $70 for an additional 1 mpg improvement for cars, and to about $60 to $130 for light trucks. The marginal values decline slowly as mileage improves.

As noted earlier, we have not assessed in any way the potential responsiveness of vehicle manufactures to such credits. We therefore have not estimated the potential magnitude of the credits, and the impact on the market for allowances of this provision of the Act, but it would have two effects on the market. To the extent fuel efficiency of some vehicles were improved it

Table 8. Potential Value in 2010 of Exceeding by 20% the Current CAFE Standards for Light Duty Gas Vehicles (cars) of 27.5 mpg and Light Duty Gas Trucks of 20.7 mpg

Case	2010 CO_2-e Price	Exceed car fleet CAFE mpg by 20%	*Marginal value for additional 1 mpg improvement*			Exceed truck fleet CAFE mpg by 20%	*Marginal value for additional 1 mpg improvement*		
			34 mpg	35 mpg	36 mpg		25.9 mpg	26.9 mpg	27.9 mpg
2	21	$245	$36	$34	$32	$360	$70	$64	$60
4	39	$455	$67	$63	$60	$668	$129	$120	$111
5	25	$291	$43	$40	$38	$428	$83	$77	$71
7	20	$233	$34	$32	$31	$342	$66	$61	$57
9	17	$198	$29	$27	$26	$291	$56	$52	$48
12	8	$93	$14	$13	$12	$137	$26	$24	$23

would reduce energy use and CO_2 emissions, and thus fewer allowances would be needed to cover transportation fuel sales. This would lower the allowance price. Further, since the credits could be used in lieu of allowances, they would further reduce the allowance price. Both of these effects would then lower the partial equilibrium incentive we calculated in Table 8. Use of the vehicle fuel efficiency credits is also potentially limited under the 15% (Phase I) and 10% (Phase II) limits on the use of credits. If these limits are binding then we would expect the credit market clearance price to be below the allowance market clearance price. As discussed above, a generous interpretation for sequestration credits could essentially drive the credit market clearance price to near zero, squeezing out the other credits sources, and dropping to near zero the value of these credits for more efficient vehicles.

5. SUMMARY

The Climate Stewardship Act of 2003 is the most developed proposal for instituting a cap-and-trade system in the U.S. to control greenhouse gas emissions. It would cover perhaps 90% of CO_2 emission and somewhat less of all greenhouse gas emissions. The cap for Phase I (2010-2015) would return covered sources to 2000 emissions levels, and for Phase II (2016-2020) would return to 1990 emissions. The Phase II tightening of the cap is substantial and means that the banking provision is quite important in reducing overall costs. The implication, however, is that the total cost and the CO_2-equivalent price are much higher during the Phase I period than they would have been if the cap remained at its Phase I level. We were not able to exactly replicate the specific sectoral exemptions specified in the Act, and the operation of the credit system depends on specific details of implementation. It could yield few credits, or credits at virtually no cost up to the limits in the Act. A possible reasonable bound, for reference projections of GDP and emissions growth, on the costs of the Act with Phase II tightening of the target, are those given by scenario 4 (no credits) and scenario 9 (greenhouse gas credits as economic), both with banking. Based on these scenarios an estimate of the cost of the Act as it is currently written would be a CO_2-equivalent price ranging from under $20 to nearly $40 in 2010, rising to about $30 to $65 by 2020. These estimates may be slightly low because an examination of years beyond 2020 suggests an incentive for further banking of allowances in early years for future Phases, even in the case that the target in future Phases remained at the Phase II level. The loss to the economy, measured as welfare loss (or approximate loss in macroeconomic consumption) is on the order of 0.07% to 0.25% in 2010, rising to 0.11% to 0.40% in 2020 in these two cases. This would translate to an annual loss of about $50 to $175 per household in 2010, rising to about $100 to $350 per household in 2020. In contrast, when the target does not tighten in Phase II and credits from the non-CO_2 greenhouse gases are available the average cost per household remains below $20 per year.

As is obvious from these ranges, the credit provisions of the Act could significantly reduce the costs. If not designed carefully, credits could represent no real reduction and simply a relaxation of the cap. The biggest source of such "no-reduction" credits could be sequestration. Current sequestration of 902 million tons of CO_2 per year is occurring simply because forests harvested decades ago have been left to regrow. This sequestration alone could supply the entire 15% limit on credits in Phase I of the program. And, because these do not fall under the cap it may be difficult to assure that sequestration does not remain a source of "no-reduction" credits for many years. If the entire forest sector were brought under the cap, even if it were given credit for sequestration currently occurring it would at least create an incentive for real reductions beyond the "no-reduction" credits. Also, it would establish a more complete monitoring and inventory system for entities with large forest and land holdings. Non-CO_2 greenhouse gases also could be a substantial source of real reductions, but if the "no-reduction" forest sequestration is credited these reductions will be crowded out.

The foreign credit system is largely a wild-card at this point because it remains unclear what it will look like, who will participate, and, thus, what clearing price might emerge. Apart from having a poor fix on Annex B trading prices in the first commitment period, targets and participation in the second period have not been discussed yet, and so these are highly speculative. Moreover, there is an economic advantage to the U.S. to obtain these credits from domestic sources.

Finally, as with any cap-and-trade system, assuming it is enforced and not subject to leakage, one can know with more or less certainty what the emissions will be but the costs of meeting that cap can vary greatly depending on how the economy grows. If the economy and emissions grow much more rapidly than projected in current reference projections, the costs could easily be 25 or 35% higher than our reference estimates. On the other hand, slow growth could reduce the costs of meeting the target. Of course, even with the higher costs of limiting greenhouse gas emissions, the economy would be far better off with, than without, more rapid economic growth.

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