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Climate Change Modeling Including Discussion of Administration's Analysis [1]

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# CLIMATE CHANGE

*State of Knowledge*



## **A Growth Target for Argentina: Technical Considerations**

### **Introduction**

Now that developed countries have agreed to greenhouse gas (GHG) targets in the Kyoto Protocol, some non-Annex I countries have begun to consider adoption of their own binding targets. For developing countries, adoption of such a target could yield significant ancillary economic and environmental benefits through increased energy efficiency, improvements in air quality and conservation of resources. In addition, adoption of a growth target would allow developing countries to participate in international trading of greenhouse gas allowances.

Realistic targets for developing countries must accommodate their sustainable development and accommodate some emissions growth. However, the targets should also result in real reductions in emissions below the projected business as usual (BAU) level. In response, some analysts have proposed an emission growth targets for developing countries. A growth target is a target set higher than the current emission levels, but lower than the business as usual (BAU) projection. Emission growth targets would provide for continued economic development but with a lower emission growth rate.

Determination of the appropriate level of a target is a challenging task for any country, and requires assessment of key factors such as economic output, the size and structure of the energy sector, and the cost and benefits of emission abatement. It was clear in the negotiations of the Kyoto Protocol, that Annex I countries vary greatly in their national circumstances, and that these differences influenced the cost and availability of emission abatement opportunities. Ultimately, the differentiated targets in the Kyoto Protocol, and for some countries the EU burden-sharing agreement, reflect variations in countries national circumstances. Table I illustrates these differences and countries adopted targets.

These same factors will be important for a developing country's consideration of a GHG growth target. This task may be complicated by the particular challenges facing a specific developing country. These challenges may include volatile economic growth rates, evolving energy structures, availability of long-term data resources, and limited resources. While these factors create additional difficulty in assessing an appropriate target, they may also present significant opportunities for developing countries to cost-effectively reduce emissions. This paper outlines some of the issues involved in designing a growth target for Argentina, and suggests some related areas of potential collaboration between the United States and Argentina.

### **Target Formulation**

Setting an emissions target is, in the end, a decision based on political, economic, and environmental factors. It is important to inform this decision with relevant analysis, including the projected business as usual emissions, the costs of abating greenhouse gas emissions, and the benefits of emissions abatement.

### *Business As Usual*

Projections of greenhouse gas emissions, like any long-term projection, is an inherently difficult task, since these projections are premised on several uncertain variables, such as economic growth. For example, if Argentina's emissions grew at a rate comparable to what it experienced during the 1980s, its emissions would be much lower than if emissions grew at a rate comparable to what it has experienced during the 1990s.

Projections of future emissions can be further complicated based on several other issues. First, the relationship between carbon emissions and economic growth has varied significantly over the past twenty years in Argentina. During the 1980s, carbon emissions grew while the economy contracted. However, during the first half of the 1990s, carbon emissions grew at less than half the rate of economic growth. Second, the Kyoto Protocol sets targets for a comprehensive "basket" of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>), and includes carbon sinks. Data availability on the emissions and their sources may be limited in some cases. Despite these challenges, by developing a solid understanding of the trends in the economy and the energy sector and in the other sectors that are sources to emissions of greenhouse gases other than carbon dioxide, projections of emissions can be made that can help inform decision-makers.

### *Cost of Abatement*

To evaluate the effects of a percentage reduction below business as usual, it is important to understand the costs of the opportunities to abate emissions. This task involves identifying the technologies, processes, and fuel-switching options that can reduce emissions, the costs of switching to these climate-friendly options, and the policies necessary to stimulate their adoption. The first of these is related to "bottom-up" studies that evaluate the technological potential for products and processes that can result in substituting climate-friendly capital for the existing capital stock. To gain a sense of the larger macroeconomic effects of reducing emissions, "top-down" models, such as macroeconomic and computable general equilibrium models, can assess the impact of reductions on GDP, energy prices, energy consumption, and, in the case of the macro models, employment. These models can be used to effectively develop a marginal abatement cost curve for specific energy sub-sectors or for the country as a whole. Finally, the policies under consideration to reduce emissions can also affect the evaluation of costs. Most top-down models assume that emissions are reduced cost-effectively (e.g., through a

tradable permit system or a carbon tax). However, if other approaches to reduce emissions are pursued because of other policy criteria, it is important to understand how the costs of these policies may vary from what the models may estimate.

### *Benefits of Abatement*

In addition to the costs of abatement, it is important to evaluate the benefits of abatement when considering an emissions target. First, by reducing emissions of greenhouse gases, the climate benefits from lower global emissions. However, it is quite difficult to assess the long-term climate benefits associated with emissions reductions undertaken by one country. In addition to the climate benefits, reducing greenhouse gas emissions can generate ancillary benefits, such as improved air quality. Since emissions of several local air pollutants, including particulate matter, sulfur dioxide, NO<sub>x</sub>, and volatile organic compounds are associated with the combustion of fossil fuels, any policies that reduce emissions of combustion-related carbon dioxide would also reduce emissions of these pollutants. Depending on the extent of existing pollution, and the magnitude of the emissions reduction, the public health benefits could be significant. Further, policies to stimulate sink activity could result in multiple ancillary benefits, such as watershed protection and wildlife habitat.

### *Opportunities through International Trading*

By taking on an emissions target, Argentina could participate in international trading of emissions allowances. This participation would provide two benefits. First, it mitigates the risk that a target could impose significant economic costs, because there would be the option to purchase emissions allowances at a lower cost from other countries were Argentina's reductions costly. Second, if Argentina found that reducing its emissions cost less than the international trading price for emissions allowances, it could undertake reductions beyond those specified in its target, sell these excess allowances to other countries, and earn economic gains from these trades.

### **Next Steps**

#### *Data Development*

To improve an understanding of the potential range of BAU over a 10 to 20 year horizon, it is important to develop and refine projections of economic output and of energy consumption.

Argentina may have, or may have the capacity to have, significant carbon dioxide sequestration activity. Resolving the uncertainties regarding data on carbon sinks may be helpful to better understand the costs of complying with a specified target.

The Argentine National Communication provides estimates of emissions of some, but not all, greenhouse gases. It is important to complete an inventory of all greenhouse gases, and to refine estimates of emissions from sources where there may be significant uncertainties, such as from agriculture.

#### *Abatement Studies*

To develop reliable estimates of the economic cost of carbon mitigation, a computable general equilibrium model, incorporating detailed treatment of the energy sector, or a macroeconomic model of the Argentine economy would be needed. The former is more appropriate for longer time horizons while the latter can assess short-term transition effects. Coupled with the cost of abating carbon emissions, the analytic capacity to evaluate the reduction in emissions of local air pollutants and the resulting change in public health should also be developed. The U.S. Government could work with Argentine researchers to develop this capacity.

#### *Identification of Policy Mechanisms*

The Kyoto Protocol stipulates that all Annex B countries have the discretion to implement their own policies and measures to comply with their targets. It is important for the Argentine Government to assess which policies and measures may be most appropriate for Argentina's circumstances. Possible policies include a domestic cap and trade program, a carbon tax on energy, efficiency standards, tax incentives, removal of subsidies, investment in R&D, etc. The United States could share its experiences with these various policies with the Argentine Government.

**Table I: Comparison of Annex I Country Indicators and Emission Targets**

| Country        | 1990 Carbon Intensity <sup>1</sup> | 1990 GDP per capita <sup>2</sup> | Kyoto Protocol Target | Internal EU Target |
|----------------|------------------------------------|----------------------------------|-----------------------|--------------------|
| Australia      | 2.95                               | 14,440                           | + 8%                  | NA                 |
| Japan          | 1.63                               | 14,330                           | -6%                   | NA                 |
| Hungary        | 3.16                               | 5,350                            | -6%                   | NA                 |
| Iceland        | 1.62                               | 13,360                           | +10%                  | NA                 |
| Poland         | 6.54                               | 3,820                            | -6%                   | NA                 |
| United States  | 2.93                               | 18,050                           | -7%                   | NA                 |
| France         | 1.22                               | 13,900                           | -8%*                  | 0%                 |
| Germany        | 2.03                               | 14,340                           | -8%*                  | -21%               |
| Ireland        | 2.50                               | 9,270                            | -8%*                  | +13%               |
| Portugal       | 1.55                               | 7,480                            | -8%*                  | +27%               |
| United Kingdom | 2.05                               | 13,220                           | -8%*                  | -12.5%             |

<sup>1</sup> Ton of Carbon Equivalent per \$100 Gross Domestic Product (1985 International Dollars)

<sup>2</sup> 1985 International Dollars

\* Common European Union Target

Sources: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory;  
Penn World Data Tables;  
United Nations Population Division.

### Illustrative Business As Usual Projections for Argentina

| Carbon Growth Rate, 1995-2010 | Source of Carbon Growth Rate                                                                                 | Projected 2010 BAU Emissions | Percent Above 1990 Emissions |
|-------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|
| 1.25%                         | Assumes Argentina's 1980-95 carbon growth rate applies through 2010                                          | 42.5 MMTCE                   | 42%                          |
| 2.7%                          | Assumes Argentina's 1990-95 carbon growth rate applies through 2010                                          | 52.7 MMTCE                   | 76%                          |
| 4.2%                          | Assumes the EIA carbon growth rate for Other Central/South America region for 1995-2020 applies through 2010 | 65.5 MMTCE                   | 119%                         |
| 5.0%                          | Assumes Argentina's GDP grows 5% through 2010 and carbon grows at the same rate                              | 72.8 MMTCE                   | 143%                         |

This table is based on 1995 emissions of 35.3 MMTCE (Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory). Argentina's 1995 combustion-related carbon emissions were about 18% higher than its 1990 level of 30.0 MMTCE.

## **Talking Points on EIA's Analysis of Implementation of the Kyoto Protocol**

### **September 1998**

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The Energy Information Administration's (EIA) recent analysis of the Kyoto Protocol is flawed. In modeling implementation of the Protocol, EIA fails to take into account the Protocol's flexibility mechanisms and incorrectly assumes that most businesses will fail to take action to address climate change until 2005 or later. In contrast, the Administration's economic analysis of the Protocol, released in July, demonstrates that with effective market mechanisms, meaningful developing country participation, and a realistic ramp up period, the costs of meeting the Kyoto target should be modest.

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In addition, the Administration determined that taking action to address global warming amounts to an insurance policy against a serious threat; that there are significant opportunities for low-cost reductions both at home and abroad; and that the benefits of averting climate change could be very large.

#### **The EIA Analysis Omits the Kyoto Protocol's Flexibility**

- **The EIA analysis fails to model international trading.** EIA's model is not capable of modeling international emissions trading, even though this is a critical feature in reducing the cost of compliance for the United States and other countries. By contrast, the Administration explicitly modeled international trading, as has every modeling team participating in the exercise assessing Kyoto conducted under Stanford's Energy Modeling Forum -- which includes virtually all of the leading energy economic modelers in the world. These models have demonstrated that international trading among industrialized countries could lower costs of emissions reductions by as much as half.

EIA does attempt to include scenarios which assume an amount of domestic reductions intended to mirror the level of domestic reductions implied in the model used by the Administration. However, these EIA scenarios still overstate the cost of permits because they fail to take into account the way that an international market, bidding to a single international permit price, lowers cost.

- **The EIA analysis does not account for all six categories of greenhouse gases.** This study assumes that the United States would achieve its target only through carbon dioxide reductions, even though all six major types of greenhouse gases are covered by the Protocol. In fact, the Kyoto agreement covers all six major greenhouse gases, and permits countries to achieve their targets through reductions made in any of these gases. This flexibility allows countries and companies to make reductions in the most cost-effective manner possible, reducing the cost of compliance.

#### **EIA Assumes Firms Take Little or No Action to Address Climate Change before 2005**

- **EIA assumes most firms do not anticipate climate change policies.** In EIA's study,

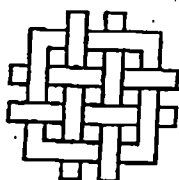
most businesses do not take action to address climate change until 2005, and therefore only have a short time until the 2008-2012 budget window to reduce emissions. Studies have demonstrated that the amount of lead time a company takes has dramatic economic implications. For example with EIA's model, a 5-year "ramp-up" (starting in 2005) would result in economic costs 65% greater than that associated with a 10-year "ramp-up" (starting in 2000). Thus, EIA's assumption that many businesses would fail to plan for the future results in higher projected costs.

- Already businesses are taking action to address climate change. For example, on September 18, British Petroleum announced their plan to reduce emissions of greenhouse gases worldwide by 10% below 1990 levels by the year 2010 and, in July, United Technologies, a \$25 billion company that produces high-tech systems, announced their plan to reduce energy consumption by 25% by the year 2007. In addition, many other companies in the manufacturing and energy production sectors are starting to develop long-term plans to reduce greenhouse gas emissions.

#### **The EIA Analysis Does Not Include Policy Elements That Will Lower Costs**

- In the Administration's analysis, additional elements of policy were recognized as having the potential to significantly decrease the costs of compliance and increase the amount of reductions that might be accomplished at home. These policies were not factored into the illustrative model the Administration cited, but were qualitatively taken into account in reaching the conclusion that the United States could meet its Kyoto target for a relatively modest cost. The EIA analysis, however, ignores elements such as forestry activities (covered under the Kyoto Protocol) and the Administration's electricity restructuring proposal, which could significantly lower compliance costs.

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## **Contributions to Climate Change**

by

Duncan Austin, Jose Goldemberg and Gwen Parker,  
World Resources Institute

*Current policy debates usually refer to annual emissions from industrial sources to assess how much developed and developing countries are contributing to climate change. An alternative measure—'stock contribution'—reflects how much developed and developing countries have actually contributed to the build-up of the atmospheric stock of CO<sub>2</sub> that has occurred since pre-industrial times. This measure accounts not only for releases from fossil fuel burning but also from deforestation and land-use change.*

### **Background**

The relative contributions of developed and developing countries to climate change have occupied center stage in recent debates over climate policy. Estimates of those contributions carry significant political weight, informing the relative level of effort that developed (Annex I) and developing (non-Annex I) countries should undertake in reducing greenhouse gas emissions. For example, in calling for scheduled commitments for emissions reductions by developing countries, the Byrd-Hagel Senate Resolution cites the fact that GHG emissions from developing countries are expected to surpass those of OECD countries by 2015. Developing countries, on the other hand, have argued that it is only fitting that developed countries take the lead on reducing emissions, given their substantially greater historical contributions.

Annual emissions, the most commonly used metric, do not accurately reflect the current contribution of developed and developing nations to climate change because the heat-trapping effect of greenhouse gases is dependent not on the annual *flow* of those gases to the atmosphere but on their total *stock* in the atmosphere. This is why stabilizing the stock, or concentration, of GHGs in the atmosphere is the ultimate goal of international efforts to avoid climate change.

### **Methodology**

The increase in stock can also be calculated as the sum of all prior CO<sub>2</sub> emissions back to 1850, with earlier emissions 'discounted' to reflect the fact that CO<sub>2</sub> is gradually removed from the atmosphere into the oceans and terrestrial sinks. Such discounting is necessary to avoid overstating the increase in the atmospheric carbon stock as a simple summing of past emissions would do. For example, between 1850 and 1990, a total of 330 GtC of CO<sub>2</sub> emissions were released globally. However, 180GtC was absorbed into the oceans and into vegetation and soils, leaving 150GtC still in the atmosphere. We denote the 150GtC as the 'total stock contribution' in 1990. Stock contribution figures for any other year can also be calculated, based on the emissions record from that year back to 1850.

The advantage of this method is that it allows one to estimate the composition of the stock contribution at any point in time, whether by region or emissions source. Each region's net addition to the atmospheric stock since 1850 — or their own 'stock contribution' — can be calculated by

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using prior emissions from that region alone. Similarly, the stock contribution attributable to industrial and non-industrial sources, such as deforestation, can also be estimated.

### **Key points:**

Using this methodology raises or reaffirms the following points:

- 1) *Annual emissions understate the contribution of developed countries to the buildup of CO<sub>2</sub> in the atmosphere.* Developed countries accounted for 61 percent of CO<sub>2</sub> emissions from fossil fuel use in 1995; but they accounted for 80 percent of the build-up of atmospheric CO<sub>2</sub> that can be attributed to fossil fuel use to 1995.
- 2) *It will be several decades before developing countries will have contributed as much as developed countries to the build-up of CO<sub>2</sub> in the atmosphere.* Trends in annual industrial emissions suggest that developing countries will be emitting as much as developed countries on an annual basis by 2015. But the stock contribution measure shows that they will not have added equal amounts to the atmosphere until 2055-2060 (industrial sources alone) or 2035-2040 (industrial and land use sources).
- 3) *The usual focus on annual industrial emissions overlooks contributions from land use change.* Of the roughly 140 GtC that has been added to the atmosphere over pre-industrial levels, about 70 percent has come from fossil fuel use. The other 30 percent has come from land use change and deforestation.
- 4) *The majority of the stock contribution from land use change has come from developing countries; and almost all future contributions from land use change are expected to come from the developing world.* Developing countries have contributed about 77 percent of the atmospheric build-up of CO<sub>2</sub> that can be attributed to land use change. Looking forward, the stock contribution from land use change will come almost entirely from developing countries.
- 5) *Developed countries have added much more to the atmospheric build-up of CO<sub>2</sub> on a per capita basis, and their 'population-adjusted' stock contributions are likely to remain far above those of developing countries throughout the coming century.* As of 1990, the per capita stock contribution from the industrialized world was nearly 8 times that from the developing world. Even as late as 2100, their contribution could be 4 times greater than that of developing countries on a per capita basis.

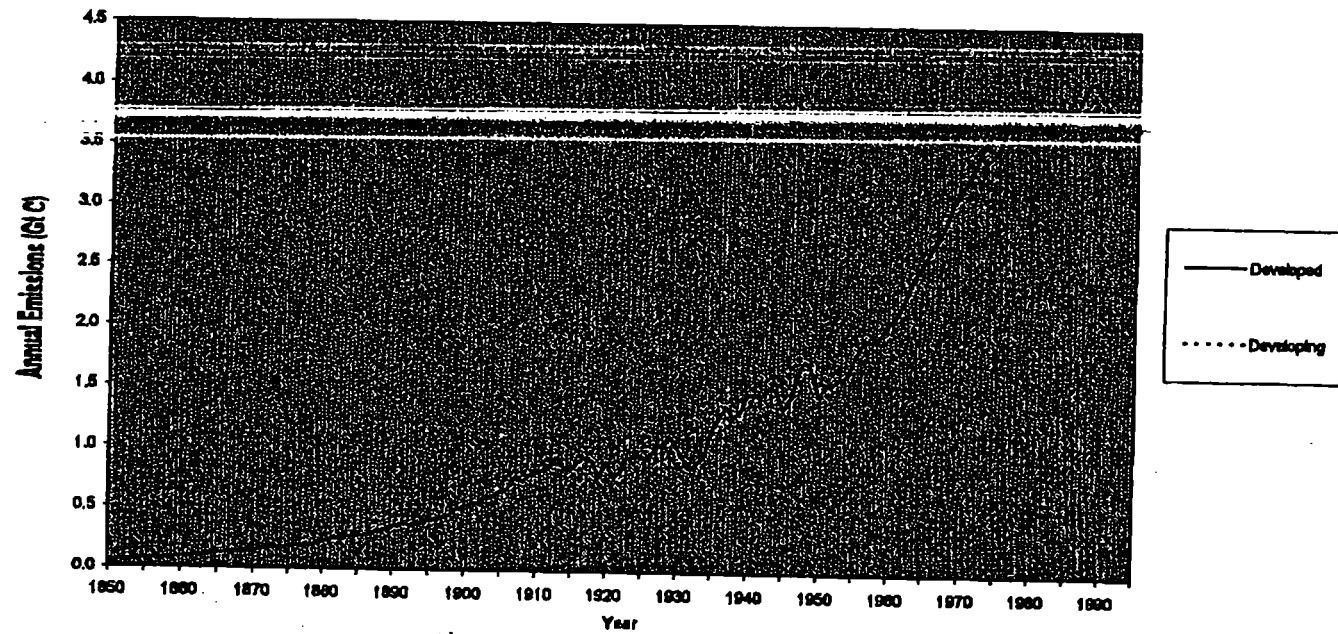
### **Policy Recommendations:**

- 1) Consistent with the principles in the Framework Convention on Climate Change and the Kyoto Protocol, developed countries should shoulder the burden of initial binding emissions reductions.
- 2) International climate policies should recognize as broad a range of land use and forestry-based mitigation options as is feasible, giving emphasis to options that further sustainable development.

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*Annual emissions from developed countries have exceeded those from developing countries, though the latter are catching up*

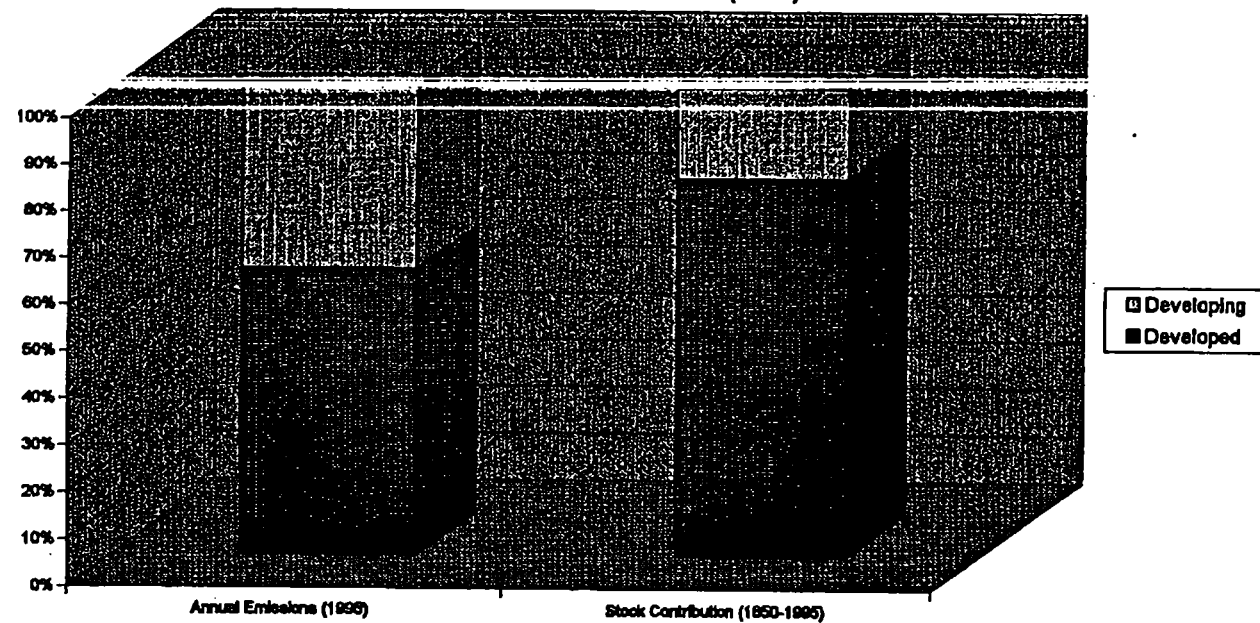
Figure 1: Annual Emissions of CO<sub>2</sub> from Industrial Sources, 1850 to 1995



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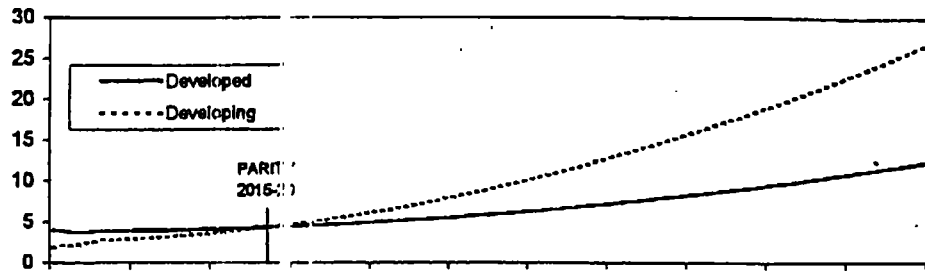
***Conventional measure underestimates developed countries'  
actual contribution to atmospheric stock***

**Figure 2: Relative contribution from industrial sources  
under different measures (1995)**

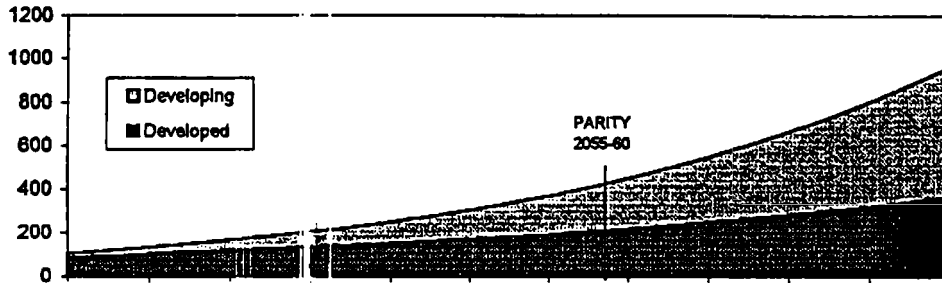


While developed countries released 61% of emissions from industrial sources in 1995, they contributed 81% of the total stock contribution attributable to industrial sources.

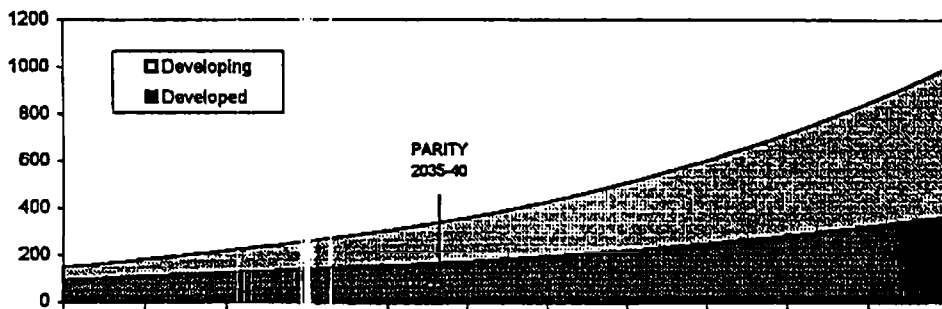
### Annual Industrial Emissions



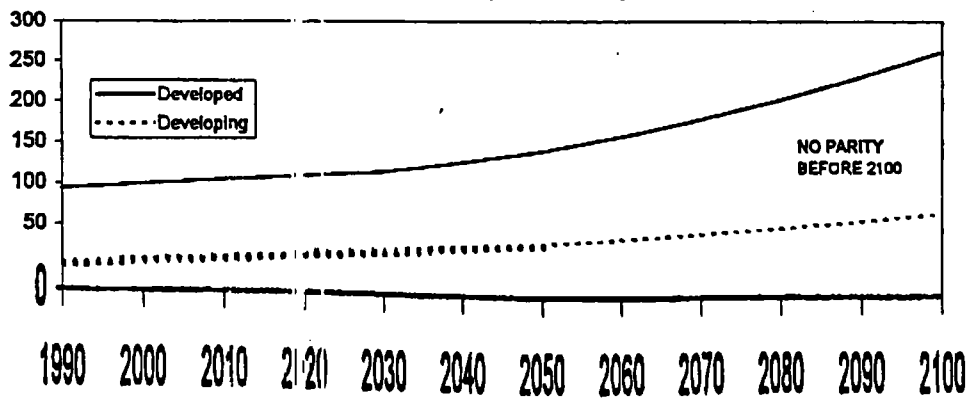
### Stock Contributions from Industrial Sources



### Stock Contributions from All Sources



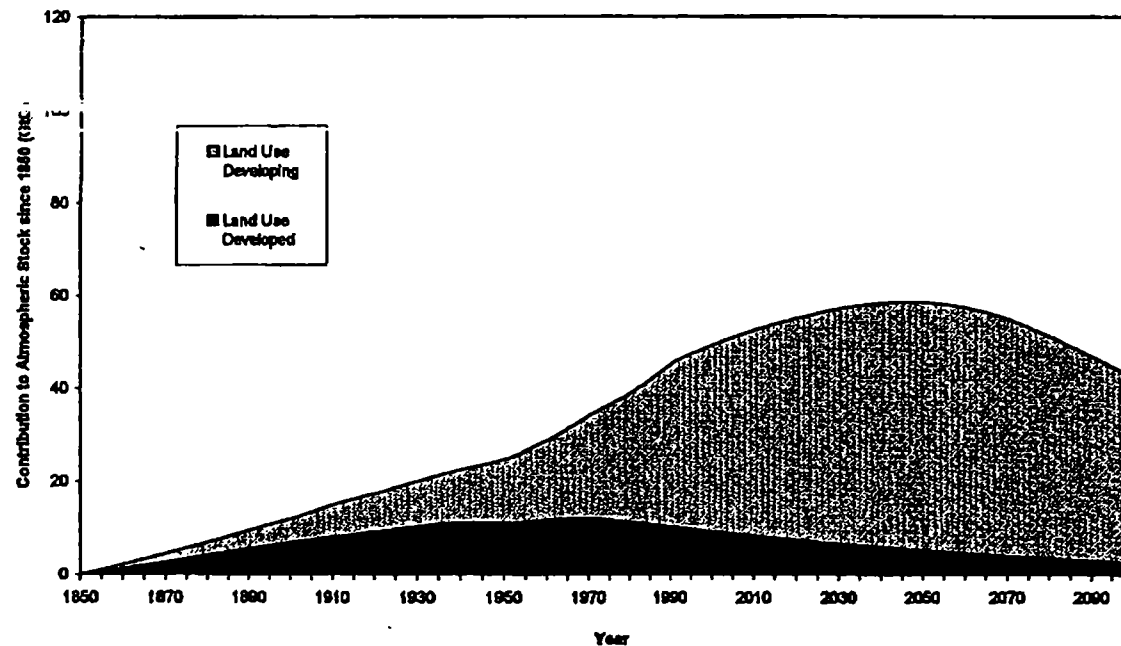
### Stock Contribution adjusted for Population



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*[Emissions from land-use change also make a significant contribution]*

Figure 4: Regional Composition of the Stock Contribution  
from Land Use Change, 1850 to 2100

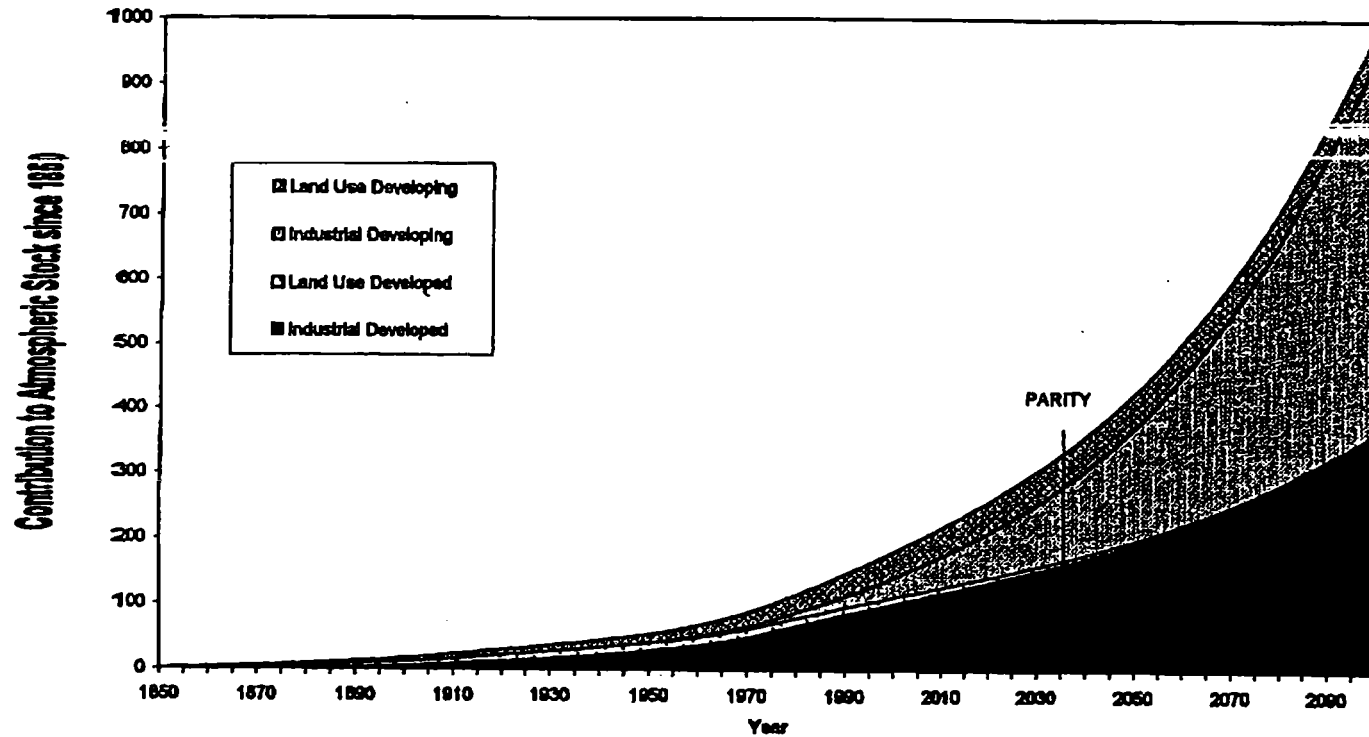


Releases from land use change, the bulk of which have come from developing countries, have made a significant contribution. [Note difference in scale with Figure 3].

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*Including land-use contributions brings cross-over date forward to 2035-2040*

Figure 5: Total Stock Contribution by Region and Source,  
1850 to 2100



When both industrial and land use sources are included, the stock contribution from developing countries reaches that of developed countries in 2035-2040.

## Talking Points for Washington Policy Seminar Talk

### Common Point

Both the Jones and Montgomery studies ignore real aspects of the Kyoto Protocol and essential elements of the President's policy:

- 1) No Annex I trading
- 2) No LDC participation (no CDM or "growth targets")
- 3) Do not include the role of other gases and sinks.

These studies reinforce and underscore the Administration's own analysis (CRA results are similar to CEA estimates given relevant assumptions) and negotiating position that flexible mechanisms are essential to responding to climate change.

### Russell Jones Analysis

Jones and Dougher use the "Kaya Identity" (emissions = carbon intensity of energy \* energy intensity of output \* per capita output \* population) to look at historical changes in the factors contributing to our emissions to show that the changes necessary to meet Kyoto commitments are "unprecedented".

- **Assumes commitment is met entirely at home.** The Kyoto Protocol includes various flexibility mechanisms that enable us to reduce emissions elsewhere at lower cost.
- **We have never tried to reduce carbon intensity of energy.** Looking at historical changes in the carbon intensity of energy is misleading. While we have tried to improve our economy's energy intensity in the past, we have never tried to improve our carbon intensity of energy. Therefore, looking at our historical experience in this field will not be indicative of what we may expect in the future.

### Charles River Associates (Montgomery) Analysis

The Charles River Associates' (CRA) June assessment of the Administration's economic analysis of Kyoto says that the costs would be higher than the Administration's estimates, under more "realistic assumptions." Again, this analysis ignores central elements of the Kyoto Protocol and of the Administration's policy. Moreover, other claims by CRA are unfounded and/or unresolved.

- **"Realistic" Trading Assumptions.** CRA claims that without trading, the costs of complying with our Kyoto target would be higher. This is precisely why the Administration advocated and won international trading and other flexibility mechanisms

in the Kyoto Protocol and is insisting on meaningful participation by developing countries. Assessments purportedly of the Kyoto Protocol that exclude trading, or assume trading constraints, are neither analyses of the Protocol nor of the Administration's position on implementing the Protocol. We are pleased to see that the CRA model, given the relevant assumptions, does generally replicate the low price effects estimated with Pacific Northwest Laboratories' SGM Model and in the Administration's economic analysis.

- **Measurement of Economic Costs.** CRA claims that the Administration's assessment of economic costs underestimates the true costs to the whole economy. First, it should be noted that this claim only concerns the definition and calculation of total resource costs given a specific permit price -- the argument does not address the estimated effects on prices. Second, CRA does not provide any specific demonstration or intuition as to what the indirect costs are, or why the direct and indirect costs would be several times higher than what is evident in the measurement of direct costs. Finally, the issue of calculating costs with energy models is a part of an ongoing debate in the economic modeling community; so the CRA conclusion, while meriting further intellectual inquiry, should not be considered representative of a definitive consensus.
- **"Rapid" replacement of coal plants with natural gas plants.** CRA claims that the Administration assumes extremely rapid replacement of coal-fired plants with natural gas plants by 2008. This is not true. The Administration's estimates of natural gas consumption and coal consumption, relative to what they would be without any efforts to reduce greenhouse gas emissions, rebut this claim. With permit prices of \$14 to \$23/ton, natural gas consumption is roughly equal to what it is projected to be otherwise, while coal consumption, though somewhat lower than it would otherwise be, is still higher than present consumption. Thus there is no rapid reduction of coal-fired capacity.
- **Technology Assumption.** CRA in May 19 testimony had erroneously guessed that the Administration's analysis must have employed "free lunch" technology optimism. The Administration analysis uses the default assumption about energy efficiency improvement used by the modelers who developed the Second Generation Model. The assumption is based on the projected energy consumption in EIA's Annual Energy Outlook.



## United States Department of State

*Bureau of Oceans and International  
Environmental and Scientific Affairs*

Washington, D.C. 20520

**URGENT**

August 13, 1998

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FROM: OES/EGC - Daniel A. Reifsnyder *DAR*

SUBJECT: Draft Responses of U/S Eizenstat to Q's from Minnesota Utility Investors

Attached are draft responses from U/S Eizenstat to six questions posed by the Minnesota Utility Investor's Quarterly Newsletter. The intention is to public U/S Eizenstat's response to these questions together with responses from Cong. Sensenbrenner, Bill Grant (Isaac Walton League in Minnesota) and Marsha Kelly (Partners for Affordable Energy) in the newsletter.

Please provide your comments (in the form of specific textual additions and deletions) or clearance by 5:00 p.m. today. Apologies for the short fuse. My telephone is: (202) 647-3935; the fax is: (202) 647-0191. My e-mail is: dreifsny @state.gov.

Note that the entire response can be only 675 to 700 words; these draft responses are already at 718 words. Therefore, additions must be balanced by deletions.

Attachment:

As stated: 4 pages

**EXPEDITE***Pls.*

**Q5. Given the international desire to reduce greenhouse gas emissions, do you see nuclear power playing an increasingly important role?**

**A5. Nuclear power -- which produces no greenhouse gas emissions -- certainly has the potential to do so. What we need to come to terms with are issues such as cost and the persistent concerns here in the United States about safety and radioactive waste disposal. (43)**

**Q6. Any final thoughts?**

**A6. Ask those who criticize the Kyoto Protocol what they would do to address global warming -- ask them to talk with their children and grandchildren about the kind of world they want us to leave behind. Ask them also whether we can afford to enter the 21st century without a reasonably priced insurance policy. (53)**

**(718 words overall)**

**Drafted:OES/EGC:DAREifsnnyder:647-3935:8/13/98**

**Clearance: OES:RPomerance  
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WHCCTF:TStern?**

**DRAFT  
(8/13/98)**

**The Kyoto Global Climate Change Treaty --  
Futuristic or Flawed?**

[Note to Reviewers: These are proposed U/S Eizenstat responses to Q's of Minnesota Utility Investor's Quarterly -- for publication along with responses from Cong. Sensenbrenner, Bill Grant (Issac Walton League in Minn.) and Marsha Kelley (Partners for Affordable Energy). Entire response must be 675 to 700 words; draft is 718 words. So additions must be balanced with deletions. Please phone (202-647-3935) or fax (202-647-0191) comments (in the form of specific proposals for additions/deletions) or clearance to Dan Reifsnyder in OES/EGC by 2:00 p.m., Thursday, August 13 -- deadline for final is COB]

**Q1. Is it futuristic or flawed and why?**

A1. The Kyoto Protocol marks an historic step in the efforts of nations to protect the Earth from the adverse effects of global warming. Acknowledging the scientific consensus that we must act now, the entire industrialized world agreed for the first time to limit or reduce its greenhouse gas emissions. Since pre-industrial times, the atmospheric concentrations of these gases (including carbon dioxide, methane, nitrous oxide) have increased dramatically. Carbon dioxide alone has increased from about 270 parts per million (PPM) to about 360 PPM, largely from the burning of fossil fuels (coal, oil and natural gas) but also from deforestation and land use change.  
(104)

The science is clear -- the relentless build up of these gases in the atmosphere will force a change in the Earth's climate system. Among other things, that change is likely to increase global mean surface temperature, raise global sea levels, and alter

*Caroline*  
precipitation patterns, (producing floods in some areas and drought in others). Changing the Earth's climate system may well increase the spread and incidence of disease (such as malaria, dengue fever, and encephalitis), produce biodiversity loss, and put millions of people at risk in low-lying and coastal areas. And these are only a few of the concerns scientists have identified. (102)

Is the treaty futuristic? Yes, in that nations have had the good sense to act without waiting to resolve every aspect of the science, without waiting for absolute proof that human actions are changing the Earth's climate system, and most importantly, without waiting to experience the most dire impacts of global warming. We can't afford to. (56)

Greenhouse gases "live" in the atmosphere for very long periods, from 100 to 200 years for carbon dioxide and up to 10,000 years for some of the "synthetic gases" (e.g., sulfur hexafluoride). So, we can't quickly or easily fix the problem. By the time that even the most die-hard skeptic is willing to acknowledge that we've got a big problem, it may well be too late -- and delaying sensible action now will be very costly. (76)

Is the treaty flawed? Only if you think we can ignore all that science has told us over the last two decades. (22)

(360 words to here)

**Q.2 What is the scientific justification for your viewpoint?**

See above. (2)

**Q3. Why were developing nations with rapidly emerging economies, such as China, India, Mexico and Brazil, exempted from having to take action under the treaty?**

A.3 They weren't exempted. Developing nations already have binding obligations under the Framework Convention on Climate Change that entered into force in 1994. Under the Kyoto Protocol, they agreed to take a variety of steps to continue the implementation of those commitments. And many are already taking important action to improve energy efficiency, switch to cleaner forms of energy, make greater use of renewables, limit deforestation, etc. (66)

Still, we believe that they should do more to participate meaningfully in the global response that is needed, particularly developing nations with rapidly emerging economies. And President Clinton has been very clear -- he will not send the Kyoto Protocol to the Senate for its advice and consent until we have made greater progress on this front. (56)

**Q4. Your view as to whether the treaty is an economic threat or opportunity. What impact do you believe it will have on the American public?**

A4. The treaty creates enormous opportunities for U.S. companies that are willing to develop new technologies, embrace new markets, and meet new challenges. Don't forget, U.S. ingenuity put a man on the moon and has risen to countless other challenges. (39)

Besides, the treaty contains important "flexibility mechanisms" -- such as global emissions trading -- that are designed to promote cost-effective reductions in greenhouse gas emissions. We pushed hard for this market-based approach, and we won. (35)

With full recourse to these flexibility mechanisms, with sufficient time to meet our target (which doesn't begin until 2008), with the ability to address all six important greenhouse gases and to count efforts to reduce emissions as well as to plant trees and to enhance other carbon "sinks", the economic impact on the American public should be small -- yet the rewards will be immense. (64)

# **The National Energy Modeling System: An Overview 1998**

**February 1998**

**Energy Information Administration**  
Office of Integrated Analysis and Forecasting  
U.S. Department of Energy  
Washington, DC 20585

This report was prepared by the Energy Information Administration, the independent statistical and analytical agency within the U.S. Department of Energy. The information contained herein should be attributed to the Energy Information Administration and should not be construed as advocating or reflecting any policy position of the Department of Energy or any other organization.

# PREFACE

*The National Energy Modeling System: An Overview* provides a summary description of the National Energy Modeling System (NEMS), which was used to generate the forecasts of energy production, demand, imports, and prices through the year 2020 for the *Annual Energy Outlook 1998* (AEO98), (DOE/EIA-0383(98)), released in December 1997. AEO98 presents national forecasts of energy markets for five cases—a reference case and four additional cases that assume higher and lower economic growth and higher and lower world oil prices than in the reference case. The *Overview* presents a brief description of the methodology and scope of each of the component modules of NEMS. The model documentation reports listed in the appendix of this document provide further details.

The *Overview* was prepared by the Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting under the direction of Mary J. Hutzler (mhutzler@eia.doe.gov, 202/586-2222), Director of the Office of Integrated Analysis and Forecasting; Arthur T. Andersen (aanderse@eia.doe.gov, 202/586-1441), Director of the Energy Demand and Integration Division; Scott Sitzler (ssitzer@eia.doe.gov, 202/586-2308), Director of the Energy Supply and Conversion Division; and Andy S. Kydes (akydes@eia.doe.gov, 202/586-2222), Senior Modeling Analyst. Detailed questions concerning NEMS may be addressed to the following analysts:

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AEO98 is available on the EIA CD-ROM and the EIA Home Page on the Internet (<http://www.eia.doe.gov/oiaf/aeo98/homepage.html>) including text, forecast tables, and graphics. To download the tables, go to the EIA FTP site (<ftp://ftp.eia.doe.gov/pub/forecasting/aeo98/aeo98tables>). To download the entire report in Portable Document Format (PDF), go to [ftp://ftp.eia.doe.gov/pub/forecasting/aeo98/reports/0383\(98\).pdf](ftp://ftp.eia.doe.gov/pub/forecasting/aeo98/reports/0383(98).pdf). Assumptions underlying the projections, tables of regional projections and other underlying details of the reference case, model documentation reports, and *The National Energy Modeling System: An Overview* are also available on the CD-ROM and the Home Page.

For ordering information and for questions on energy statistics, please contact EIA's National Energy Information Center.

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The National Energy Modeling System (NEMS) is a computer-based, energy-economy modeling system of U.S. energy markets for the midterm period through 2020. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE).

*The National Energy Modeling System: An Overview* presents an overview of the structure and methodology of NEMS and each of its components. This chapter provides a description of the design and objectives of the system, followed by a chapter on the overall modeling structure and solution algorithm. The remainder of the report summarizes the methodology and scope of the component modules of NEMS. The model descriptions are intended for readers familiar with terminology from economics, operations research, and energy modeling. More detailed model documentation reports for all the NEMS modules are also available from EIA (Appendix, "Bibliography").

## Purpose of NEMS

NEMS is used by EIA to project the energy, economic, environmental, and security impacts on the United States of alternative energy policies and of different assumptions about energy markets. Projections are made for each year from the present through 2020. This time period is one in which technology, demographics, and economic conditions are sufficiently understood in order to represent energy markets with a reasonable degree of confidence. NEMS provides a consistent framework for representing the complex interactions of the U.S. energy system and its response to a wide variety of alternative assumptions and policies or policy initiatives.

Baseline forecasts are developed with NEMS and published annually in the *Annual Energy Outlook*. In accordance with the requirement that EIA remain policy-neutral, the *Annual Energy Outlook* projections assume that all existing legislation, regulations, and policies remain unchanged. Analyses are also prepared in response to requests for special studies by the U.S. Congress, the DOE Office of Policy and International Affairs, other offices in DOE, and other government agencies. The first version of NEMS, completed in

December 1993, was used to develop the forecasts presented in the *Annual Energy Outlook 1994*.<sup>1</sup> This report describes the version of NEMS used for the *Annual Energy Outlook 1998*,<sup>2</sup> which is the first *Annual Energy Outlook* to extend the projections through 2020.

The forecasts produced by NEMS are not considered to be absolute predictions of the future. They are contingent on the key assumptions made about U.S. energy systems. Contingencies include, for example, the estimated size of the economically recoverable resource base of fossil fuels, changes in world energy supply and demand, the rate at which new energy technologies are developed and the rate and extent of their penetration into commercial markets, and existing or prospective government actions or policies.

NEMS can be used to analyze the effects of existing and proposed government laws and regulations related to energy production and use; the potential impacts of new and advanced energy production, conversion, and consumption technologies; the impacts of increased use of renewable energy sources; the potential savings from increased efficiency of energy use; and the changes in emission levels that are likely to result from such policies as the Clean Air Act Amendments of 1990 and regulations on the use of alternative or reformulated fuels and climate change policy. Other examples of energy topics that can be, or have been, addressed by NEMS include the following:

- Impacts of energy tax policies on the U.S. economy and energy system
- Responses of the energy and economic systems to changes in world oil market conditions as a result of changing levels of foreign production and demand in the developing countries
- Impacts of new technologies on consumption and production patterns and emissions
- Effects of specific policies, such as mandatory appliance efficiency and building shell standards, on energy consumption
- Impacts of fuel-use restrictions (for example, required use of oxygenated and reformulated gasoline or mandated use of alternative-fueled vehicles) on emissions, energy supply and prices, and economic growth

<sup>1</sup> Energy Information Administration, *Annual Energy Outlook 1994*, DOE/EIA-0383(94) (Washington, DC, January 1994).

<sup>2</sup> Energy Information Administration, *Annual Energy Outlook 1998*, DOE/EIA-0383(98) (Washington, DC, December 1997).

# INTRODUCTION

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- Impacts on the production and price of crude oil and natural gas resulting from improvements in exploration and production technologies
- Impacts on the price of coal resulting from improvements in productivity
- Impacts on energy prices, energy consumption, and electricity generation in response to carbon mitigation policies such as carbon fees or permit trading systems.

In addition to producing the analyses in the *Annual Energy Outlook*, NEMS has been used for a variety of DOE studies. Recent studies conducted for the Office of Policy and International Affairs and the Office of Energy Efficiency and Renewable Energy include analyses of the impacts of lower electricity prices due to industry restructuring, more rapid efficiency improvements of consumption technologies due to research and development, lower capital costs of renewable generation technologies, and an analysis of carbon mitigation policies.<sup>3</sup> Other studies include an analysis of the costs and economic impacts of oil imports for the General Accounting Office<sup>4</sup> and an analysis of carbon mitigation policies for the U.S. Environmental Protection Agency.<sup>5</sup> Two analyses were conducted for Senator Jeffords (R-VT) on open access regulatory changes and their impacts on the electricity industry<sup>6</sup> and on Senate bill 687 which proposed renewable portfolio standards and limits on carbon, sulfur dioxide, and nitrogen oxide emissions by electric generators. NEMS has also been used for EIA's own analysis of electricity industry restructuring and competitive prices.<sup>7</sup>

## Representations of Energy Market Interactions

NEMS was designed to represent the important interactions of supply and demand in U.S. energy markets. In the United States, energy markets are driven primarily by the fundamental economic interactions of supply and demand. Government regulations and policies can exert considerable influence, but the

majority of decisions affecting fuel prices and consumption patterns, resource allocation, and energy technologies are made by private individuals or companies attempting to optimize their own economic interests. NEMS represents the market behavior of the producers and consumers of energy at a level of detail that is useful for analyzing the implications of technological improvements and policy initiatives.

### *Energy Supply/Conversion/Demand Interactions*

NEMS is designed as a modular system. Four end-use demand modules represent fuel consumption in the residential, commercial, transportation, and industrial sectors, subject to delivered fuel prices, macroeconomic influences, and technology characteristics. The primary fuel supply and conversion modules compute the levels of domestic production, imports, transportation costs, and fuel prices that are needed to meet domestic and export demands for energy, subject to resource base characteristics, industry infrastructure and technology, and world market conditions. The modules interact to solve for the economic supply and demand balance for each fuel. Because of the modular design, each sector can be represented with the methodology and the level of detail, including regional detail, that is appropriate for that sector. The modularity also facilitates the analysis, maintenance, and testing of the NEMS component modules in the multi-user environment.

### *Domestic Energy System/Economy Interactions*

The general level of economic activity, represented by gross domestic product, has traditionally been used as a key explanatory variable or driver for projections of energy consumption at the sectoral and regional levels. In turn, energy prices and other energy system activities influence economic growth and activity. NEMS captures this feedback between the domestic economy and the energy system. Thus, changes in energy prices affect the key macroeconomic variables—such as gross domestic product, disposable personal income, industrial output, housing starts, employment, and interest rates—that drive energy consumption and capacity expansion decisions.

<sup>3</sup> Energy Information Administration, *Analysis of Carbon Stabilization Cases*, SR-OIAF-97-01 (Washington, DC, October 1997).

<sup>4</sup> Energy Information Administration, *The Impacts on U.S. Energy Markets and the Economy of Reducing Oil Imports*, SR-OIAF-96-04 (Washington, DC, September 1996).

<sup>5</sup> Energy Information Administration, *An Analysis of Carbon Mitigation Cases*, SR-OIAF-96-01 (Washington, DC, June 1996).

<sup>6</sup> Energy Information Administration, *An Analysis of FERC's Final Environmental Impact Statement for Electricity Open Access and Recovery of Stranded Costs*, SR-OIAF-96-03 (Washington, DC, September 1996).

<sup>7</sup> Energy Information Administration, *Electricity Prices in a Competitive Environment: Marginal Cost Pricing of Generation Services and Financial Status of Electric Utilities*, DOE/EIA-0614 (Washington, DC, August 1997).

### *Domestic/World Energy Market Interactions*

World oil prices play a key role in domestic energy supply and demand decisionmaking, and oil price assumptions are the typical starting point for energy system projections. The level of oil production and consumption in the U.S. energy system also has a significant influence on world oil markets and prices. In NEMS, an international energy module represents world oil production and demand, as well as the interactions between the domestic and world oil markets, and this module calculates the average world crude oil price and the supply of specific crude oils and petroleum products. As a result, domestic and world oil market projections are internally consistent. Imports and exports of natural gas, electricity, and coal—which are less influenced by volatile world conditions—are represented in the individual fuel supply modules.

### *Economic Decisionmaking Over Time*

The production and consumption of energy products today are influenced by past investment decisions to develop energy resources and acquire energy-using capital stock. Similarly, the production and consumption of energy in a future time period will be influenced by decisions made today and in the past.

Current investment decisions depend on expectations about future markets. For example, expectations of rising energy prices in the future increase the likelihood of current decisions to invest in developing alternative energy sources. A variety of assumptions about planning horizons, the formation of expectations about the future, and the role of those expectations in economic decisionmaking are applied within the individual NEMS modules.

### **Technology Representation**

A key feature of NEMS is the representation of technology and technology improvement over time. Five of the sectors—residential, commercial, transportation,

electricity generation, and refining—include explicit treatment of individual technologies and their characteristics, such as initial cost, operating cost, date of availability, efficiency, and other characteristics specific to the sector. In addition, for new generating technologies, the electricity sector accounts for technological optimism in the capital costs of first-of-a-kind plants and for a decline in the costs as experience with the technologies is gained both domestically and internationally. In each of these sectors, equipment choices are made for individual technologies as new equipment is needed to meet growing demand for energy services or to replace retired equipment.

In the other sectors—industrial, oil and gas supply, and coal—the treatment of technologies is more limited due to limitations on the availability of data on individual technologies. In the industrial sector, technology in the energy-intensive industries is represented by technology bundles, with technology possibility curves representing efficiency improvement over time. In the oil and gas supply sector, technology progress is represented by trend-based improvement in finding rates, success rates, costs, and the size of the resource base. Productivity improvements over time represent technological progress in coal production.

### **External Availability**

In accordance with EIA requirements, NEMS is fully documented and archived. EIA runs NEMS on three EIA RS/6000 workstations under the AIX Version 4.2 operating system. The archive file provides the source language, input files, and output files to replicate the *Annual Energy Outlook* runs on an identically equipped computer; however, it does not include proprietary mathematical libraries from an external vendor. NEMS, or portions of it, is installed at the National Renewable Energy Laboratory, other national laboratories, the Electric Power Research Institute, and several private consulting firms.

# OVERVIEW OF NEMS

NEMS represents domestic energy markets by explicitly representing the economic decisionmaking involved in the production, conversion, and consumption of energy products. For example, the penetration of a new or advanced technology for electricity generation is projected only if the technology is deemed to be economic when considering the cost-minimizing mix of fuels over the life of the equipment.

Since energy costs and availability and energy-consuming characteristics can vary widely across regions, considerable regional detail is included. Other details of production and consumption categories are represented to facilitate policy analysis and ensure the validity of the results. A summary of the detail provided in NEMS is shown below.

| Energy Activity                              | Categories                                                                                                                                                                      | Regions                                                                                                                            |
|----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Residential demand                           | Fifteen end-use services<br>Three housing types<br>Thirty-four end-use technologies                                                                                             | Nine Census divisions                                                                                                              |
| Commercial demand                            | Ten end-use services<br>Eleven building types<br>Sixty-four end-use technologies                                                                                                | Nine Census divisions                                                                                                              |
| Industrial demand                            | Seven energy-intensive industries<br>Eight non-energy-intensive industries<br>Cogeneration                                                                                      | Four Census regions,<br>shared to nine Census<br>divisions                                                                         |
| Transportation demand                        | Six car sizes<br>Six truck sizes<br>Fifty-five conventional fuel-saving technologies<br>Gasoline, diesel, and fourteen alternative-fuel vehicle<br>technologies<br>Ten vintages | Nine Census divisions                                                                                                              |
| Electricity                                  | Eleven fossil technologies<br>Seven renewable technologies<br>Conventional and advanced nuclear<br>Marginal and average cost pricing<br>Capacity expansion                      | Fifteen electricity supply regions<br>Nine Census divisions for<br>demand                                                          |
| Renewables                                   | Wind, geothermal, solar thermal, solar photovoltaic, municipal<br>solid waste, biomass, conventional hydropower                                                                 | Fifteen electricity supply regions                                                                                                 |
| Oil supply                                   | Conventional onshore and shallow offshore<br>Conventional deep offshore<br>Enhanced                                                                                             | Six lower 48 onshore regions<br>Three lower 48 offshore regions<br>Three Alaska regions                                            |
| Natural gas supply                           | Conventional onshore and shallow offshore<br>Conventional deep offshore<br>Coalbed methane<br>Gas shales<br>Tight sands<br>Canadian, Mexican, and liquefied natural gas         | Six lower 48 onshore regions<br>Three lower 48 offshore regions<br>Three Alaska regions<br>Five liquefied natural gas<br>terminals |
| Natural gas transmission<br>and distribution | Firm vs. interruptible<br>Peak vs. offpeak<br>Pipeline capacity expansion                                                                                                       | Twelve lower 48 regions<br>Nine pipeline border points                                                                             |
| Refining                                     | Five crude oil categories<br>Seven product categories<br>Thirty-two technologies<br>Refinery capacity expansion                                                                 | Three refinery regions<br>aggregated from Petroleum<br>Administration for Defense<br>Districts                                     |
| Coal supply                                  | Three sulfur categories<br>Four thermal categories<br>Underground and surface mining types                                                                                      | Eleven supply regions<br>Thirteen demand regions<br>Sixteen export regions<br>Twenty import regions                                |

### Major Assumptions

Each module of NEMS embodies many assumptions and data to characterize the future production, conversion, or consumption of energy in the United States. Two major assumptions concern economic growth in the United States and world oil prices, as determined by world oil supply and demand.

The five comprehensive, integrated cases in the *Annual Energy Outlook 1998 (AEO98)* are defined by setting assumptions that lead to a high, mid, or low economic growth rate for the domestic economy and to a high, mid, or low world oil price path. The reference case uses the mid-range assumptions for both the economic growth rate and the world oil price. Higher and lower economic growth and higher and lower world oil prices define the other four cases. The primary determinants for different economic growth rates are the growth rates of the labor force and productivity, while different assumptions on oil production capacity in the Organization of Petroleum Exporting Countries (OPEC) and non-OPEC production lead to different levels of world oil prices.

In addition to the five baseline cases, the *AEO98* includes 29 other cases that explore the impacts of varying key assumptions in the individual components of NEMS. Many of these cases involve changes in the assumptions that impact the penetration of new or improved technologies, which is a major uncertainty in formulating projections of future energy markets. Other cases include potential legislative and regulatory changes, such as electricity industry restructuring and renewable portfolio standards, changes in nuclear retirement assumptions, a sensitivity on electricity demand growth, changes to oil and gas resource assumptions, and changes to coal supply productivity and miner wages. Some of these cases exploit the modular structure of NEMS by running only a portion of the entire modeling system in order to focus on the first-order impacts of the changes in the assumptions.

### NEMS Modular Structure

Overall, NEMS represents a modeling system that simulates the behavior of energy markets and their interactions with the U.S. economy. The model achieves a supply/demand balance in the end-use demand regions, defined as the nine Census divisions (Figure 1), by solving for the prices of each energy product that will balance the quantities producers are willing to supply with the quantities consumers wish to consume. The system reflects market economics, industry

structure, and energy policies and regulations that influence market behavior.

NEMS consists of four supply modules (oil and gas, natural gas transmission and distribution, coal, and renewable fuels); two conversion modules (electricity and petroleum refineries); four end-use demand modules (residential, commercial, transportation, and industrial); one module to simulate energy/economy interactions (macroeconomic activity); one module to simulate world oil markets (international energy activity); and one module that provides the mechanism to achieve a general market equilibrium among all the other modules (integrating module). Figure 2 depicts the high-level structure of NEMS.

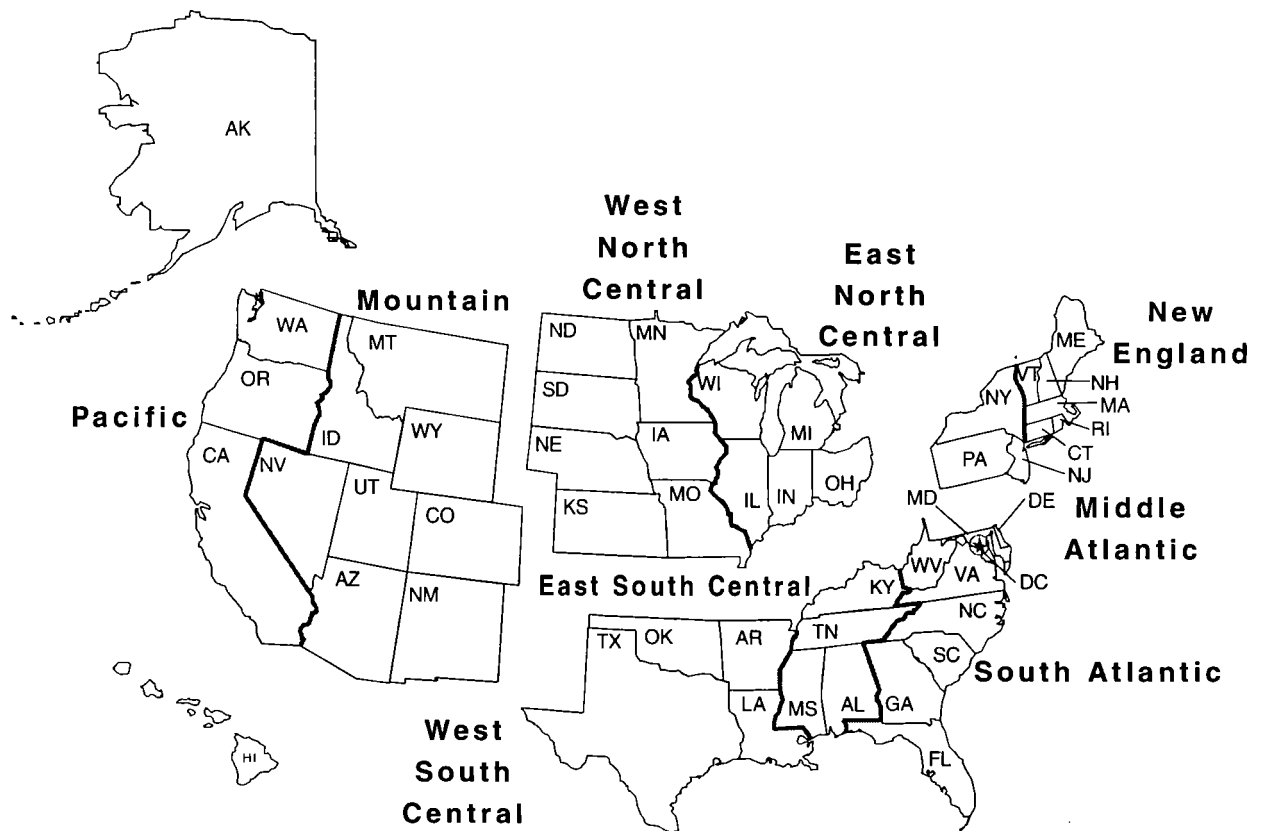
Because energy markets are heterogeneous, a single methodology does not adequately represent all supply, conversion, and end-use demand sectors. The modularity of the NEMS design provides the flexibility for each component of the U.S. energy system to use the methodology and coverage that is most appropriate. Furthermore, modularity provides the capability to execute the modules individually or in collections of modules, which facilitates the development and analysis of the separate component modules. The interactions among these modules are controlled by the integrating module.

The NEMS Global Data Structure is used to coordinate and communicate the flow of information among the modules. These data are passed through common interfaces via the integrating module. The Global Data Structure includes energy market prices and consumption; macroeconomic variables; energy production, transportation, and conversion information; and centralized model control variables, parameters, and assumptions. The Global Data Structure excludes variables that are defined locally within the modules and are not communicated to other modules.

A key subset of the variables in the Global Data Structure are the end-use prices and quantities of fuels which are used to equilibrate the NEMS energy balance in the convergence algorithm. These delivered prices of energy and the quantities demanded are defined by product, region, and sector. The delivered prices of fuel encompass all the activities necessary to produce, import, and transport fuels to the end user. The regions for the price and quantity variables in the Global Data Structure are the nine Census divisions. The four Census regions (shown in Figure 1 by breaks between State groups) and nine Census divisions are a common, mainstream level of regionality widely used by EIA and other organizations for data collection and analysis.

# OVERVIEW OF NEMS

Figure 1. Census Divisions



**Division 1**  
**New England**

Connecticut  
Maine  
Massachusetts  
New Hampshire  
Rhode Island  
Vermont

**Division 2**  
**Middle Atlantic**

New Jersey  
New York  
Pennsylvania

**Division 3**  
**East North Central**

Illinois  
Indiana  
Michigan  
Ohio  
Wisconsin

**Division 4**  
**West North Central**

Iowa  
Kansas  
Minnesota  
Missouri  
Nebraska  
North Dakota  
South Dakota

**Division 5**  
**South Atlantic**

Delaware  
District of Columbia  
Florida  
Georgia  
Maryland  
North Carolina  
South Carolina  
Virginia  
West Virginia

**Division 6**  
**East South Central**

Alabama  
Kentucky  
Mississippi  
Tennessee

**Division 7**  
**West South Central**

Arkansas  
Louisiana  
Oklahoma  
Texas

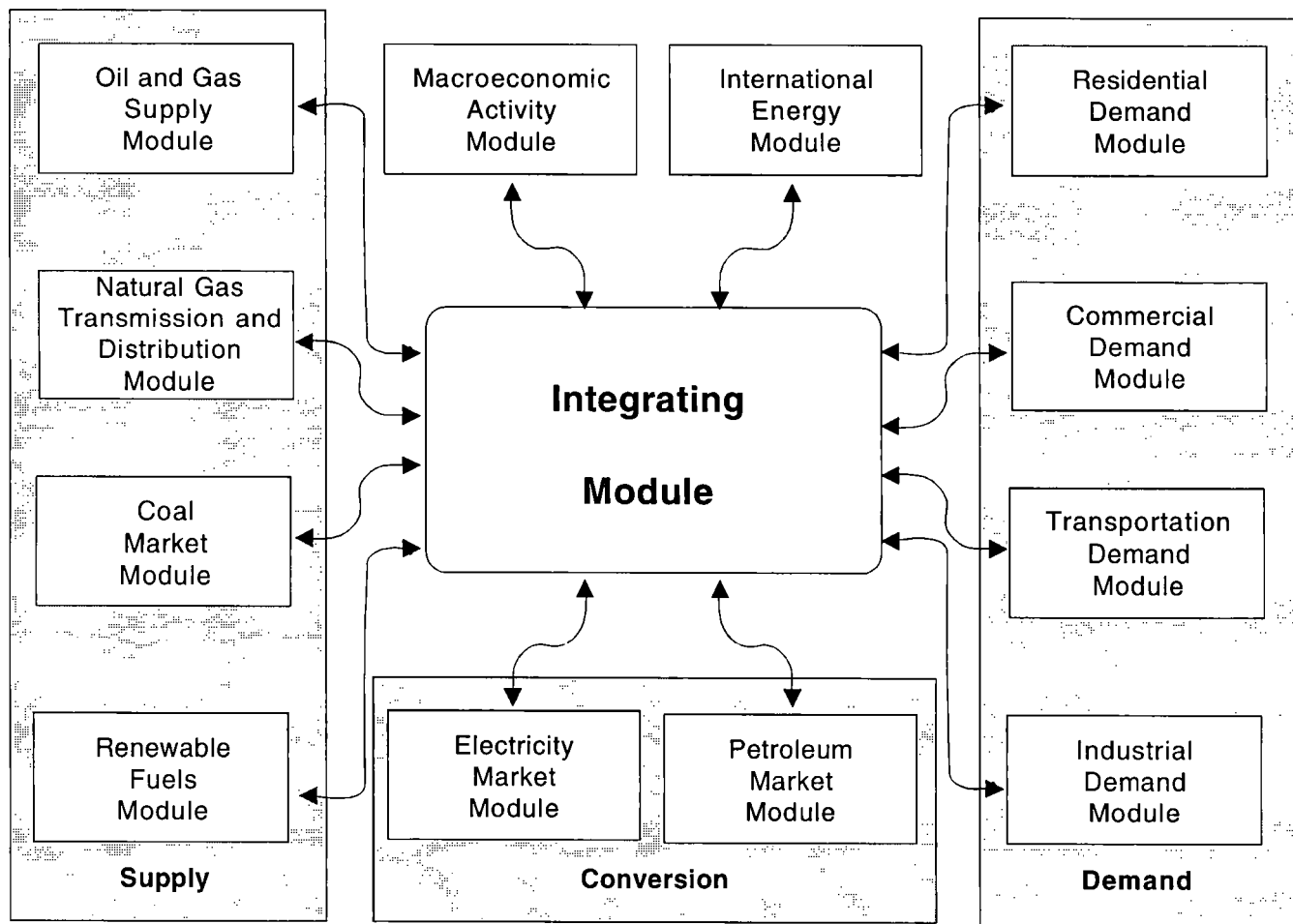
**Division 8**  
**Mountain**

Arizona  
Colorado  
Idaho  
Montana  
Nevada  
New Mexico  
Utah  
Wyoming

**Division 9**  
**Pacific**

Alaska  
California  
Hawaii  
Oregon  
Washington

**Figure 2. National Energy Modeling System**



## Integrating Module

The NEMS integrating module controls the entire NEMS solution process as it iterates to determine a general market equilibrium across all the NEMS modules. It has the following functions:

- Manages the NEMS Global Data Structure
- Executes all or any of the user-selected modules in an iterative convergence algorithm
- Checks for convergence, while reporting variables that remain out of convergence
- Implements price relaxation between iterations to accelerate convergence
- Updates expected values of the key NEMS variables.

The integrating module executes the demand, conversion, and supply modules iteratively until it achieves an economic equilibrium of supply and demand in all the consuming and producing sectors. Each module is called in sequence and solved, assuming that all other variables in the energy markets are fixed. The modules are called iteratively until the end-use prices and quantities remain constant within a specified tolerance—a condition defined as convergence. Equilibration is achieved annually throughout the midterm period, currently 2020, for each of the nine Census divisions.

In addition, the macroeconomic and international modules are executed iteratively to incorporate the feedback on the economy and international markets from changes in the domestic energy markets. The convergence tests check the stability of a set of key macroeconomic and international trade variables in response to interaction with the domestic energy system.

## OVERVIEW OF NEMS

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The NEMS algorithm executes the system of modules until convergence is reached. The solution procedure for one iteration involves the execution of all the component modules, as well as the updating of expectation variables (related to foresight assumptions) for use in the next iteration. The system is executed sequentially for each year in the forecast period. During each iteration within a year, each of the analytical modules is executed in turn, with intervening convergence checks that isolate specific modules that are not converging. A convergence check is made for each price and quantity variable to see whether the percentage change in the variable is within the assumed tolerance. To avoid unnecessary iterations for changes in insignificant values, the quantity convergence check is omitted for quantities less than a user-specified minimum level. The order of execution of the modules may affect the rate of

convergence but will generally not prevent convergence to an equilibrium solution or significantly alter the results. An optional relaxation routine can be executed to dampen swings in solution values between iterations. With this option, the current iteration values are reset partway between solution values from the current and previous iterations.

Because of the modular structure of NEMS and the iterative solution algorithm, any single module or subset of modules can be executed independently. Modules not executed are bypassed in the calling sequence, and the values they would calculate and provide to the other modules are held fixed at the values in the Global Data Structure, which would be the solution values from a previous run of NEMS. This flexibility is an aid to independent development, debugging, and analysis.



robert\_stavins @ Harvard.Edu  
10/02/98 01:58:26 PM

Record Type: Record

To: Byron Swift <swift @ eli.org>  
cc: hahn @ erols.com, quindi @ usa.net  
Subject: Re: (Fwd) RE: Comments

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Thanks much for your note. Could you please send me a copy of your paper?

Rob Stavins

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"Byron Swift" <swift@eli.org> on 10/02/98 01:53:03 PM

To: rstavins@fido.harvard.edu  
cc: (bcc: Robert Stavins/FS/KSG)  
Subject: (Fwd) RE: Comments

Dr. Stavins:

I had a couple thoughts on the paper you presented at AEI, and Dallas encouraged me to send them on to you. They arise in the context of my workign as co-author of the UNCTAD paper just released on greenhouse gas trading framework:

a) I think the distinction between ITQs and ITPs is useful, as many

countries, i.e European, may never embrace allowance type trading at a private firm level, in which case one is left with ITQs. We have already

seen EC countries trading country obligations in defining their country caps under the EC bubble, and I would think they would take this a step further and trade ITQs with other nations. The problem with this is that it would limit inter- or intra-firm trading to credit programs, with their high transaction costs, and there will be much lower levels of trading and hence cost reductions.

b) my second point concerns liability. In discussions with others, especially Europeans, re. the UNCTAD paper, I found myself unable to support my own strong preference for seller liability for Article 17 Emission Trading, due to particular problems under the Protocol. I think a robust trading system depends on seller liability, a view borne out by the history of emissions trading in the US.

However, seller liability relies on a strong compliance system, and in particular an air-tight system for getting a ton of exceedances replaced so the environment is made whole. This turns out to be difficult under the Kyoto Protocol, due in large part to the long 5 year budget period - there are no annual budget periods. That means the tried-and-true method for getting a ton back - taking it out of the source's next budget period - is weak, as we don't even know if there is a next budget period after Kyoto, nor what limits it will have.

I think this point re. the importance of the lack of annual budget periods re. compliance, should be emphasized in discussions of the topic. Although the single 5 year budget period is itself a "flexibility" mechanism, it has the negative aspect that it eviscerates the enforceability of the other flexibility mechanisms, and so turns out to be a bad idea, and may make it difficult to implement a robust allowance trading program, in particular a seller liability one.

The situation is not lost, however, as possibly, annual budget periods could be made a requisite of entering a trading system, or at least could be included in a post-Kyoto agreement for 2012-2017.

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To: Bob Hahn and Robert Stavins  
Fr: Dallas Burtraw  
October 2, 1998

Re: Further comment on your paper and AEI presentation - Liability

Dear Bob and Rob:

I am writing to submit a further comment on your paper with respect to the issue of liability. This issue is attracting a great deal of attention in climate policy discussions. Listening to your presentation at AEI, and subsequent detailed conversations with John Palmisano, Mike Toman, and Byron Swift (ELI) who were all in attendance, led me to try to forge a synthesis of the ideas I have heard and seen. Since I believe your paper will be influential when it is issued, I would like to contribute this perspective for your consideration.

(Indeed, working only from overheads I may have attributed to you views that are not your own, and I am sorry about that. So you may already have bought, or have rejected, aspects of the perspective I offer.)

John Palmisano offers a very thorough argument in favor of buyer liability. I have attached his paper to my e-mail along with this message. I think many people misunderstand the institutions that would be involved in buyer liability; and I have. I have seen influential economists wince at the suggestion of how buyer liability might work. John has a much more sophisticated model in mind than occurred to me when first hearing of buyer liability. In brief, John proposes an analogy to unsecured debt and/or sovereign national debt, both of which are actively and sometimes significantly discounted in financial markets. The given in John's model is that "carbon credits" of some type will be denominated by country. A reasonable approach by an initial or second-hand purchaser in a buyer liability regime would be to pay a price for a credit that reflects the risk premium for a country. That premium would be visible in an international market and the result of research activity by accounting firms, third parties, etc.

I think John is right that at some level this could work. The question in my mind is what is the right place for buyer liability, and what long-term institutions and incentives does it spawn.

Byron Swift is co-author of the UNCTAD paper that supports seller liability. The arguments in favor of seller liability are easiest to make from an armchair perspective. This approach would treat permits as a homogenous good in an international market and seemingly this homogeneity would be helpful to trading. Nations would be accountable for meeting their own budget net of permit sales and purchases.

At AEI I argued in favor of seller liability because I think it reflects an institutional arrangement that is much simpler and has the potential for much greater liquidity. I argued that enforcement is not the major problem facing a climate policy regime; participation is the major problem. Hence I feel that we need to design institutions that will entice players in the stands to come onto the field and enter the game. The enticement is the transfer of revenues that would accompany sales from these (developing nation) players. Also, this provides incentives and a mechanism for the emergence of financial and democratic institutions that complement the development of free markets and international trade. With respect to enforcement, I place attention on monitoring and accounting. I think enforcement largely takes care of itself under the conditions that (a) annual budgets be established within the flexibility mechanism and (b) participation in subsequent years be contingent on performance in a given year. Given these conditions, participants have the incentive to comply and that is far more important than specific penalties such as pay-back ratios, etc.

I note that the Kyoto Protocol does not have annual budget cycles. Also, John cautioned me that under WTO the type of trade sanction (exclusion from trade in subsequent periods) is not allowed. Therefore, he asks how I can sustain the notion of seller liability?

I view both these conditions as requisite characteristics for a successful seller liability program. I imagine that such a program may not necessarily encompass all Annex 1 (Annex B) countries. Instead, I imagine that the condition for participation for such a seller liability regime be thoroughly worked out and then sanctioned as part of the flexibility mechanism. Individual countries within Annex B could opt into this subset of countries that voluntarily submit to these and other rules and this qualifies them to participate in a market with seller liability, and they are allowed to do so only as long as they meet the conditions. It could be that this liquid permit market broadens to encompass all of Annex B; I would certainly hope so. The lingering question for me is whether there is any potential institutional reality to the picture I am illustrating. If there is, I think it a compelling model.

Byron wrote to me his view. He said that he found his own strong support for seller liability somewhat unstable. He believes that a robust trading system depends on seller liability, as born out in the history of emission trading in the US. However, seller liability relies on a strong compliance system. "This turns out to be difficult under the Kyoto Protocol, due in large part to the long 5 year budget period... This means the tried-and-true method for getting a ton back – taking it out of the source's next budget period – is weak."

Byron's concern reinforces my own. The emergence of some kind of annual compliance period seems essential. It could either emerge as part of COP negotiations, or else the COP could establish conditions for a subset of countries to qualify to initiate real international permit trading (ITPs in your vocabulary), and that subset could develop rules that include an annual allocation within the COP five year budgets.

Finally, let me turn to Mike's view that led me to a synthesis of these opinions. Mike feels there is a role for both buyer and seller liability. A liquid market would best be served by seller liability and would best serve the interest of developed countries for whom accounting and monitoring can be expected. This group probably consists of a large part of Annex I countries but not necessarily all. Mike reserves buyer liability for "getting trades started" through joint implementation (JI) and clean development mechanism (CDM) projects. John also invokes the need to "get trades started" as a justification for buyer liability. Mike's idea applies this in a more discriminatory fashion by reserving the potentially more cumbersome institution of buyer liability for where it is most needed.

In summary, I foresee a mixed institution of trading to accommodate the need for rapid, low transaction exchanges among parties in the developing world, and the need for greater scrutiny of trading involving parties that may have less well developed institutions. This hybrid system could sustain both seller liability and buyer liability obligations for countries in alternative standing within the COP.

I think I speak for all of the people I reference in saying that your own taxonomy of international tradable quotas (ITQs) and international tradable permits (ITPs) is a valuable contribution. I argued, as Mike has suggested in previous writing, that an ITQ system is really an allocation scheme that rests on international negotiation and foreign aid. It is not a trading system. Ultimately we want to see ITPs emerge as a meaningful institution, hopefully as soon as November of this year.

Thank you for taking the time to read this long note and I welcome further dialogue.  
Best regards, Dallas.

## **A Growth Target for Argentina: Technical Considerations**

### **Introduction**

Now that developed countries have agreed to targets in the Kyoto Protocol, some non-Annex I countries have begun consideration of their own binding targets. The approach used in setting targets for Annex I countries -- a fixed proportion of a historic year's emissions -- would be very restrictive on developing countries expecting high rates of economic growth. Realistic targets for developing countries should reflect their projected development and accommodate some emissions growth. However, the targets should also reflect real reductions in emissions below the projected business as usual level.

Recognizing that developing countries' emissions should be permitted to grow, some analysts have proposed "growth targets" for developing countries. A growth target is a target set higher than the current emission level, but lower than the business as usual (BAU) projection. Growth targets provide for continued economic development but with a lower emission growth rate. In addition, adoption of a growth target would allow developing countries to participate in international trading of greenhouse gas allowances. This paper outlines some of the issues involved in designing a growth target for Argentina, and suggests some related areas of potential collaboration between the United States and Argentina.

### **Target Formulation**

While setting an emissions target is, in the end, a political decision, it is important to inform this decision with relevant analysis. To facilitate the decision-making, analysis should be conducted on several issues, including the projected business as usual emissions, the costs of abating greenhouse gas emissions, and the benefits of emissions abatement.

#### *Business As Usual*

Projections of greenhouse gas emissions, like any long-term projection, is an inherently difficult task, since these projections are premised on several uncertain variables, such as economic growth. For example, consider these three illustrative cases based on 1995 carbon emissions from fossil fuel combustion of 35.3 MMTCE.

| Growth Rate, 1995-2010 | Source of Growth Rate                                                                                        | Projected 2010 Emissions |
|------------------------|--------------------------------------------------------------------------------------------------------------|--------------------------|
| 2.7%                   | Assumes 1990-95 carbon growth rate applies through 2010                                                      | 52.7 MMTCE               |
| 4.2%                   | Assumes the EIA carbon growth rate for Other Central/South America region for 1995-2020 applies through 2010 | 65.5 MMTCE               |
| 5.0%                   | Assumes GDP grows 5% through 2010 and carbon grows at the same rate                                          | 72.8 MMTCE               |

The highest projection is nearly 40% greater than the lowest projection in this illustration. Of course, the lower bound reflects an emissions growth rate that occurred while the Argentine economy grew at 5.7%, so if the rate of economic growth were lower than this between 1995 and 2010, the lower bound even could be too high.

Given this uncertainty, a fixed target for Argentina established in the near future would present some risks. The target could be inadvertently stringent if Argentina experienced faster economic growth than was expected, resulting in higher costs than what might have been projected. Conversely, the target could be inadvertently lax, even non-binding on an economy, if the economy grows slower than was expected, resulting in fewer actual emissions reductions (or paper tons) than what might have been projected.

Projections of future emissions can be further complicated based on several other issues. First, the relationship between carbon emissions and economic growth has varied significantly over the past twenty years in Argentina. During the 1980s, carbon emissions grew while the economy contracted. However, during the first half of the 1990s, carbon emissions grew at less than half the rate of economic growth. Second, the Kyoto Protocol sets targets for a comprehensive "basket" of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs, SF<sub>6</sub>), and includes carbon sinks. Data availability on the emissions and their sources may be limited in some cases.

To address the risks associated with establishing a target, consider a couple of options. First, Argentina could agree to a binding target that would be indexed to a set of economic and demographic variables that explain greenhouse gas emissions well. While the concept of a target would be agreed to in the near term under this approach, the target level would not actually be set until these economic and demographic variables were known for 2007. This approach, by eliminating the uncertainty associated with projecting economic performance between now and 2007, would address much of the risk of an inadvertently stringent target and the risk of an inadvertently lax target. Of course these risks could still be realized if economic performance varies significantly between the commitment period and the year(s) prior to the period. It should also be noted that some greenhouse gases may not track the same economic variables as does carbon dioxide, so multiple methodologies may be necessary to capture the entire basket of gases.

Alternatively, Argentina could agree to a binding target coupled with a "safety valve". In a sense, the combination of the target and safety valve would reflect a hybrid quantity/price approach to

reducing emissions. For example, if the cost of reducing emissions reached or exceeded a pre-specified level, then Argentina would be granted additional allowances. This would provide a ceiling on the cost of compliance. Further, since this ceiling cost would be set at some positive level, Argentina would have to undertake some emissions reduction before triggering the safety valve, thereby eliminating the risk that a target could create hot air. Of course, identifying this ceiling would be difficult, and would depend on the cost of abatement as well as the policies implemented to reduce emissions.

### *Cost of Abatement*

To evaluate the effects of a percentage reduction below business as usual, it is important to understand the costs of the opportunities to abate emissions. This task involves identifying the technologies, processes, and fuel-switching options that can reduce emissions, the costs of switching to these climate-friendly options, and the policies necessary to stimulate their adoption. The first of these is related to "bottom-up" studies that evaluate the technological potential for products and processes that can result in substituting climate-friendly capital for the existing capital stock. To gain a sense of the larger macroeconomic effects of reducing emissions, "top-down" models, such as macroeconomic and computable general equilibrium models, can assess the impact of reductions on GDP, energy prices, energy consumption, and, in the case of the macro models, employment. These models can be used to effectively develop a marginal abatement cost curve for specific energy sub-sectors or for the country as a whole. Finally, the policies under consideration to reduce emissions can also affect the evaluation of costs. Most top-down models assume that emissions are reduced cost-effectively (e.g., through a tradable permit system or a carbon tax). However, if other approaches to reduce emissions are pursued because of other policy criteria, it is important to understand how the costs of these policies may vary from what the models may estimate.

According to information provided in Argentina's National Communication, the Argentine economy is relatively carbon efficient compared to many other developing, and some developed, countries. Indeed, the carbon-to-GDP ratio for Argentina in 1990 is lower than the ratio for the United States. This low carbon-to-GDP ratio reflects Argentina's high reliance on carbon-lean and non-carbon sources of energy, such as hydropower and natural gas.<sup>1</sup> For this reason, Argentina may not have as many opportunities to reduce emissions as countries that are more coal-intensive.

### *Benefits of Abatement*

In addition to the costs of abatement, it is important to evaluate the benefits of abatement when considering an emissions target. First, by reducing emissions of greenhouse gases, the climate benefits from lower global emissions. However, it is quite difficult to assess the long-term climate benefits associated with emissions reductions undertaken by one country. Complementing the climate benefits, reducing greenhouse gas emissions can generate ancillary benefits, such as improved air quality. Since emissions of several local air pollutants, including particulate matter, sulfur dioxide, NO<sub>x</sub>, and volatile organic compounds, are associated with the combustion of fossil fuels, any policies that reduce emissions of combustion-related carbon dioxide would also reduce

emissions of these pollutants. Depending on the extent of existing pollution, and the magnitude of the emissions reduction, the public health benefits could be significant. Further, policies to stimulate sink activity could result in multiple ancillary benefits, such as watershed protection and wildlife habitat.

## **Next Steps**

### *Data Development*

To improve an understanding of the potential range of BAU over a 10 to 20 year horizon, it is important to develop and refine projections of economic output and of energy consumption.

Argentina may have, or may have the capacity to have, significant carbon dioxide sequestration activity. Resolving the uncertainties regarding data on carbon sinks is extremely important to better understand the costs of complying with a specified target.

The Argentine National Communication provides estimates of emissions of some, but not all, greenhouse gases. It is important to complete an inventory of all greenhouse gases, and to refine estimates of emissions from sources where there may be significant uncertainties, such as from agriculture.

### *Abatement Studies*

To develop reliable estimates of the economic cost of carbon mitigation, a computable general equilibrium model, incorporating detailed treatment of the energy sector, or a macroeconomic model of the Argentine economy would be needed. The former is more appropriate for longer time horizons while the latter can assess short-term transition effects. Coupled with the cost of abating carbon emissions, the analytic capacity to evaluate the reduction in emissions of local air pollutants and the resulting change in public health should also be developed. The U.S. Government could work with Argentine researchers to develop this capacity.

### *Identification of Policy Mechanisms*

The Kyoto Protocol stipulates that all Annex B countries have the discretion to implement their own policies and measures to comply with their targets. It is important for the Argentine Government to assess which policies and measures may be most appropriate for Argentina's circumstances. Possible policies include a domestic cap and trade program, a carbon tax on energy, efficiency standards, tax incentives, removal of subsidies, investment in R&D, etc. We could share the U.S. experiences with these various policies with the Argentine Government.

## Towards a Proposal for an Early Credit Mechanism

### I. BACKGROUND ISSUES

#### *Why Early Credit?*

The motivation for an early credit mechanism is threefold:

- To reduce the costs to the U.S. economy of compliance with the Kyoto Protocol. Economic costs are minimized when firms adjust more slowly over time to their required changes in production patterns, rather than suddenly in 2008. By acting early, firms can incorporate carbon considerations into their natural pattern of capital turnover.
- To provide the environmental benefit of earlier emissions reductions. While it is the ultimate concentration of greenhouse gasses in the atmosphere that determines global warming, there are still some small benefits to reductions sooner rather than later. By reducing emissions a decade or more before the end of the first commitment period, we reap these benefits.
- To build support in the business community for the Kyoto Protocol, and motivate their action.

#### *Why Should We Provide Incentives for Early Action?*

If early action will lower the costs of compliance with the Kyoto Protocol, why won't firms in the U.S. simply take these actions themselves? What is the role for a government inducement to early action? There are at least two rationales for such a governmental role.

- Catalytic Effect: Firms face two types of uncertainties about the Kyoto Protocol:
  - Uncertainty about the seriousness of these reduction targets. We cannot commit future Administrations or Congresses to the same seriousness that we have demonstrated on this topic.
  - Uncertainty about the ultimate allocation mechanism. Firms cannot be sure about how permits will be allocated in 2008: by auction or grandfathering; and, if the latter, to whom they will be grandfathered. As a result, the value of emissions reductions today is unclear: if there were definitely going to be an auction, then emissions reductions today would be of value to reduce the cost of meeting the 2008-2012 target; but if there is going to be grandfathering at the firm level, then there is no great need to reduce emissions (indeed, firm wealth may be maximized by having high emissions, to establish a baseline).

Given these uncertainties, firms may be reluctant to make investments in emissions reductions now, even if these investments are cost effective from the perspective of 2008. Thus, providing a credible early credit incentive can have a catalytic effect, promoting firms to undertake these investments despite the residual uncertainties.

- Technological Pioneering: In a context in which cost-reduction strategies are to some extent unknown and uncertain, it may be useful to induce some firms to act as pioneers, discovering what works and providing demonstration projects for other firms.

#### *How Much Early Credit?*

As is discussed below, we will cap the level of early action credit. But the overarching question is the ease of qualifying for these early credits, given the level of the cap.

- The advantage of making it easy to qualify is that it increases the extent to which firms can take advantage of this program. This could increase the base of support for climate change action in the long run. Moreover, making it easy to qualify avoids the administrative burden of the alternative, which requires the determination of whether the tons claimed are actually additional.
- The disadvantage of making it easy to qualify is that, with a given cap, it devalues the early credits that are given. This may reduce the environmental and economic gains from early credit, since there is a smaller economic incentive on the margin to undertake real action to incrementally reduce emissions. That is, to the extent that firms can qualify for actions that are not additional (producing "anyway" reductions), we reduce the value to firms who want to take truly additional actions.
- On the other hand, if we make it too difficult to qualify, then we may actually reduce total early actions to reduce emissions -- since actions with modest environmental benefits aren't rewarded.

### *Do We Prejudge the Allocation Mechanism for 2008?*

An important consideration with an early credit mechanism is whether its structure, or indeed its very existence, prejudices the allocation mechanism that we will be using in 2008.

- At this point, we want to keep our options open both as to whether there will be an auction or some other allocation system, and, if the latter, where in the production/ distribution chain the allocation will take place.
- In theory, an early credit mechanism does not prejudice the allocation structure for 2008. The mechanism will allocate *credits* redeemable for permits during the first budget period. These permits can then be traded in the permit trading system, regardless of whether the holder is at the level at which trading will occur. That is, if a utility holds an early credit, and permit redemption is upstream, then the utility will sell that credit to upstream holders of permits for its value in the trading system.
- In practice, it might be natural to infer from the very existence of an early credit system that allocation will be achieved by grandfathering at that level in the production/distribution chain. Care should be taken to make clear that the early credits are not permits, and that the early credit approach does not in fact prejudice our decisions for 2008.

## II. IMPLEMENTATION ISSUES

### *The Weak Form of Early Credit -- Do we Commit to a Pre-2008 Baseline?*

One *weak form* of early credit is to commit that, if we choose a non-auction allocation mechanism, we will choose an early year for our baseline, e.g., 1990, 1993, or 1999. This has three advantages:

- It provides automatic rewards for firms that are early actors
- It removes the uncertainty about allocation mechanism described above, which inhibits early action
- As a result, it removes any incentive for firms to resist early action because it might reduce their allocation in 2008 -- or even to raise emissions in the hopes of having more permit wealth allocated to them in 2008.

But committing today to our baseline for 2008 has at least three major problems:

- It may be politically untenable to commit today to such an enormous wealth reallocation 10 years from now.
- It may compromise our ability to choose an auction mechanism in 2008, since it will automatically create a class of opponents who feel that they already have claims on the system, and for whom this allocation is their primary reward for early action.
- It may be unwise from a policy perspective to commit now to the allocation of a valuable property right that may be critical to successfully paving the way for implementation in 2008.

Recommendation: For the latter three reasons, the general sense of the working group is that we should *avoid precommitting to the baseline year for our ultimate 2008 allocation.*

### ***A Two Part Early Credit System***

The working group recommends that we implement a two part system:

- In the first part, we will give credit for actions taken before the system is announced, for example, January 1, 1999. Since firms will already have committed the resources to take these actions, these *very early action credits* will not affect firms' decisions. Instead, the goal of very early action credit is to make good on our commitments to those who have already acted early, and to lay a foundation for a post-announcement early action system.
  - There should be a separate cap for credits for this period. This part will rely on the best available data from firms for the past, and will involve auditing firm-specific reports on emissions.
- In the second part, we will give credit for actions taken between today and 2008. This part will have its own cap, but the value of that cap may depend on the level of early credits claimed for the first period. Before the beginning of the second part, we will put into place a common data reporting system to ease the monitoring and measurement of early credit. This system will form the basis of our ultimate reporting, and possibly allocation, system in 2008.

### ***Setting the Caps***

It is clear that a cap on the total value of early credit is required to ensure that we do not today make our ultimate allocation decision for 2008. This cap becomes particularly important if there is a relatively loose definition of what activities qualify for early credit.

There are three open issues with a cap:

#### ***First Come First Served vs. "Truing Up" at End of Period***

One alternative is to provide credits which have a full, predetermined value (such as one credit equals one ton of emissions). Given a binding cap, these credits would have to be allocated on a first-come-first-served basis.

#### **Pros:**

- Provides firms certainty over the value of their actions, if they act early.
- Gives an incentive for very early action.

#### **Cons:**

- No incentive for earlier action for period ending today, since actions have been taken.
- Could create substantial inequities between firms who apply for credits only days or weeks apart, once the cap is hit.
- Going forward, this approach is incompatible with approaches other than project-by-project evaluation, and therefore is susceptible to gaming of the type described below (firms could qualify for early credit for a project in 2000, and then undo these gains with other environmentally unsound projects later).

The other alternative is to "true up" the value of credits at the end of the period, by comparing the number of credits claimed with the level of the cap.

#### Pros:

- Compatible with other evaluation approaches, such as comparing net emissions or emission rate changes over the period to a baseline value.
- Doesn't create inequities, since credits to all firms have same value.

#### Cons:

- If we go with a project-by-project evaluation approach, creates uncertainty over the value of that project.

Recommendation: The general sense of the working group is that *we should use a "truing up" approach*. A first-come-first-served approach should only be considered if we decide for other reasons to use a project-by-project evaluation methodology

#### *The Level of the Cap*

Setting the cap at a relatively high level will maximize the value of the early credit program. But, at the same time, it limits the amount of credit that we have to allocate in 2008.

- If we allocate by auction in 2008, this implies less revenue for the government at that time.
- Even if we use another allocation mechanism, there may be political or economic reasons why we want to be able to decide in 2008 how to allocate, rather than being precommitted due to an early action plan.

How large might early credit claims be? One industry estimate concludes that early credit claims are unlikely to amount to even 10% of our 2008-2012 emissions budget. Analysis based on results from Battelle's Second Generation Model (SGM) suggests that the totals could be larger. The analysis assumes that firms will undertake any early actions that make a profit, calculating that with Annex 1 trading, firms would find it profitable to undertake 1.5 billion tons of reductions between 2000 and 2007 -- about 20 percent of the permits the US will have in the first budget period.

#### *Sub-Caps and Evolution of Caps*

One could consider a separate cap for the first period (1990 or 1993 to present) and the second period (1998 to 2008).

- The first period cap should be a hard cap that is fairly modest (e.g. 3-5%). This can be informed by the above exercise.
- The magnitude of the second period cap may be informed both by the above exercise, and by what we learn from first period demand for early credit. We may want to announce a second period cap, and then let it evolve to a higher (or even lower?) level depending on the first period outcome.

**Recommendation:** The working group recommends separate caps, but has not decided on the level of those caps.

### ***The Appropriate Measure for Early Credit***

#### **Emissions Levels**

##### **Pros:**

- The level of emissions is the ultimate metric for meeting our Kyoto target.
- Could be appealing to higher-emitting industries, which present the greatest opposition to our efforts.

##### **Cons:**

- Rewards firms simply for shrinking, and penalizes firms simply for growing.
- May reward firms for reductions that would have occurred anyway.
- Potentially difficult data problems with firms that split apart or merge, and with outsourcing.
- Some potential for gaming across firms, whereby they strategically combine assets to take advantage of program with little or no real environmental benefit.

#### **Emissions Rates** (e.g. carbon per unit of output)

##### **Pros:**

- Appropriately adjusts for changes in scale of business to reward firm efforts to reduce carbon intensity.
- Can eliminate most "anyway tons."

##### **Cons:**

- Doesn't solve problems with firm definition or with potential for gaming across firms.
- Depending on the specific definition, can create measurement problems.
- Begins to build constituency around an emissions-rate approach, which is inconsistent with our obligations internationally.

#### **Project-by-Project Evaluation** (akin to JI)

##### **Pros:**

- Limits problems with defining the firm, since doesn't require firmwide baseline measurement and emissions tracking (as project is evaluated assuming no change in other firms' behavior).

##### **Cons:**

- Could be administratively unwieldy to evaluate each project for qualification for early credit.
- Ignores increases in emissions, as firms claim credits for projects that reduce emissions but at the same time don't report projects that increase them.
- Could lead to a long list of individual projects and higher transaction costs.
- Government seen as poor at picking technological winners and losers.
- Could be perceived as akin to "policies and measures" approach that the US business community opposed internationally.

**Recommendation:** The general sense of the working group is that *emissions rates are the preferred approach here*. In particular, EPA has data from several electric utilities that show that emissions levels vary widely due to factors such as production spikes and plant sell-offs, leading to inequities and potentially large amounts of "anyway tons". But we should remain open on this pursuant to consultation with other interested parties.

## ***Defining the Baseline***

**Changes from Starting Point:** Under this scenario, reductions in emissions levels or rates from some base year (e.g. from 1993) would be credited for early action.

### **Pros:**

- Provides relatively easy qualification for early credit, particularly using emissions rate metric.
- Rewards firms that recognized the President's policy directions and kept good data.

### **Cons:**

- Apart from electric utilities, historical emissions information not readily available at the firm level, making implementation during first period difficult.
- For emissions levels, this approach penalizes firms that grow, and rewards firms that shrink.
- Broad participation unlikely, and some industries would be discouraged by low baseline.

**Changes from Business As Usual:** Under this scenario, we would project business as usual trajectories for emissions levels or rates, and reward only improvements from those business as usual projections. This requires forecasting what would have occurred.

### **Pros:**

- Allows us to account for firm growth or shrinkage in using emissions levels.
- May allow us to more accurately account for "anyway" reductions that arise from natural evolution of the business, and guarantee that more additional reductions will get credit.

### **Cons:**

- Administratively an order of magnitude more difficult than simply using starting points. Very difficult to define business as usual.

**Changes from a Projected Reduction Schedule:** Some have suggested that, rather than reward firms that have simply reduced from baseline, we instead reward only firms that have reduced on a schedule that realistically moves them towards a Kyoto target. This would take the form, for example, of giving early credit only to those firms that reduce emissions rates by more than x% per year, or for firms that reduce emissions levels below a path that would take them to x% below (above) 1990 levels by 2008.

### **Pros:**

- Minimizes credit for "anyway" tons.

### **Cons:**

- Flip side of making it tough to qualify is that it reduces the number of firms that can benefit from early credit.
- Hard to determine the right baseline trajectory.
- Harder to administer than a simple change from a starting point, although probably easier than a business-as-usual approach
- Depending on how it is implemented, still may not solve the problem with emissions levels of penalizing growing firms or rewarding shrinking firms.

**Predefined set of eligible actions or technologies:** Another approach would set up a menu of actions that would be eligible to receive credit (e.g., improving the carbon efficiency of a boiler by a prespecified amount, installing a high efficiency chiller, etc.). This is the same approach that was taken in the CCTI program of tax incentives. For any action on the menu, a particular amount of

credit would be granted according to a predetermined schedule.

**Pros:**

- Easy to administer once list of actions is developed and crediting schedules established.
- With a list of actions that are clearly off the BAU path, can move towards ensuring that we are not rewarding "anyway" tons.
- Rewards specific pioneering activities.

**Cons:**

- Fundamental difficulties with picking winners. Very effective if the activities are truly incremental, but potential to err in picking activities that are too difficult to accomplish (and thus limiting appeal and total impact of program) or in picking "anyway" activities, perhaps due to interest group pressure.
- May exclude legitimate but harder to define actions, limiting participation.
- May be difficult to respond to evolution of approaches to emissions reductions with this predefined menu.
- Fails to reward innovation and creativity.

**Recommendation:** The working group has not expressed a strong preference among these options. But there is definite uneasiness among many members about picking predefined sets of eligible technologies.

### ***Hybrid Approaches***

A hybrid approach could address both the issues of defining a baseline, and setting the appropriate measure. For example:

- Firms could choose whether to use emissions levels or rates.
- If they choose emissions levels, they receive credits only for reductions in emissions below a level required to take them to 1990 levels by 2008.
- If they choose emission rates, they receive credits only for reductions in rates beyond a baseline reduction of 1% per year from the starting year.

**Pros:**

- Avoid imposing one-size-fits-all solution to menu of choices above.

**Cons:**

- Increases gaming opportunities.
- Dilutes value of early reduction credits, reducing incentive to take real actions.

### ***The Scope of Emissions Measurement***

#### ***Direct and Indirect Emissions from Production***

Firms are responsible for both direct emissions (those coming out of their stacks) and indirect emissions (those emissions occurring beyond the boundary of the firm as a result of the firm's activity). The question of whether to include these indirect emissions raises a standard tradeoff between comprehensiveness and administrability.

- Including direct emissions and only the most obvious, indirect emission sources (e.g. electricity-related emissions) may preclude cost-effective reduction opportunities, or lead to increases in emissions that are

not identified at the company level.

- For example, a company may decide to switch from trucks to rail (or rail to trucks) for shipping; in theory the associated emissions reductions (increases) should be rewarded (penalized). Similar issues arise with firms' actions to reduce employee commuting through mechanisms such as parking cash-out.
- However, as companies are required to include more sources of indirect emissions, reporting requirements will become more burdensome.
- An additional complication here is that any firm's indirect emissions are presumably another firm's direct emissions. If a producer shifts from trucks to rail, that producer will have fewer emissions, as will the trucking firm, but the rail company will have more. So any firm can be put in the position of having emissions which are their direct responsibility, but also emissions which are not. Who will make the determination that some of a firm's emissions reductions are not eligible because those reductions have been credited to another firm?

### *Emissions From Production vs. Consumption*

Firms would qualify for their own energy use in production. This covers most of the industrial/energy sector, but is not very useful for autos and other manufacturers of consumer products, who will want credits for reducing the carbon intensity of their products.

- For the auto sector, we could also consider providing credits for the carbon intensity of cars -- e.g. credits for increasing energy efficiency above CAFE levels. In practice, the auto industry might want to not even have this benefit, due to concerns about increased CAFE (as witnessed by the debate over our current proposed tax credit).
- This distinction between passive and active reductions also arises with demand side management policies of utilities. These policies will lower industrial or residential electricity use. Should the utility get credit for this reduction? Or, should credit be given to the industrial consumer? If we don't reward the utilities themselves for these activities, then we will reduce incentives for efficiency-enhancing activities that are currently a very important component of CCAP. Further, granting credit for passive reductions (e.g. for high-efficiency kilowatt hours purchased by a utility's customers) would greatly complicate the system.

Recommendation: The working group has expressed a preference for direct production-related emissions only, but recognizes the difficulties with excluding indirect and consumption-related emissions.

### *Data Issues*

#### *Defining a Firm*

For using either emissions levels or energy efficiency indicators, it is critical that the unit of observation be the entire firm, rather than sub-units (such as plants); otherwise, there is expanded potential for gaming, whereby firms submit for early credit those units that are performing well on emissions or efficiency, and do not submit those units that are not.

How should a firm be defined for purposes of an early credit program? In general, environmental regulations do not apply to firms (although enforcement does); they apply to devices located at particular plants or facilities in

a particular geographic location. In the industrial sector, regulations apply to individual facilities defined by legal property boundaries. In the electric sector, an individual electric generating unit (of which there may be several in a single plant) is usually the point of regulation. Under a voluntary program, however, focusing solely on individual facilities or units could lead to emissions leakage. As such, reporting, monitoring and verification may be required both at the facility and the firm level.

Defining a firm is not simple (which is why most environmental regulations apply to facilities). For example, a single parent firm may own several individual electric utility companies. In other cases, plants may be owned and operated by two or more different companies, or individual facilities may be jointly owned. Mergers and divestitures will make it even more difficult to track company-level emissions over time. In order to avoid leakage and obvious gaming strategies such as rearranging assets or outsourcing, it may be necessary to require firms to report any changes in ownership of facilities, or even to maintain comprehensive GHG accounting systems in order to participate in the early credit program.

It will be difficult to define rules for crediting actions taken between 1993 and 1998. With the exception of electric utilities, firm specific emissions information is limited. In addition, many firms have reported emission reduction actions on a project specific basis under Section 1605(b) of the Energy Policy Act of 1992. This program allows entities to select their own baseline for reporting and likely consists of a large number of "anyway tons."

### *Measuring Carbon Efficiency*

The basic concept of carbon efficiency is to compare carbon utilization to production. If production is measured by dollars of sales, this is fairly straightforward; but dollars of sales has a number of problems, such as the fact that changes in market prices which have nothing to do with energy or carbon efficiency will change the measured efficiency. For example, how would we account for the fact that auto prices are rising over time while computer prices are falling. If production is measured by units of sales or production, we face a new issue of how to measure units when a company's product mix may be changing.

### *Other Logistical Issues*

*Different Gasses:* We could give credits for all types of gasses, or only for CO<sub>2</sub>. Because measurement protocols exist for such gases and there are some extremely cost-effective early action opportunities, inclusion of non-CO<sub>2</sub> gasses is warranted. This would also expand the eligibility for the program to a wider set of actors.

*Sinks:* The program could include sinks, although in this instance the inclusion would have to be on a project-by-project basis, which may raise issues of consistency if we don't choose this approach for other sectors. Again, there appear to be many cost-effective opportunities for taking action, and inclusion of sinks would also expand the eligibility for the program to a wider set of actors. However, any decision must be taken with careful consideration of its implications for the international negotiations regarding sinks. Options include:

- No credits for sinks
- A limit on the amount of credit (e.g., 25%) for sink enhancement within the overall early reduction/credit program
- Equal treatment of sinks

*Interaction with CDM Early Credits:* Under the Kyoto Protocol, after the year 2000 firms can qualify for early credit for CDM activities. These credits are added to the first period budget. This can easily be integrated with the domestic early action program by separately accounting for CDM credits, giving the party involved a full emissions credit (as opposed to a credit which is worth some

fraction of a credit in 2008), and adding that credit to our budget in 2008.

Office of Economic Policy

Department of the Treasury  
Washington, D.C. 20220

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Date: 6/12/98  
Number of pages including cover sheet: 12

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From: Jon Gruber

Re: Early Credit Memo - Revision

Here is a revision of the early credit memo which reflects our meeting on Monday and subsequent comments received from a number of agencies. I have taken the liberty of adding a "recommendation" to many of the subsections. I may have been too aggressive here, and we should obviously discuss if these are indeed our consensus recommendations before going forward with this paper.

Everything you need to know in New York tomorrow...

August 10, 1998

## Linking Health Effects to Changes in Climate

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### Related Article

- [In New York, Mosquitoes and Ticks Arrived Early](#)

### Graphic

- [Bad Weather, Abundant Disease](#)
- 

By WILLIAM K. STEVENS

**S**cientists have long theorized that climatic changes related to global warming could unleash outbreaks of diseases like malaria, dengue fever, cholera and heat stroke. But with the modest amount of warming experienced so far, they have been unable to produce much hard evidence.

Now the experts have a research gift from an unlikely benefactor: El Niño. Combined with an underlying global warming trend, say scientists who track such things, El Niño will probably make 1998 the warmest year in several centuries. And the heavy rains, droughts and other extreme weather fostered by El Niño over the last year are precisely what many scientists expect will also result from a predicted warming of the globe in the decades ahead.

So, in the belief that 1997 and 1998 may provide a taste of what is to come, those who pay attention to the health effects of climate are now pulling together data about weather-related illness and death in recent months. Though most of the evidence is circumstantial, consisting of correlations and coincidences, it suggests that amid all the scientific smoke there is some fire.

These are some of the clues:

- The World Health Organization reports "quantitative leaps" in the incidence of malaria around the world, coincident with extreme weather events associated with El Niño.

Heat and variations in rainfall affect transmission of the disease by mosquitoes.

- Tens of thousands of people in Kenya and Somalia were afflicted by another

In both cases the surge in cases was associated with heavy rainfall and floods linked to El Niño.

- In the southern Rockies, a warm, wet winter brought on by El Niño has produced abundant food and cover for deer mice, which transmit the deadly hantavirus to humans.

The number of mice has increased, and the deaths of three people have been ascribed to the disease. Federal disease-control agents are still analyzing the problem.

- Forest fires in Southeast Asia, made possible by a killing drought attributed to El Niño, subjected hundreds of thousands of people to respiratory ailments.

While this and similar evidence is sifted and tested, scientists are also beginning to focus more closely on the health impact of extreme weather events quite apart from El Niño, especially in the United States. One thing they are finding is that there is a statistically significant association in the United States between heavy rainstorms and outbreaks of waterborne diseases.

These include hepatitis, E. coli infections and the cryptosporidium parasite that infected 400,000 people and killed 50 to 100 in Milwaukee in 1993, as well as other gastrointestinal diseases caused by viruses, bacteria and parasites.

### **In East Africa, Model and Portent**

**I**f the relationship between heavy rain and disease is a solid one and climate experts are right, the country may be in for a surge of climatically induced waterborne illness.

Analyses of the last century's weather records by the National Climatic Data Center have found that extremely heavy rainstorms have become more common.

For example, single rainfalls on the order of eight and nine inches each deluged the Boston area in mid-June, the Ohio Valley in late June and south-central Tennessee in mid-July.

Climatologists say that this is just the kind of increase in extreme rainstorms that would be expected in a warming atmosphere, which holds more moisture and causes more water to evaporate from the oceans. The heavier rain that results is more likely to cause floods that not only kill people but also overwhelm drinking-water purification systems.

"If extreme weather events are part of a changing climate," said Dr. Paul R. Epstein, associate director of the Center for Health and the Global Environment at Harvard Medical School, "we've seen lots of evidence of the profound health effects associated with climate change this year."

East Africa, he said, especially illustrates the risk to health posed by climatic factors.

There, simultaneous outbreaks of cholera, malaria and Rift Valley fever followed heavy rains and flooding.

Dr. Epstein has long held the view that global warming will have a serious effect on health.

His group at Harvard has also made a compilation of possible health effects of El Niño in the last year.

The view has provoked argument. In the always contentious debate over climate change and the uncertainties that attend it, it has been especially difficult to get a handle on the question of health and disease. The Intergovernmental Panel on Climate Change, an international group of scientists advising the United Nations, recognized this in its most recent report, issued in 1995.

The panel predicted that if emissions of heat-trapping industrial waste gases like carbon dioxide were not reduced, the average surface temperature of the earth would rise by about 3.5 degrees Fahrenheit by the end of the next century.

This is roughly half the amount of warming experienced since the depths of the last ice age. About a degree of warming has taken place in the last century, and the latest surface readings combined with tree-ring studies made by climatologists at the University of East Anglia in Britain indicate that 1997 was the warmest year in the last 1,000 and that 1998 will probably be warmer still.

Some recent events, the intergovernmental panel said in 1995, might plausibly be early signals of climate-induced changes in human health. The panel cited a surge in heat-related deaths in India in 1995 (there was a similar surge this year), changes in the ranges of some insect-borne diseases and the spread of cholera along coastal areas in some developing countries.

But the group also said it was "not possible to attribute particular, isolated events to a change in climate or weather pattern."

The problem, said Dr. Duane Gubler, director of the division of vector-borne infectious diseases at the Federal Centers for Disease Control and Prevention in Atlanta, "is that we may see some correlations" between climate and disease outbreaks, "but we don't know whether it's cause and effect." So, he said, "we're kind of cautious" in tying climatic change to changes in health.

### **More Than One Way to Kill a Mosquito**

**N**ot a few experts point out, for instance, that while a warming atmosphere would theoretically be expected to expand the range of mosquito-borne tropical diseases like malaria and dengue fever, reality is not so simple.

Temperature, humidity, rainfall and other weather factors are indeed some of the main things that influence transmission of the diseases. In some instances, temperature increases the virulence of the disease itself, by prompting viruses to multiply more.

Heavier rainfall creates more standing water for some kinds of mosquitoes to breed in, and populations soar.

Drought encourages people to store water in open containers, with the same result.

But in the developed countries, experts like Dr. Gubler say, public health pluses like pest control and better living conditions (more tightly built houses, for example) have pretty much slammed the door on epidemics of mosquito-borne illness. Until early this century, malaria, dengue fever and yellow fever were common in the United States. Today, outbreaks of those diseases are small,

isolated and rare.

Usually, says Dr. Gubler, the cases have arrived from somewhere else.

This public-health success, a number of experts say, would probably stop any climate-induced invasion by mosquito-borne diseases at the United States border -- as indeed might have happened already: dengue fever, resurgent in the Caribbean and Central America in recent years, has not become a major problem in the United States, even though, Dr. Gubler says, the temperature along the Gulf Coast is higher than in the Caribbean.

While Texas reported only a handful of cases in 1995 and again in 1997, said Dr. Gubler, there were thousands of cases a stone's throw away, in Mexico.

Dr. Gubler, Dr. Epstein and many others agree that developing countries, with less effective and in some cases nonexistent controls on mosquitoes, would be highly vulnerable to any climatically induced surge in diseases borne by vectors, or animals, usually insects, that carry a disease from a host to another animal.

They also agree that efforts to improve public health measures there and limit climatic change globally are necessary.

But the richer countries, including the United States, may not be immune to climate-sensitive health problems.

Two big cases in point are heat waves and waterborne diseases.

Many climate experts say that heat waves are likely to become more frequent and intense, and therefore more deadly. If they are right, what has happened in Texas this summer may be a foretaste. More than 100 people have died there in a heat wave that saw temperatures in Dallas rise above 100 degrees Fahrenheit for weeks on end.

It was even worse in India, where the most intense heat wave in 50 years sent the temperature soaring above 120 degrees in some places. Nearly 1,300 people died.

Skeptics point out that people in the southern United States have become acclimatized to heat, and argue that northerners will adapt if the climate warms.

But Dr. Laurence S. Kalkstein of the University of Delaware, who has long studied the subject, says that people become vulnerable to heat whenever it reaches a certain threshold above what they are used to -- even if they are used to high temperatures. The lethal Southern and Indian heat waves this year may provide some evidence of this.

The important unanswered question, Dr. Kalkstein said, is whether heat waves will get hotter with the general climate.

"If New York's climate becomes more like Jacksonville's and all the days stay about the same in the summer," he said, "I think New Yorkers will acclimatize." But if hotter heat waves are then superimposed on top of a generally warmer climate, "we are going to get more deaths," he said.

Skeptics also point out that cold-related deaths would probably drop in the winter.

**Methods for Ensuring Compliance in an  
International Greenhouse Gas Trading System:  
Summary of Key Points**

1. An *international cap-and-trade system* in principle appears to be one of the most cost-effective means of reducing GHG emissions.

2. *Maintaining the integrity of the trading system* is of primary importance in ensuring that trading helps countries to meet their GHG commitments. This may best be accomplished by limiting participation in trading to *Annex I countries that maintain strong domestic compliance systems*. At first, trading will be country-to-country but should quickly evolve to *include companies*. Preserving the integrity of the trading system will also require the establishment of a *strong international compliance system*.

3. *Domestic Compliance*: Prior to the climate negotiations in Kyoto in December 1997, the US Administration proposed a number of preconditions for participation in trading. These include the adoption of international measurement standards and the establishment of domestic compliance and enforcement programs. In addition to these, minimum preconditions for participation in trading should include establishment of a) *tough domestic financial penalties* on companies that exceed allowed emissions; and b) *seller responsibility* for the quality of allowances traded.

4. *International Compliance*: Key features of the international compliance system include:

- A. *Interim compliance*: Reporting should occur annually, as called for in the U.S. proposal, while in-depth reviews should take place both during and at the end of budget periods. If interim in-depth reviews uncover major weaknesses in domestic administrative systems, then interim sanctions should be applied. These could include *loss of the right to sell allowances or inclusion on a Greenhouse Watch List*.
- B. Strict rules regarding the *participation of companies from countries not adopting cap-and-trade systems*. Only the governments of these countries should engage in trading; they could make side arrangements with companies making GHG reductions.
- C. *The imposition of sanctions*: End-of-period sanctions could include *trade sanctions and financial penalties on countries*, although both of these would be politically difficult to achieve. Financial penalties would be imposed per ton of exceedance and be large enough to deter violations. More feasible sanctions options include *a reduction of future allowances and loss of the right to sell allowances*.

5. The trading rules established post-Kyoto should include the requirements already proposed by the U.S. as well as tough domestic financial penalties for non-compliance.

# Methods for Ensuring Compliance in an International Greenhouse Gas Trading System

## *I. Introduction*

An international cap-and-trade system in principle appears to be one of the most cost-effective means of reducing GHG emissions. The success of such a system, however, would depend upon establishment of the proper administrative structure to ensure compliance.<sup>1</sup> Key administrative functions would include monitoring and enforcement, both of which must be performed nationally (national governments must regulate entities) and internationally (the international community must regulate countries.)

This paper describes certain features of the GHG trading regulatory infrastructure that would help ensure compliance with GHG emissions caps. The focus of the paper is on compliance by countries within the GHG trading system rather than the integration of reductions from non-participating countries into the system. The latter topic is discussed in a companion paper.

The paper takes the position that **maintaining the integrity** of the trading system is of primary importance in ensuring that trading helps countries to meet their GHG commitments. The system must ensure that allowances sold represent reductions of emissions below required levels. The paper describes two ways that this could be done:

- First, participation in trading should take place only among Annex I nations that have established and maintain ***strong domestic compliance programs***. These programs should incorporate international standards for GHG emissions measurement and should include appropriate monitoring and enforcement provisions, as called for in the current U.S. protocol proposal. In addition, countries that wish to participate in the trading system and plan to adopt domestic cap-and-trade programs would be expected to impose and enforce ***strict financial penalties on companies*** in non-compliance. The basis for this recommendation is the recognition that emissions sources will be motivated to comply primarily by the threat of strict financial penalties. Establishment of tough domestic compliance systems is of primary importance in ensuring that targets are met because these domestic systems will directly regulate GHG emitters. An example of the effectiveness of such systems is provided by the U.S. Acid Rain program, in which continuous monitoring and financial penalties that far exceed the cost of allowances have led to 100 percent compliance.
- A second, complementary component is the development of a tough ***international compliance system that includes sanctions for non-compliance***. To ensure the integrity of allowances

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<sup>1</sup> Under a cap-and-trade system non-compliance would occur when net emissions for a particular country in a given budget period exceeded the country's initial allocation of allowances, plus allowances purchased, plus JI credits purchased, minus allowances sold.

traded, emissions reporting should occur every year (as called for in the U.S. proposal), in-depth review of country GHG administrative structures should occur during multiyear budget periods, and measures should be taken during budget periods against countries that are found to have poor administrative systems. These interim measures could include loss of the right to sell allowances and inclusion on a "Greenhouse Watch List." In addition, sanctions should be applied at the end of budget periods. Options include trade sanctions and strict financial penalties on countries, although these would be difficult to accomplish politically. More feasible options include a reduction in future allowances and loss of the right to sell allowances.

Article 16 bis of the Kyoto Protocol states that the "Conference of the Parties shall define the relevant principles, modalities, rules and guidelines ... for emissions trading."<sup>2</sup> In addition to those already included in the U.S. protocol proposal, these should include the establishment and enforcement of strong domestic penalties on firms that violate their GHG emissions allowances.

## *II. The Trading and Regulatory Structures*

The Protocol adopted at the third Conference of the Parties to the FCCC in Kyoto last December provided for the establishment of a GHG emissions cap-and-trade system. The US was the chief proponent of emissions trading.

It is likely that the trading system that is established will follow an "allowance" model, in which countries are allowed to emit certain amounts of GHGs and can sell any allowances that they do not need. The Protocol allows countries but not companies to engage in international trading. It is desirable, however, that countries be allowed to assign allowances to domestic entities, which could then trade them internationally.

UNCTAD has recently completed a study that suggests a legal infrastructure for an international trading system (Stewart et al., 1996.) According to this proposal, to establish an international trading system countries would make an agreement to establish an international **Governing Body** to implement the system and enforce penalties in cases of trading violations. The agreement also would establish a **Monitoring Body** to monitor and certify the annual GHG emissions of the trading nations, and a **Trading Body**, which would oversee the trading of allowances. One possible arrangement is that the Monitoring Body would independently certify net emissions to the Trading Body, which would then determine whether or not the trading country was eligible for trading. If the country was not, this would be reported to the Governing Body, which would take appropriate measures.<sup>3</sup>

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<sup>2</sup> Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations Framework Convention on Climate Change Secretariat. December 10, 1997. Version FCCC/CP/L.7/Add.1. Subject to technical revision.

<sup>3</sup> In Stewart et al., 1996, the three international bodies are known as the Council, Monitor and International Emissions Trading Organization (IETO), respectively.

The Monitoring Body could be the Secretariat, which now reviews national communications and leads in-country reviews. The Governing Body might also be the Secretariat but probably would be a new organization, because the mandates of the Secretariat and the subsidiary bodies to the FCCC (SBSTA, SBI, etc.) do not provide for an enforcement role. The Trading Body would be new and independent, because existing organizations do not possess the expertise needed to regulate market activity.

The success of the trading system in bringing about low-cost compliance with GHG emissions commitments ultimately will depend on ensuring that members of the system have confidence that all allowances traded represent real reductions beyond required levels. If this integrity is not maintained, then some countries may believe that others are meeting their commitments by buying cheap but illegitimate reductions. Trading might then come to be viewed as a means of evading commitments rather than a tool for achieving low-cost compliance.

Two key factors in ensuring compliance will be 1) requiring the establishment of strong domestic compliance systems; and 2) the development of appropriate international regulatory infrastructure.

### ***III. In-Country Monitoring and Enforcement***

Because domestic monitoring and enforcement systems will directly regulate GHG sources, the most important step in ensuring compliance in a GHG cap-and-trade system would be ***to limit participation in trading to countries with strong national compliance systems***. These systems would ensure the buyers of allowances that reductions they purchase represent reductions below allowed levels, while the international community would be sure that trading countries and the world as a whole were moving towards their GHG reduction targets.

Minimum preconditions for participation in the trading system should include:

1. Commitment to GHG emissions **targets and timetables** under the FCCC.
2. Enactment of **enabling legislation** that would establish a domestic regulatory program, designate a specific agency to administer the program and appropriate adequate budget resources to that agency. The establishment of national compliance and enforcement programs as a precondition for trading is now provided for in the U.S. protocol proposal.
3. **Adoption of minimum standards for monitoring and reporting** which would be developed by the international Monitoring Body. This requirement also is included in the U.S. proposal. Government agencies would monitor emissions by examining emissions and fuel use records. This effort would be supplemented by some site inspection and the use of independent data to confirm reported information.

4. **Submission to international law:** Agreement to submit to both the monitoring activities of the Monitoring Body and any sanctions imposed by the Governing Body.

In addition, two other rules would apply to countries adopting cap-and-trade systems. These are:

1. **Adoption and enforcement of strict domestic penalties for non-compliance.** These could include financial penalties on companies in non-compliance and a reduction in allowances. The U.S. experience with acid rain regulation has demonstrated that such measures are an effective means of bringing about compliance. To accommodate local norms countries would be able to choose from a menu of enforcement options or perhaps free to tailor the standards according to their unique circumstances, subject to approval of the Monitoring Body.
2. **Seller Responsibility:** Establishment of laws and/or financial mechanisms that would make sellers rather than buyers responsible for ensuring that allowances are of high quality. If sellers have a financial incentive to create high-quality allowances, fewer violations will occur. Therefore they should bear the legal burden of proof that their allowances are legitimate and transferable. One possibility here is that sellers could be required by domestic law to insure their allowances.

Putting the onus on sellers would be preferable to a “buyer beware” system, under which buyers of allowances would have to take steps to ensure the allowances they bought represented real reductions below the sellers’ commitments. The two main objections to this approach are that 1) investors would have to incur high transactions costs, which would dampen market activity; and 2) buyers would have difficulty ascertaining whether or not allowances were backed by real reductions below required levels. In effect, application of the “buyer beware” principle would introduce uncertainty as to whether or not targets were being met.

These additional rules would mean that the allowances sold by these countries would be especially secure, because the emissions sources in these countries will have been directly regulated. This will not be the case in countries adopting policies and measures.

Theoretically, it would be possible to have an international trading system that included countries that did not adopt tough domestic monitoring and enforcement provisions. This would lead to a two-tier system in which allowances from countries with strong infrastructure and tough laws would represent “the gold standard” and allowances from other countries might be viewed as “junk bonds.” (A third tier, credits from joint implementation projects undertaken in countries not in the trading system, might also exist.) Buyers would pay less for allowances from countries that had less stringent mechanisms. The problem with this approach is that it would essentially inject a “buyer beware” dynamic into international carbon trading, thereby introducing uncertainty about the quality of allowances and whether or not global GHG reduction targets were being met.

Ultimately, the best way to ensure the integrity of the system would be to avoid the development of a two-tier system and require the adoption of strong in-country compliance systems.

In sum, tough in-country monitoring and enforcement provisions represent the primary means of ensuring that the international cap-and-trading system is producing legitimate tradable allowances and that the participating countries are in compliance with their emissions targets. The language about trading in the protocol adopted in Kyoto should allow trading countries to establish strict domestic compliance measures as a precondition for participation in the system. The establishment and use of domestic financial penalties on firms in non-compliance would be an especially important precondition.

#### ***IV. International Monitoring and Enforcement***

A companion measure for ensuring compliance in an international GHG trading system would be to establish a ***strong international monitoring and inspection regime*** supported by tough enforcement mechanisms.

An important first principle in thinking about international compliance is that most countries will be inclined to comply with their GHG caps. Countries do not make treaties lightly; they expend considerable resources in analyzing, negotiating and ratifying treaties. In the case of the FCCC it is fair to say that countries have signed and ratified the treaty because they believe that doing so serves their long-term interests. The same could be said for countries that choose to participate in an international GHG trading system.

This principle notwithstanding, and even given the establishment of strong national regulatory programs, it would be necessary to adopt international mechanisms for ensuring compliance. This would be especially true if emissions caps were ratcheted down and allowance prices were to rise, because the rewards for non-compliance would be greater under these circumstances.

Features of the international trading infrastructure that would help ensure compliance include annual reporting accompanied by regular in-depth reviews; strict rules regarding company participation in international trading; seller responsibility for delivering real reductions; and sanctions.

##### **A. Annual Monitoring and Enforcement**

One feature of the GHG trading system that would complicate international compliance is the budget period, under which all Annex I countries would commit to making reductions over a multiyear period rather than year by year. Budget periods would give countries flexibility in the timing of GHG reductions; a country expecting an economic downturn or the penetration of clean technologies could wait on making reductions, thereby lowering its cost of compliance. The issue raised by a multiyear approach is whether monitoring and enforcement should take place only at

the end of the budget period or whether interim monitoring and enforcement should take place as well.

A major difficulty associated with interim monitoring and enforcement would be the definition of non-compliance. At the end of a budget period non-compliance may be said with certainty to either have occurred or not: It would occur when actual emissions exceeded allowances, adjusted for purchases and sales. In contrast, an interim finding of non-compliance would require the Governing Body to make a subjective judgment, because it would not know with certainty that at the end of the budget period the country's emissions for the entire period will exceed its allowances. Even in the case where a country has used up its initial allowances in the middle of the budget period and yet is attempting to sell allowances, it could be argued that the country could make up its deficit by buying allowances before the end of the budget period.

We believe that the Governing Body and the Monitoring Body should be empowered to address potential non-compliance during the budget period. Emissions reporting should take place annually (as called for in the U.S. proposal); in addition, the Monitoring Body should conduct in-depth reviews during the budget period to assess whether or not the administrative systems of trading countries are satisfactory. (International reviews are also provided for in the U.S. proposal, though their frequency is not specified.) If domestic monitoring, reporting and enforcement systems were found to be unsatisfactory, then interim enforcement measures could be applied. These would be less forceful than end-of-period sanctions and might consist of inclusion on a "Greenhouse Watch List", loss of trading rights or a reduction of allowances. These options are discussed further below.

Publicizing probable emissions violations could lead to shame and public outcry, which in turn could lead to diplomatic pressure. Thus even if the Governing Body did not apply formal sanctions, interim measures might enable it to marshal the weight of international diplomacy.<sup>4</sup>

Finally, it is worth keeping in mind that the importance of interim monitoring and enforcement would be reduced by the shortening of budget periods. In determining the length of these periods, delegates will need to weigh the economic benefits of longer periods against the attendant increase in the difficulty of ensuring compliance.

## **B. Rules Governing Company Trading**

Another matter that complicates the design of an international compliance system is the fact that countries in the trading system will use different domestic regulatory systems to meet their targets. Some will use cap-and-trade systems, others will adopt national policies and measures, and yet others will use a combination of the two. The difficulty comes in trying to go below the country level to include companies in international trading.

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<sup>4</sup> For a deeper discussion of the importance of diplomatic pressure in international law, see Chayes and Chayes 1995.

Countries that adopt cap-and-trade systems would fit neatly into an international trading system that allowed for company-to-company trading. This would be especially true if the companies in the domestic trading system were responsible for the country's entire commitment. In this case, the allocation of international trading allowances would be identical to the allocation of domestic allowances. A company reducing GHG emissions below allowed levels could sell the allowances on either the domestic or the international market. If it chose the international market, both the company's emissions budget and the country's emissions budget would be reduced by the amount of allowances sold. The integrity of both the domestic and international systems would be maintained: Because the seller was participating in a domestic cap-and-trade system, the buyer would know that the allowance purchased was backed by reductions that fit into an overall national reduction strategy.

Allowing trading by companies from countries adopting national policies and measures such as carbon taxes and building efficiency standards would be more problematic, because these measures do not assign responsibility for emissions reductions to specific domestic parties.<sup>5</sup> In this case, it is possible that the emissions reduction credits offered by the company were backed by real reductions but that the country as a whole was substantially out of compliance.

One solution to this problem would be to require that only the government of a country using policies and measures could hold the country's allowances and engage in international trading. Under this approach, companies would not be able to profit directly by trading; however, they might be able to make side arrangements with their governments to receive (some or all of) the proceeds from the sale of allowances. In this situation, the government would essentially act as a broker on the company's behalf.

### **C. Seller Liability for Allowances**

A third important feature of the international trading system would be to make sellers rather than buyers liable for the delivery of the reductions backing allowances, just as with domestic trading systems. Again, establishment of this dynamic rather than "buyer beware" will reduce buyers' transaction costs, provide sellers with an incentive to make required reductions and reduce uncertainty as to the legitimacy of allowances sold.

There are a variety of ways that seller responsibility could be established. One way would be for the Governing Body to require countries to create (together or separately) a reserve pool of allowances that could be drawn on as insurance. Costa Rica has discussed such a pool that would rely on the carbon sequestered in its national parks.

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<sup>5</sup> Companies from these countries would trade "emissions reduction credits" ("ERCs") rather than allowances. Each ERC would represent a reduction below a baseline level of emissions. This is how joint implementation now works.

A major difficulty with the insurance pool concept is the fact that countries would have to overcomply to fund the pool. For example, if a country needed to reduce emissions by one hundred million tons per year and was required to contribute ten percent of its reduction requirement to the reserve pool, it could sell allowances only after it had made 110 million tons of reductions. Given that countries are now having difficulty meeting their stabilization targets, this could prove to be a formidable barrier. On the other hand, third party brokers would likely step in and create such pools based on emission reduction option purchases and other hedging techniques.

An alternative approach would be to let a private insurance market develop. Under this model private insurers would agree to provide GHG emissions reductions in the event that allowances sold were not backed by reductions below commitments; in exchange sellers of allowances would pay premiums, which would be set by insurers based on the probability of non-delivery.

#### **D. Sanctions**

Even given the appropriate design of the international trading system, the use of sanctions to deter country GHG exceedances would be important in ensuring compliance. Possible sanctions include:

1. **Loss of vote** in the Governing Body or the COP.
2. **International disapproval.** One option here is the inclusion of countries in non-compliance on a "Greenhouse Watch List", which would be similar to the lists used to call attention to countries violating human rights. Another, more severe option is the issuance of a formal condemnation.
3. **Loss of the right to sell allowances.** This enforcement mechanism is contained in the current U.S. proposal.
4. **Reduction of allowances.** This sanction, which is also contained in the U.S. proposal, would reduce the allowances granted to the country in non-compliance in a future budget period. The ratio of exceedances to allowances removed would have to be determined; a ratio of 1:1 would require the country to simply make up for prior exceedances, while a higher ratio would impose a penalty by reducing the country's total allowances. A 1:1 reduction provision is included in the U.S. acid rain law; coupled with financial penalties, it has been very effective.
5. **Devaluation of Allowances.** Under this sanction, the allowances of the country in non-compliance would be devalued by a certain percentage upon their sale. For example, the buyer of ten allowances from a country in non-compliance would have fewer than ten allowances added to its emissions budget. This would reduce the payments received by the host country, making the country less competitive with other sellers.

6. **Trade sanctions** tied to GHG-emitting industries. These could include duties on the imports of countries in non-compliance, import bans, quotas and other forms of retaliation. The World Trade Organization (WTO) has not taken a position as to whether it would have jurisdiction over the trading of carbon allowances, so it is not now clear whether trade sanctions would be imposed under WTO auspices. This topic is discussed in greater detail below.
7. Imposition of **financial penalties** by the Governing Body on the country in non-compliance. The penalty could be assessed on a per-ton basis; for instance, the penalty might be \$100 per ton of carbon dioxide-equivalent of exceedance. A penalty of this size would act as a significant deterrent to non-compliance because it is likely to far exceed the cost of compliance.

Financial penalties would be paid into a fund, perhaps the new clean development mechanism (CDM), which would then purchase GHG reductions. To ensure payment of penalties, countries might be required to offer a bond or other form of assurance. A variation on this sanction would be withdrawal of the ability to sell credits through the CDM, though this would not affect most participating countries, which at least initially would include Annex I countries only.

8. **Loss of multilateral development funds.** This also would not affect most participating countries.

These options may be judged on several criteria. These include certainty of compliance (i.e., environmental effectiveness), transaction costs, political feasibility, and flexibility in implementation (i.e., the ability to issue various gradations of penalties.)

#### *1. Certainty of Compliance*

The effectiveness of the various options in ensuring compliance would be a function of the perceived impact that they would impose, unless they were so strict that they were seen as unenforceable.

In general, stiff financial penalties and trade sanctions represent the most powerful deterrents of non-compliance. Financial penalties probably pose the most immediate and tangible threat; they would be especially effective if they triggered immediately upon a finding of non-compliance rather than after negotiation, and if they were designed to be greater than the penalties imposed by the countries on their companies in non-compliance. This would give countries an additional incentive to enforce domestic laws. An important strength of the use of financial penalties in ensuring compliance is that it would create funding for the purchase of reductions to cover the shortfall of the country in non-compliance. The international community thus could be sure that the GHG exceedance by the country in violation did not cause the trading community as a whole to fail to meet targets.

Measures that tie to trading (a loss of selling rights, devaluation) would be effective only to the extent that a country would achieve large cost savings or earn significant revenues through trading. This will vary by country, meaning that the penalty will work better in some cases than others. Similarly, the pain associated with a reduction in allowances would be a function of the cost of making further reductions. A reduction in allowances and loss of the right to sell would provide a greater deterrent than devaluation.

The options that appear to be strictly diplomatic (loss of voting rights in the COP and international disapproval) probably would be less effective than other options. One reason is that it may be more difficult to mobilize public opinion around global climate change than around the subjects of other international treaties, such as human rights and nuclear proliferation. In addition, as already mentioned, the need for significant cuts in emissions would drive allowance prices up, further increasing the benefits of buying and selling illegitimate allowances. It is important to note, though, that a seemingly diplomatic sanction such as inclusion on a Greenhouse Watch List would have a financial component, in that it would send a negative signal to potential allowance buyers. This would result in a drop in the value of a country's allowances.

Sanctions would be most effective if applied in tandem. For instance, enforcement provisions could call both for payment of penalties and the loss of allowances, as is the case with the acid rain law. Another possibility is that penalties could be applied sequentially, with tougher measures imposed only after lesser ones have been tried. As an example, loss of selling rights could serve as an interim sanction, applied only during the budget period, with financial penalties applied at the end of the budget period.

## *2. Political Feasibility*

International environmental agreements typically rely on peer pressure and public outcry to bring about compliance. In contrast, there has been very little use of financial sanctions, which are seen as threats to national sovereignty, burdensome and simply not the norm.<sup>6</sup> Loss of voting rights in the COP and international disapproval probably are the most politically feasible options, because they fit best with the accepted practices of international diplomacy.

This does not mean that financial measures (options 3 through 8) could not be used. Options such as the loss of trading rights, devaluation and reduction of allowances probably would be more acceptable than financial penalties and trade sanctions because they "fit the crime", that is, they are tied to the trading system.

The imposition of fines probably would be most politically difficult, primarily because requiring the payment of fines to an international body might be viewed as an infringement upon national sovereignty. In addition, fines might be resisted simply because they are tough and because they

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<sup>6</sup> The Montreal Protocol is the only international environmental agreement that calls for financial penalties. To date these penalties have not been applied. Stewart et al., 1996; Vaughan, 1997.

might require the posting of a bond. The latter feature might be opposed by country treasuries, which would not want to incur an extra obligation. One way financial penalties could be made more palatable would be to impose them only as end-of-budget period measures, after a process of dispute resolution, and/or after other options had been exhausted. For instance, one strategy would be to employ a less severe measure such as loss of the right to sell allowances as an interim sanction and financial penalties only at the end of budget periods.

Shadowing the discussion of political feasibility is the issue of WTO treatment of GHG allowances. WTO is the organizational foundation of the international trading system. It is the successor to GATT and is "the platform on which trade relations among countries evolve."<sup>7</sup> All Annex I countries are WTO members. If WTO were to consider allowances to be a good or service regulated under its agreements, then trading would be subject to WTO rules. If this were the case, then any of the sanctions discussed might be found to be inconsistent with the WTO agreements. Trade sanctions for GHG exceedances would be especially problematic, because generally, the WTO allows for trade sanctions only in retaliation against dumping (the sale of goods at predatory prices) and the use of subsidies to protect domestic industries. On the other hand, WTO jurisdiction over allowance trading may improve the political feasibility of applying sanctions: If trade sanctions could be applied under WTO auspices, then there would be no question as to their legitimacy.

The WTO has not yet taken a stand on GHG trading.<sup>8</sup> Given, though, that the WTO has never taken up an investigation of an international environmental agreement,<sup>9</sup> there is no reason to presume that WTO regulation would preclude the use of penalties in the governance of the trading system.

### *3. Transaction Costs*

The level of technical and organizational complexity associated with an enforcement mechanism determines the level of transaction costs. When transaction costs are lower implementation becomes more feasible.

The level of transaction costs associated with particular options would depend to a large extent on the events deemed to trigger sanctions. A sanction might be imposed immediately upon a finding of non-compliance by the Monitoring Body, in which case transaction costs would be relatively low. Alternatively, sanctions might be imposed after a process of investigation and negotiation -- perhaps by a tribunal, as is the case under the Montreal Protocol, or through a dispute resolution process such as that employed by the WTO. If this were the case, then the transaction costs associated with any of the sanction alternatives presented would be high.

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<sup>7</sup> WTO Internet web site, as of April 3, 1997.

<sup>8</sup> Stewart et. al., 1996; personal communication with Scott Vaughan, WTO Secretariat, April 7, 1997.

<sup>9</sup> Vaughan 1997.

Under either scenario, some measures would be more costly to implement than others. Measures such as loss of vote in the COP, loss of trading rights and reduction of allowances would be relatively simple to administer, once the Governing Body had decided upon them. In contrast, the imposition of options such as trade sanctions and reductions in foreign aid would require further investigation, analysis and coordination and therefore would entail higher costs. Devaluation of allowances might or might not be costly to impose, depending on whether the devaluation rates were predetermined or assessed on a case-by-case basis.

The imposition of financial penalties would be made more complex by the need to guarantee payment in the event of non-compliance. This guarantee could come in the form of a bond, a reserve pool of allowances or some other form of insurance. The creation and implementation of any of these mechanisms would demand substantial time and resources.

The application of trade sanctions might be particularly complicated if GHG trading were regulated by the WTO, in which case sanctions could be imposed only after the WTO dispute resolution process had been undertaken. This would involve consultations under WTO auspices between the accusing and accused countries and then as necessary, examination of the complaint by a WTO panel, appeal by either party, and finally, imposition of a retaliatory measure.

#### *4. Flexibility in Implementation*

It is important that the Governing Body be able to design penalties commensurate with the level of exceedances and take consideration of the reasons for non-compliance. To the extent that the enforcement of penalties took place after a process of diplomacy, then the application of any of the penalties mentioned would take place in a flexible way. If instead penalties were triggered immediately upon a finding of non-compliance, then penalties would be less flexible.

Even in this case, however, some of the measures would provide for more flexibility than others. International disapproval, reduction of allowances and trade sanctions all could be imposed in a measured way, giving the international community the opportunity to express itself carefully. In contrast, loss of vote in the COP and loss of trading rights are discrete, all-or-nothing measures that afford little flexibility. Devaluation and financial penalties both could either be specified in advance, in which case they would be inflexible, or imposed upon the judgment of the Governing Body.

#### *5. Conclusions*

Table 1 presents the ranking of the international sanction options across the four criteria mentioned. The ideal enforcement mechanism would combine environmental effectiveness with political feasibility and low transaction costs. It also would provide the international community with the opportunity to tailor penalties according to circumstances.

None of the measures reviewed represents this combination, primarily because there is a tradeoff between environmental effectiveness and political feasibility. Tough financial penalties would be the most effective deterrent of GHG exceedances, especially if imposed by the Governing Body immediately upon finding of a violation. Such penalties would be difficult to implement, however, because they are strict and because they are contrary to the norms of international diplomacy.

Trade sanctions also would provide an effective deterrent to non-compliance. They might also meet political resistance, however, unless they were imposed under WTO jurisdiction. Trade sanctions would come with high transaction costs, especially if the international GHG trading system fell under WTO rules.

Loss of trading rights and a reduction of allowances also could be effective measures, and might be more agreeable to potential trading countries because they relate directly to GHG exceedances. The reduction of allowances appears especially attractive because required reductions could be tailored according to specific circumstances. Inclusion of countries exceeding their allowances on a Greenhouse Watch List also could be an effective interim enforcement mechanism, in that it would carry diplomatic weight and also send a signal to markets.

| <b>Table 1</b><br><b>Evaluation of International Sanction Alternatives</b> |                                           |                                     |                                             |                           |
|----------------------------------------------------------------------------|-------------------------------------------|-------------------------------------|---------------------------------------------|---------------------------|
| <b>Measure and Measure Type</b>                                            | <b><i>Environmental Effectiveness</i></b> | <b><i>Political Feasibility</i></b> | <b><i>Feasibility of Implementation</i></b> | <b><i>Flexibility</i></b> |
| Loss of Vote in the COP                                                    | Weak                                      | Easy                                | Easy/Moderate                               | Inflexible                |
| International Disapproval                                                  | Weak/<br>Moderate                         | Easy                                | Moderate/<br>Difficult                      | Flexible                  |
| Loss of Trading Rights                                                     | Moderate                                  | Moderate                            | Easy/Moderate                               | Inflexible                |
| Reduction of Allowances                                                    | Moderate                                  | Moderate                            | Easy/ Moderate                              | Flexible                  |
| Devaluation of Allowances                                                  | Moderate                                  | Moderate                            | Easy/Moderate                               | Moderate                  |
| Trade Sanctions                                                            | Strong                                    | Difficult                           | Difficult                                   | Flexible                  |
| Financial Penalties                                                        | Strong                                    | Difficult                           | Moderate                                    | Moderate                  |
| Loss of Development Funds                                                  | Strong                                    | Difficult                           | Difficult                                   | Flexible                  |

## *V. Summary*

This paper has described two options for ensuring compliance with GHG emissions caps, as embodied in an international GHG allowance trading system. The most critical component of the overall GHG trading structure would be the requirement of strong national monitoring and enforcement mechanisms. This is the first line of defense in ensuring that allowances are real and countries are meeting their targets.

The second critical component is the establishment of the appropriate international trading and compliance structure. Monitoring and reporting should occur annually, while in-depth reviews should take place both during and at the end of budget periods. If these reviews were to uncover major weaknesses in domestic compliance systems, then measures such as loss of trading rights and inclusion on a Greenhouse Watch List could be applied. If politically viable, tougher sanctions such as trade sanctions and financial penalties should be imposed at the ends of budget periods. If these are not feasible, then options such as a reduction of future allowances and loss of trading rights should be considered.

The emissions trading rules adopted post-Kyoto should establish strict rules for participation in trading. These preconditions should include many features proposed earlier by the US, including the adoption of international measurement standards and submission to international review and sanctions. In addition, countries employing domestic cap-and-trade systems should be required to establish and impose strict enforcement measures against companies exceeding their caps. These conditions would ensure that the allowances traded represent real reductions below allowed levels, thereby guaranteeing that trading is a tool that helps countries to meet their targets.

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## **What to Expect from an International System of Tradable Permits for Carbon Emissions**

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### **ABSTRACT**

We use an econometrically-estimated multi-region, multi-sector general equilibrium model of the world economy to examine the effects of using a system of internationally-tradable emissions permits to control world carbon dioxide emissions. We focus, in particular, on the effects of the system on flows of trade and international capital. Our results show that international trade and capital flows significantly alter projections of the domestic effects of emissions mitigation policy, compared with analyses that ignore international capital flows, and that under some systems of international permit trading the United States is likely to become a significant permit *seller*, the opposite of the conventional wisdom.

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*The views expressed in this paper are those of the authors and should not be interpreted as reflecting the views of the organizations with which they are affiliated.*

## 1 Introduction

One of the leading proposals for controlling global climate change is an international system of tradable permits for carbon dioxide emissions. In fact, the Kyoto Protocol to the United Nations Framework Convention on Climate Change, signed in Kyoto in December 1997, includes provisions for setting up just such a system among industrial ("Annex I") countries. The theoretical attraction of permit trading is that it is efficient: it guarantees that emissions reductions will be obtained at minimum cost. As a political matter, especially in the United States, an equally important virtue of a permit system is that it does not involve new taxes.

Despite the enthusiasm for international permit trading, little empirical work has been done on estimating the effects of such a policy. In this paper we attempt to fill that gap by using a multi-region, multi-sector intertemporal general equilibrium model of the world economy called "G-Cubed".<sup>1</sup> We examine and compare three potential policies: (1) unilateral stabilization of U.S. carbon emissions at 1990 levels, (2) stabilization of OECD emissions at 1990 levels on a country by country basis without international permit trading, and (3) joint stabilization of OECD emissions with full international permit trading. We focus particularly on the effects of the policies on output, exchange rates and international flows of goods and capital. In addition, by comparing the second and third simulations we are able to calculate the gains from allowing international permit trading.<sup>2</sup>

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<sup>1</sup> G-Cubed stands for "Global General Equilibrium Growth".

<sup>2</sup> We examine trading within the OECD rather than within the broader "Annex I" group which includes Eastern Europe and the states of the former Soviet Union. The reason is that we want to measure the efficiency gains from trading and in order to do that we need the overall level of abatement to be the same with or without trading. That would not be the

## 2 Model Structure

At the most abstract level G-Cubed consists of a set of eight general equilibrium models, each corresponding to a geographic region, linked by international flows of goods and assets. We assume the regions each consist of a representative household, a government sector, a financial sector, twelve industries, and a sector producing capital goods. The regions and sectors are listed in Table 1. Although the regions are similar in structure (that is, they consist of similar agents solving similar problems), they differ in endowments, behavioral parameters and government policy variables.<sup>3</sup> In the remainder of this section we present the key features of the regional models.<sup>4</sup> To keep the notation from becoming cumbersome, we will generally not subscript variables by country. The complete model, however, consists of eight regional modules linked by trade and asset flows.

### 2.1 Producer Behavior

Within a region, each producing sector is represented by a single firm which chooses its inputs and its level of investment in order to maximize its stock market value subject to a multiple-input production function and a vector of prices it takes to be exogenous. We assume that output can be represented by a constant elasticity of substitution (CES) function of inputs of

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case if we examined Annex I trading because the former Soviet Union is currently about 300 million metric tons below its 1990 emissions. If we included it in the trading regime, moving from independent stabilization to trading would essentially just relax the emissions constraint by 300 million metric tons.

<sup>3</sup> This is enough to allow the regions to be quite different from one another. For example, even though all of the regions consist of the twelve industries in Table 2 we do not impose any requirement that the output of a particular industry in one country be identical to that of another country. The industries are themselves aggregates of smaller sectors and the aggregation weights can be very different across countries: the output of the durable goods sector in Japan will not be identical to that of the United States. The fact that these goods are not identical is reflected in the assumption (discussed further below) that foreign and domestic goods are generally imperfect substitutes.

<sup>4</sup> A more complete description of the model is contained in McKibbin and Wilcoxon (forthcoming).

capital, labor, energy and materials. Energy and materials, in turn, are CES aggregates of inputs of intermediate goods: energy is composed of the first five goods in Table 1 and materials is composed of the remaining seven.

We used a nested system of CES equations rather than a more flexible functional form because data limitations make even the CES model a challenge to estimate. In principle we need price and quantity data for 14 inputs (twelve goods plus capital and labor) in each of 96 industries (12 industries in 8 regions). Moreover, data on intermediate inputs (which is published in the form of input-output tables) is not collected annually in any major country and is collected infrequently, if at all, in developing countries. For many of our regions we had access to only a single input-output table. There is simply too little data for a more flexible specification to be feasible.

In fact, the scarcity of input-output data requires us to restrict the model further by imposing the assumption that the substitution elasticities for each industry be identical across countries (although they may differ across industries). In other words, we assume that each industry has the same energy, materials and KLEM substitution elasticities no matter where it is located. This is consistent with the econometric evidence of Kim and Lau in a number of papers (see for example Kim and Lau, 1994).

Although the substitution elasticities are identical across countries, the overall production models are not identical because we obtain the CES input weights from the latest available input-output data for each country or region.<sup>5</sup> Thus, the durable goods sectors in the United States and

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<sup>5</sup> Input-output tables were not available for the regions in the model larger than individual countries. The input weights for those regions were based on data for the United States.

Japan, for example, have identical substitution elasticities but different sets of input weights. The consequence of this is that the cost shares of inputs to a given industry are based on data for the country in which the industry operates, but the industry's response to price changes is identical across countries.

In effect we are assuming that all regions share production methods that differ in first-order properties but have identical second-order characteristics. This is intermediate between one extreme of assuming that the regions share common technologies and the other extreme of allowing the technologies to differ across regions in arbitrary ways. The regions also differ in their endowments of primary factors, their government policies, and patterns of final demands, so although they share some common parameters they are not simple replicas of one another.

To estimate the elasticities we constructed time-series data on prices, industry inputs, outputs and value-added for the country for which we were able to obtain the longest series of input-output tables: the United States. The following is a sketch of the approach we followed; complete details are contained in McKibbin and Wilcoxon (1995).

We began with the benchmark input-output transactions tables produced by the Bureau of Economic Analysis (BEA) for years 1958, 1963, 1967, 1972, 1977 and 1982.<sup>6</sup> The conventions used by the BEA have changed over time, so the raw tables are not completely comparable. We transformed the tables to make them consistent and aggregated them to twelve sectors. We then shifted consumer durables out of final consumption and into fixed investment.<sup>7</sup> We also increased

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<sup>6</sup> A benchmark table also exists for 1947 but it has inadequate final demand detail for our purposes. Subsequent to our estimation work a 1987 table has become available.

<sup>7</sup> The National Income and Product Accounts (and the benchmark input-output tables as well) treat purchases of consumer durables as consumption rather than investment.

the capital services element of final consumption to account for imputed service flows from durables and owner-occupied housing. Finally, we used a data set constructed by Dale Jorgenson and his colleagues to decompose the value added rows of the tables,<sup>8</sup> and a data set produced by the Office of Employment Projections at the Bureau of Labor Statistics to provide product prices.

Table 2 presents estimates of the substitution elasticities for each industry; standard errors are shown in parentheses.<sup>9</sup> A number of the estimates had the wrong sign or could not be estimated (the estimation procedure failed to converge). In such cases we examined the data and imposed elasticities that seemed appropriate; these values are shown in the table without standard errors.<sup>10</sup> For most of the imposed parameters, the data suggest complementarities among inputs, which is incompatible with the CES specification. If more data were available, it would be worthwhile to use a more flexible functional form.

Maximizing the firm's short run profit subject to its capital stock and the production functions above gives the firm's factor demand equations. At this point we add two further levels of detail: we assume that domestic and imported inputs of a given commodity are imperfect substitutes, and that imported products from different countries are imperfect substitutes for each other. As noted earlier, given the model's level of aggregation these are more a simple acknowledgment of reality than an assumption.<sup>11</sup> Thus, the final decision the firm must make is

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<sup>8</sup> This data set is the work of several people over many years. In addition to Dale Jorgenson, some of the contributors were Lau Christiansen, Barbara Fraumeni, Mun Sing Ho and Dae Keun Park. The original source of data is the Fourteen Components of Income Tape produced by the Bureau of Economic Analysis. See Ho (1989) for more information.

<sup>9</sup> The parameters were estimated using systems of factor demand equations derived from the KLEM portion of the production function and the dual versions of the energy and materials tiers.

<sup>10</sup> For this study we also imposed lower KLEM substitution elasticities on a few of the energy industries where it seemed that the estimated elasticities might overstate the true ability of the industry to shift factors of production.

<sup>11</sup> This approach is based on the work of Armington (1969).

the fraction of each of its inputs to buy from each region in the model (including the firm's home country). Due to data constraints we represent this decision using a Cobb-Douglas function.<sup>12</sup> Moreover, we assume that all agents in the economy have identical preferences over foreign and domestic varieties of each particular commodity.<sup>13</sup> We parameterize this decision using trade shares based on aggregations of the United Nations international trade data for 1987.<sup>14</sup> The result is a system of demand equations for domestic output and imports from each other region.

In addition to buying inputs and producing output, each sector must also choose its level of investment. We assume that capital is specific to each sector, it depreciates geometrically at rate  $\delta$ , and that firms choose their investment paths in order to maximize their market value. Following the cost of adjustment models of Lucas (1967), Treadway (1969) and Uzawa (1969) we assume that the investment process is subject to rising marginal costs of installation. To formalize this we adopt Uzawa's approach by assuming that in order to install  $J$  units of capital the firm must buy a larger quantity,  $I$ , that depends on its rate of investment ( $J/K$ ) as follows:

$$(1) \quad I = \left( 1 + \frac{\phi}{2} \frac{J}{K} \right) J$$

where  $\phi$  is a non-negative parameter and the factor of two is included purely for algebraic convenience. The difference between  $J$  and  $I$  may be interpreted many ways; we will view it as installation services provided by the capital vendor.

Setting up and solving the firm's investment problem yields the following expression for

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<sup>12</sup> This assumption is far from ideal and we intend to relax it in future work.

<sup>13</sup> Anything else would require time-series data on imports of products from each country of origin to each industry, which is not only unavailable but difficult to imagine collecting.

<sup>14</sup> Specifically, we aggregate up from data at the 4-digit level of the Standard International Trade Classification.

investment in terms of parameters, the current capital stock, and marginal  $q$  (the ratio of the marginal value of a unit of capital to its purchase price):

$$(2) \quad I = \frac{1}{2\phi} (q^2 - 1)K$$

In this expression  $\tau_2$  is the corporate tax rate and  $\tau_4$  is rate of the investment tax credit. Following Hayashi (1979), we extend (2) and write  $I$  as a function not only of  $q$ , but also of the firm's current profit  $\pi$ :

$$(3) \quad I = \alpha_2 \frac{1}{2\phi} (q^2 - 1)K + (1 - \alpha_2) \frac{\pi}{(1 - \tau_4)P^I}$$

This improves the empirical behavior of the specification and is consistent with the existence of firms that are unable to borrow and therefore invest purely out of retained earnings. The parameter  $\alpha_2$  was taken to be 0.3 based on a range of empirical estimates reported by McKibbin and Sachs (1991).

In addition to the twelve industries discussed above, the model also includes a special sector that produces capital goods. This sector supplies the new investment goods demanded by other industries. Like other industries, the investment sector demands labor and capital services as well as intermediate inputs. We represent its behavior using a nested CES production function with the same structure as that used for the other sectors, and we estimate the parameters using price and quantity data for the final demand column for investment. As before, we use U.S. data to estimate the substitution elasticities and country or region data to determine the  $\gamma$  parameters.

## 2.2 Households

Households consume goods and services in every period and also demand labor and

capital services. Household capital services consist of the service flows of consumer durables plus residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they receive imputed income from ownership of durables and housing, and they also may receive transfers from their region's government.

Within each region we assume household behavior can be modeled by a representative agent with an intertemporal utility function of the form:

$$(4) \quad U_t = \int_0^{\infty} (\ln C(s) + \ln G(s)) e^{-\theta(s-t)} ds$$

where  $C(s)$  is the household's aggregate consumption of goods at time  $s$ ,  $G(s)$  is government consumption, which we take to be a measure of public goods supply, and  $\theta$  is the rate of time preference and is equal to 2.5 percent.<sup>15</sup> The household maximizes its utility subject to the constraint that the present value of consumption be equal to human wealth plus initial financial assets. Human wealth,  $H$ , is the present value of the future stream of after-tax labor income and transfer payments received by households. Financial wealth,  $F$ , is the sum of real money balances, real government bonds in the hands of the public (Ricardian neutrality does not hold in this model because some consumers are liquidity-constrained; more on this below), net holdings of claims against foreign residents and the value of capital in each sector. Under this specification, the desired value of each period's consumption is equal to the product of the time preference rate and household wealth:

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<sup>15</sup> This specification imposes the restriction that household decisions on the allocations of expenditure among different goods at different points in time be separable. Also, since utility is additive in the logs of private and government

$$(5) \quad P^C C = \theta(F + H)$$

There has, however, been considerable debate about whether the actual behavior of aggregate consumption is consistent with the permanent income model.<sup>16</sup> Based on the evidence cited in Campbell and Mankiw (1990), we assume that only a fraction  $\beta$  of all consumers choose their consumption to satisfy (5) and that the remainder consume based entirely on current after-tax income. This could be interpreted in various ways, including the presence of liquidity-constrained households or households with myopic expectations. For the purposes of this paper we will not adopt any particular explanation and will simply take  $\beta$  to be an exogenous constant.<sup>17</sup>

This produces the final consumption function shown below:

$$(6) \quad P^C C = \beta\theta(F_t + H_t) + (1 - \beta)\gamma INC$$

where  $\gamma$  is the marginal propensity to consume for the households consuming out of current income. Following McKibbin and Sachs (1991) we take  $\beta$  to be 0.3 in all regions.<sup>18</sup>

Within each period, the household allocates expenditure among goods and services in order to maximize  $C(s)$ , its intratemporal utility index. In this version of the model we assume that  $C(s)$  may be represented by a nested CES function. At the top tier, consumption is composed of inputs of capital services, labor, energy and materials. Energy and materials, in turn, are CES

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consumption, changes in government consumption will have no effect on private consumption decisions.

<sup>16</sup> Some of the key papers in this debate are Hall (1978), Flavin (1981), Hayashi (1982), and Campbell and Mankiw (1990).

<sup>17</sup> One side effect of this specification is that it will prevent us from using equivalent variation or other welfare measures derived from the expenditure function. Since the behavior of some of the households is implicitly inconsistent with (8), either because the households are at corner solutions or for some other reason, aggregate behavior is inconsistent with the expenditure function derived from our utility function.

<sup>18</sup> Our value is somewhat lower than Campbell and Mankiw's estimate of 0.5.

aggregates of inputs of individual goods.<sup>19</sup> The elasticities of substitution at the energy and materials tiers were estimated to be 0.8 and 1.0, respectively. In this version of the model the top tier elasticity has been imposed to be unity.

Finally, the supply of household capital services is determined by consumers themselves who invest in household capital. We assume households choose the level of investment to maximize the present value of future service flows (taken to be proportional to the household capital stock), and that investment in household capital is subject to adjustment costs. In other words, the household investment decision is symmetrical with that of the firms.

### **2.3 Labor Market Equilibrium**

We assume that labor is perfectly mobile among sectors within each region but is immobile between regions. Thus, within each region wages will be equal across sectors. The nominal wage is assumed to adjust slowly according to an overlapping contracts model where nominal wages are set based on current and expected inflation and on labor demand relative to labor supply. In the long run labor supply is given by the exogenous rate of population growth, but in the short run the hours worked can fluctuate depending on the demand for labor. For a given nominal wage, the demand for labor will determine short-run unemployment.

Relative to other general equilibrium models, this specification is unusual in allowing for involuntary unemployment. We adopted this approach because we are particularly interested in the transition dynamics of the world economy. The alternative of assuming that all economies are always at full employment, which might be fine for a long-run model, is clearly inappropriate

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<sup>19</sup> This specification has the undesirable effect of imposing unitary income and price elasticities. There is abundant

during the first few years after a shock.

## 2.4 Government

We take each region's real government spending on goods and services to be exogenous and assume that it is allocated among final goods, services and labor in fixed proportions, which we set to 1987 values for each region. Total government spending includes purchases of goods and services plus interest payments on government debt, investment tax credits and transfers to households. Government revenue comes from sales, corporate, and personal income taxes, and by issuing government debt. In addition, there can be taxes on externalities such as carbon dioxide emissions.

The difference between revenues and total spending gives the budget deficit, which is endogenous. Deficits are financed by sales of government bonds. We assume that agents will not hold bonds unless they expect the bonds to be serviced, and accordingly impose a transversality condition on the accumulation of public debt in each region that has the effect of causing the stock of debt at each point in time to be equal to the present value of all future budget surpluses from that time forward. This condition alone, however, is insufficient to determine the time path of future surpluses: the government could pay off the debt by briefly raising taxes a lot; it could permanently raise taxes a small amount; or it could use some other policy. We assume that the government levies a lump sum tax in each period equal to the value of interest payments on the outstanding debt. In effect, therefore, any increase in government debt is financed by consols, and future taxes are raised enough to accommodate the increased interest costs. Thus, any increase in

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empirical evidence against this assumption and we intend to generalize it in future work.

the debt will be matched by an equal present value increase in future budget surpluses. Other fiscal closure rules are possible such as always returning to the original ratio of government debt to GDP. These closures have interesting implications but are beyond the scope of this paper.

Finally, because our wage equation depends on the rate of expected inflation, we need to include money supply and demand in the model. The supply of money is determined by the balance sheet of the central bank and is exogenous. We assume that money demand arises from the need to carry out transactions and takes the following form:

$$(7) \quad M = PY i^{\epsilon}$$

where  $M$  is money,  $P$  is the price level,  $Y$  is aggregate output,  $i$  is the interest rate and  $\epsilon$  is the interest elasticity of money demand. Following McKibbin and Sachs (1991) we take  $\epsilon$  to be -0.6.

## 2.5 International Trade and Asset Flows

The eight regions in the model are linked by flows of goods and assets. Each region may import each of the 12 goods from potentially all of the other seven regions. In terms of the way international trade data is often expressed, our model endogenously generates a set of twelve 8x8 bilateral trade matrices, one for each good. The values in these matrices are determined by the import demands generated within each region.

Trade imbalances are financed by flows of assets between countries. We assume that asset markets are perfectly integrated and that financial capital is freely mobile.<sup>20</sup> Under this

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<sup>20</sup> The mobility of international capital is a subject of considerable debate; see Gordon and Bovenberg (1994) or Feldstein and Horioka (1980). Also, this assumption should not be confused with our treatment of *physical* capital, which we assume to be specific to sectors and regions and hence completely immobile. The consequence of assuming mobile financial capital and immobile physical capital is that there can be windfall gains and losses to owners of physical capital. For example, if a shock adversely affects profits in a particular industry, the physical capital stock in that sector

assumption, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to a set of interest arbitrage relations of the following form:

$$(8) \quad i_k + \mu_k = i_j + \mu_j + \frac{\dot{E}_k^j}{E_k^j}$$

where  $i_k$  and  $i_j$  are the interest rates in countries  $k$  and  $j$ ,  $\mu_k$  and  $\mu_j$  are exogenous risk premiums demanded by investors (possibly zero), and  $E_k^j$  is the exchange rate between the two currencies. The risk premiums are calculated in the course of generating the model's baseline and are generally held constant in simulations. Finally, we also assume that OPEC chooses its foreign lending in order to maintain a desired ratio of income to wealth subject to a fixed exchange rate with the U.S. dollar.

## 2.6 Constructing the Base Case

To solve the model, we first normalize all quantity variables by the economy's endowment of effective labor units. This means that in the steady state all real variables are constant in these units although the actual levels of the variables will be growing at the underlying rate of growth of population plus productivity. Next, we must make base-case assumptions about the future path of the model's exogenous variables in each region. In all regions we assume that the long run real interest rate is 5 percent, tax rates are held at their 1990 levels and that fiscal spending is allocated according to 1990 shares. Population growth rates vary across regions as shown in Table 3.

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will initially be unaffected. Its value, however, will immediately drop by enough to bring the rate of return in that sector back to into equilibrium with that in the rest of the economy.

A crucial group of exogenous variables are productivity growth rates by sector and country. The baseline assumption in G-Cubed is that the pattern of technical change at the sector level is similar to the historical record for the United States (where data is available). In regions other than the United States, however, the sector-level rates of technical change are scaled up or down in order to match the region's observed rate of aggregate productivity growth. This approach attempts to capture the fact that the rate of technical change varies considerably across industries while reconciling it with regional differences in overall growth. This is clearly a rough approximation; if appropriate data were available it would be better to estimate productivity growth for each sector in each region.

Given these assumptions, we solve for the model's perfect-foresight equilibrium growth path over the period 1990-2050. This a formidable task: the endogenous variables in *each* of the sixty periods number over 6,000 and include, among other things: the equilibrium prices and quantities of each good in each region, intermediate demands for each commodity by each industry in each region, asset prices by region and sector, regional interest rates, bilateral exchange rates, incomes, investment rates and capital stocks by industry and region, international flows of goods and assets, labor demanded in each industry in each region, wage rates, current and capital account balances, final demands by consumers in all regions, and government deficits.<sup>21</sup> At the solution, the budget constraints for all agents are satisfied, including both intratemporal and intertemporal constraints.

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<sup>21</sup> Since the model is solved for a perfect-foresight equilibrium over a 60 year period, the numerical complexity of the problem is on the order of 60 times what the single-period set of variables would suggest. We use software developed by McKibbin (1992) for solving large models with rational expectations on a personal computer.

### 3 The Effects of Tradable Emissions Permits

We now explore the effects of international trading in carbon permits by considering three scenarios. As a benchmark for comparison, we begin by examining the effects of unilateral stabilization by the United States. In this scenario, the U.S. government holds annual auctions of carbon emissions permits in each of the years from 2010 to 2020.<sup>22</sup> The permits are required for the use of primary fossil fuels (coal and crude oil and gas) and the quantity is set equal to U.S. emissions in 1990. Revenues from the permit sales are returned to households via a deficit-neutral lump sum rebate.<sup>23</sup> The policy is announced in 2000 so that agents have a decade to anticipate the policy and adapt to it.

In the second scenario, all countries in the OECD follow similar policies. Each country auctions permits equal to its 1990 emissions and returns the revenue to its citizens as a lump sum rebate. The permits can be traded within countries but not from one country to another.<sup>24</sup> This simulation allows us to measure the heterogeneity of the OECD regions. Differences in baseline emissions growth and initial fossil fuel prices mean that the regions face substantially different costs of achieving stabilization. This will be reflected in the pattern of permit prices (which will indicate the cost of stabilization at the margin) and GDP losses across regions.

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<sup>22</sup> Beyond 2020 the supply of permits is allowed to increase at such a rate as to leave the real permit price at its 2020 value.

<sup>23</sup> The rebate is chosen to leave the deficit unchanged. It is not necessarily equal to the revenue raised by permit sales because other changes in the economy may raise or lower tax revenue. This formulation is not equivalent to free distribution of permits ( “grandfathering”) – that would be represented in a similar fashion in the model but would involve a 100% lump-sum recycling, with no revenues retained to maintain deficits at baseline levels.

<sup>24</sup> Even though there is no trading *between* regions, trading is implicitly allowed between the countries *within* a region. In particular, the “Other OECD” region lumps together the European Union, Canada and New Zealand, so trading is implicitly allowed between these countries.

The third scenario is identical to the second except that we allow international trading in emissions permits among OECD countries. The effect of allowing trading will be that arbitrage will cause the price of a permit to be equal throughout the OECD. This will ensure that marginal costs of carbon abatement will be equal across countries and that OECD stabilization will be achieved at minimum cost. Countries with relatively low abatement costs will sell permits and abate more than in the previous scenario; countries with high costs will buy permits and do less abatement. Comparing scenarios 2 and 3 will allow us to estimate the gains to be had from international permit trading.

### **3.1 Unilateral Emissions Stabilization by the United States**

Key results for the unilateral U.S. policy are shown in Table 4. In order to achieve stabilization, emissions would need to drop by 24 percent relative to the baseline in 2010 and 35 percent in 2020.<sup>25</sup> The resulting price of carbon emissions permits would be \$51 per tonne in 2010 rising to \$59 per tonne in 2020.<sup>26</sup> Most of the drop in emissions comes about through a decline in coal consumption as total energy use drops and the fuel mix shifts toward natural gas, the least carbon-intensive fuel. This is reflected in the industry-level results shown in Table 5: the after-tax price of coal rises by more than 100 percent and coal output declines by nearly 40 percent in 2010 and by more than 50 percent in 2020. The crude oil and gas sector is also strongly affected: output declines by 12 to 26 percent over the period.

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<sup>25</sup> Some of the emissions eliminated within the United States – roughly 10% in 2010 – are offset by increases in emissions elsewhere. Initially, over half of this “leakage” is due to the fact that other countries buy and burn the oil that the U.S. stops importing. This effect diminishes over time: by 2020 about two-thirds of the leakage is due to higher energy demand resulting from greater economic activity.

<sup>26</sup> Throughout the paper carbon will be measured in metric tons (tonnes) and prices will be in 1995 U.S. dollars.

Outside the energy industries prices and output are affected very little. The only noteworthy result is that investment rises by about one percent during the period before the policy is implemented (2001-2009). This stems from the fact that the demand for services increases slightly when households and firms substitute away from energy. As a result, investment by the service industry increases as well. The increase in investment is financed by an inflow of foreign capital, which causes the exchange rate to appreciate by about 1.6 percent during that time. The exchange rate appreciation hurts exports, primarily of durable goods.

The international effects of the policy vary across regions. Most OECD countries experience mild decreases in GDP on the order of -0.1 percent, mild exchange rate depreciations, and increases in their net investment positions. The exception is Australia, which benefits from taking up the slack in U.S. coal exports. China and the former Soviet Union are almost completely unaffected. Other developing countries receive minor capital inflows after 2010, experience slight exchange rate appreciation and slightly higher GDP, but also have lower production and exports of durable goods due to the change in exchange rates.

### **3.2 OECD Emissions Stabilization Without Permit Trading**

OECD stabilization without trading produces the results shown in Table 6. The effects of the policy differ substantially across the regions: in 2010, permit prices range from a low of \$60 in the United States to a high of \$213 in the “Other OECD” region. (To avoid ambiguity we will refer to the “Other OECD” region as “Europe” in the remainder of the text).<sup>27</sup> The effect on

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<sup>27</sup> This is a misnomer since the “Other OECD” region also includes Canada and New Zealand. We adopt it, however, in order to avoid ambiguity in certain comparisons. For example, “Permit prices in the US are lower than in the rest of the OECD” compares the US to Japan, Australia and the “Other OECD” region as a group but could easily be confused

GDP follows a similar pattern: U.S. GDP is essentially unchanged from its baseline value while GDP in Japan and Europe falls by 1.5 and 1.7 percent, respectively. These results show that both marginal and average costs of abating carbon emissions differ substantially across countries. The differences among regions stem in part from differences in the fuel mix: stabilization is cheapest in coal-intensive countries like the United States and Australia; in Japan and Europe, stabilization requires larger cuts in oil and gas consumption.

Comparing this simulation with the previous one shows that the United States is significantly better off under the OECD policy than it is when it stabilizes on its own. In 2010, U.S. GDP remains at its baseline value while under the unilateral policy it would have fallen by 0.6 percent. In 2020, U.S. GDP is actually above its baseline value by 0.1 percent; under the unilateral policy it would have fallen by 0.5 percent. The reason for this lies in the fact that the United States has substantially lower marginal costs of abating carbon emissions. This causes rates of return in the U.S. to fall less than in other OECD countries, which induces investors to shift their portfolios toward U.S. assets, leading to an increase in U.S. investment. The effect is particularly apparent in the years immediately before the policy takes effect: U.S. investment is 7.4 percent above baseline in 2005. In addition, the U.S. also benefits from lower world oil prices as OECD oil demand falls. The boost in investment and lower oil prices both tend to raise energy demand and cause permit prices to rise relative to the unilateral stabilization scenario – from \$51 to \$60 in 2010 and from \$59 to \$67 in 2020. Although U.S. GDP rises slightly relative to the baseline, it would be wrong to conclude that the policy was actually good for the United States.

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with a comparison between the US and the “Other OECD” region alone. When the latter comparison is intended we will phrase it as “Permit prices in the US are lower than in Europe”.

Much of the additional resources are owned by foreigners and the results for GNP are generally less positive or actually negative.

Examining the effect of the policy on different regions, Japan and especially Europe – which face the greatest costs of stabilizing emissions – have large capital outflows, accumulating to roughly a trillion 1995 dollars by 2020. Most of this goes to the United States, although some capital flows to Australia, which has comparatively low costs of abatement, and some to developing countries, which are not controlling emissions at all. Capital flows to developing countries are limited by adjustment costs, however: it is expensive for a region with a relatively small capital stock to absorb a large flow of new capital.

Capital flows cause the U.S., Australian and developing country exchange rates to appreciate and the Japanese and European currencies to depreciate. These changes lead directly to changes in export patterns. Japanese and European exports of durable goods increase by about 13% and 18%, respectively, over baseline; U.S. exports of durables fall by 15% to 18% and exports from developing countries fall by 25% to 35%.<sup>28</sup> At the same time, capital flows cause Japanese and European GNP to fall by less than GDP.

Overall, the effect of stabilization on countries with high abatement costs (Japan and Europe) is to reduce GDP, cause an outflow of capital, depreciate the exchange rate and stimulate exports. The effect on low cost countries is the opposite: capital inflows tend to raise GDP, appreciate the exchange rate and diminish exports. Australia is somewhat of an exception: capital inflows benefit it slightly but the economy is substantially hurt by the impact of Japanese carbon

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<sup>28</sup> Even though capital inflows to developing countries raise overall economic activity, the durables sector declines slightly because exports are adversely affected by exchange rate appreciation. This effect limits the “leakage” of

controls on Australian coal exports. Finally, oil exports from OPEC countries decline about 10 percent and world oil prices decline by about 10 percent as well.

### **3.3 OECD Emissions Stabilization With Permit Trading**

Results for this scenario are shown in Table 7. In contrast to independent stabilization, international permit trading leads to a uniform permit price throughout the OECD that rises from about \$91 per tonne in 2010 to \$108 per tonne in 2020. Because it has the lowest abatement costs, the United States reduces emissions further than in the previous scenario in order to sell permits on the world market. U.S. carbon emissions decline by over 40%, significantly more than the 25% reduction needed to return U.S. emissions to their 1990 levels. Annual permit sales exceed 300 million tonnes (\$30 billion) in 2010 and reach nearly 600 million tonnes (\$64 billion) in 2020. Cumulative payments to the U.S. over the 2010-2020 period are on the order of \$500 billion. The largest purchaser by far is Europe.

Because energy prices are substantially higher in the U.S. than in the previous case, GDP during the 2010-2020 period is significantly lower (excluding permit revenue). Exchange rate changes are similar in sign but generally larger in magnitude. The Japanese and European currencies, in particular, depreciate somewhat more. This depreciation, combined with lower energy costs in those countries, causes exports from Japan and Europe to expand more than in the previous simulation. In fact, the Japanese and European trade surpluses grow by amounts roughly comparable to what each country spends on emissions permits. This leaves the pattern

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emissions arising from redirection of trade away from emissions-controlling regions to developing countries.

and magnitude of net international capital flows similar to those from the previous scenario. In effect, these countries pay for their emissions permits with exports of durables.

The overall gains from emissions trading total about \$50 billion in 2010 and between \$80 and \$90 billion in 2020. These gains reduce OECD GDP losses from about \$270 billion (1.1% of the total) to about \$220 billion (0.9%) in 2010; and from about \$340 billion (1.1%) to \$250 billion (0.8%) in 2020. Trading thus reduces overall OECD losses by 20% to 25%. The gains from trading are unevenly distributed: in 2010, Europe gains about \$50 billion in GDP from trading; Australia and Japan together gain about \$10 billion; and the U.S. loses about \$10 billion.<sup>29</sup> By 2020, the U.S. gains about \$10 billion from trading; Japan and Australia together experience gains of about \$15 billion, and Europe gains about \$60 billion.

#### 4 Conclusion

The theoretical appeal of an international permits program is strongest if participating countries have very different marginal costs of abating carbon emissions – in that situation, the potential gains from trade are largest. Our results show that within the OECD, abatement costs are indeed quite heterogeneous: the marginal cost of stabilizing emissions in Japan and Europe is nearly four times that of stabilizing emissions in the United States. Because of these differences, under a trading regime the U.S. emerges as a large seller of emissions permits and ends up doing far more abatement than if it had stabilized its emissions unilaterally. The shift of abatement to the

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<sup>29</sup> The small U.S. GDP loss from trading in 2010 is due to business cycle effects stemming from our assumption that wages adjust slowly: the sharp increase in U.S. energy prices under the trading scenario temporarily reduces labor demand relative to the no-trading case.

United States provides total gains to the OECD as a group of \$50 billion to \$90 billion a year.

International trading, in other words, provides significant gains in efficiency.

Because the United States (and to a lesser extent, Australia) can reduce carbon emissions at relatively low cost, under any OECD stabilization policy – with or without trading – it will benefit from a significant inflows of international financial capital. This will cause the dollar to appreciate which will reduce exports of durable goods. Japan and Europe, as high cost countries, will see capital outflows, exchange rate depreciation, and increased exports of durables. Total flows of capital will be substantial, accumulating to about one trillion dollars over the period between 2000 and 2020.

Finally, it is important to note that OECD trading has only a modest effect on the costs of stabilizing emissions, and that it causes the United States to do more abatement than it would otherwise. Although this is efficient, it is the opposite of what many U.S. proponents of international permit trading seem to expect. Much of the political support for trading seems to be founded on the hope that it would allow the U.S. to do substantially *less* abatement. Our results show that in order for U.S. abatement to fall under a trading regime (that is, for the U.S. to become an importer of permits), permits would have to be available at a price below \$60 per tonne and in sufficiently large quantity (substantially more than 300 million tonnes) as to be able to supply the demands of Europe and Japan as well as the United States. This will only be possible if China, Brazil and other developing countries join the trading program *and* they are given very large allotments of permits, or if the countries of the former Soviet Union are allowed to sell their 300 million tonnes of unneeded permits. The latter case, however, would do almost nothing to control emissions.

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**Table 1: Regions and Sectors in G-Cubed**

| Regions                               | Sectors                         |
|---------------------------------------|---------------------------------|
| 1. United States                      | 1. Electric utilities           |
| 2. Japan                              | 2. Gas utilities                |
| 3. Australia                          | 3. Petroleum refining           |
| 4. Other OECD countries               | 4. Coal mining                  |
| 5. China                              | 5. Crude oil and gas extraction |
| 6. Former Soviet Union                | 6. Other mining                 |
| 7. Oil exporting developing countries | 7. Agriculture                  |
| 8. Other developing countries         | 8. Forestry and wood products   |
|                                       | 9. Durable goods                |
|                                       | 10. Nondurables                 |
|                                       | 11. Transportation              |
|                                       | 12. Services                    |

**Table 2: Production Elasticities**

| Sector             | Energy         | Materials      | Output         |         |
|--------------------|----------------|----------------|----------------|---------|
|                    |                |                | Estimated      | Imposed |
| Electricity        | 0.200          | 1.000          | 0.763 ( 0.076) | 0.200   |
| Natural Gas        | 0.933 ( 0.347) | 0.200          | 0.810 ( 0.039) | 0.200   |
| Petroleum Refining | 0.200          | 0.200          | 0.543 ( 0.039) | 0.200   |
| Coal Mining        | 0.159 ( 0.121) | 0.529 ( 0.018) | 1.703 ( 0.038) | 0.493   |
| Crude Oil & Gas    | 0.137 ( 0.034) | 0.200          | 0.493 ( 0.031) |         |
| Other Mining       | 1.147 ( 0.136) | 2.765 ( 0.028) | 1.001 ( 0.315) |         |
| Agriculture        | 0.628 ( 0.051) | 1.732 ( 0.105) | 1.283 ( 0.047) |         |
| Forestry & Wood    | 0.938 ( 0.138) | 0.176 ( 0.000) | 0.935 ( 0.080) |         |
| Durables           | 0.804 ( 0.058) | 0.200          | 0.410 ( 0.019) |         |
| Nondurables        | 1.000          | 0.057 ( 0.000) | 1.004 ( 0.012) |         |
| Transportation     | 0.200          | 0.200          | 0.537 ( 0.070) |         |
| Services           | 0.321 ( 0.045) | 3.006 ( 0.073) | 0.256 ( 0.027) |         |

**Table 3: Population Growth Rates**

| Region                     | Population Growth Rate |
|----------------------------|------------------------|
| United States              | 0.5                    |
| Japan                      | 0.0                    |
| Australia                  | 0.8                    |
| Other OECD                 | 0.7                    |
| China                      | 1.5                    |
| Former Soviet Union        | 0.5                    |
| Other developing countries | 1.0                    |

**Table 4: Aggregate Effects of Unilateral U.S. Stabilization**

|                           | 2001  | 2005  | 2010   | 2020  |
|---------------------------|-------|-------|--------|-------|
| Permit price              | --    | --    | \$51   | \$59  |
| Carbon emissions          | 0.0%  | 0.1%  | -24%   | -35%  |
| Coal consumption          | 0.0%  | 0.1%  | -39%   | -53%  |
| Oil consumption           | 0.0%  | 0.3%  | -7%    | -11%  |
| Gas consumption           | 0.0%  | 0.3%  | -2%    | -3%   |
| GDP                       | 0.0%  | 0.1%  | -0.6%  | -0.5% |
| Consumption               | 0.1%  | 0.3%  | -0.7%  | 0.2%  |
| Investment                | 1.0%  | 0.9%  | -0.9%  | -1.0% |
| Exchange rate             | 1.7%  | 1.6%  | 0.7%   | 3.2%  |
| Exports                   | -1.8% | -1.9% | -0.9%  | -3.5% |
| Imports                   | 0.0%  | 0.0%  | -0.9%  | -1.0% |
| Net foreign assets (Bil.) | \$0   | -\$39 | -\$117 | \$28  |
| GNP                       | 0.0%  | 0.0%  | -0.6%  | -0.5% |

**Table 5: Industry Effects of Unilateral U.S. Stabilization**

|                                 | 2005         |            | 2010         |            | 2020         |            |
|---------------------------------|--------------|------------|--------------|------------|--------------|------------|
|                                 | <i>Price</i> | <i>Qty</i> | <i>Price</i> | <i>Qty</i> | <i>Price</i> | <i>Qty</i> |
| <b><i>Energy Industries</i></b> |              |            |              |            |              |            |
| Electric utilities              | -0.0%        | 0.2%       | 3.2%         | -3.0%      | 6.7%         | -5.0%      |
| Gas utilities                   | -0.1%        | 0.2%       | 3.4%         | -1.9%      | 6.4%         | -3.6%      |
| Petroleum refining              | -0.2%        | 0.1%       | 6.5%         | -7.4%      | 10.9%        | -13.1%     |
| Coal mining                     | 0.1%         | 0.0%       | 111.2%       | -38.8%     | 157.4%       | -52.5%     |
| Oil and gas extraction          | -0.0%        | 0.0%       | 17.2%        | -12.0%     | 25.3%        | -25.6%     |
| <b><i>Other Sectors</i></b>     |              |            |              |            |              |            |
| Other mining                    | -0.2%        | 0.0%       | 0.9%         | -1.2%      | 0.4%         | -1.7%      |
| Agriculture                     | -0.0%        | 0.1%       | 0.4%         | -1.0%      | -0.2%        | -0.3%      |
| Forestry and wood               | -0.3%        | 0.0%       | 0.3%         | -0.6%      | -0.6%        | -0.4%      |
| Durable goods                   | -0.6%        | -0.2%      | 0.2%         | -0.7%      | -1.0%        | -0.8%      |
| Nondurables                     | -0.2%        | 0.1%       | 0.5%         | -1.3%      | -0.2%        | -0.6%      |
| Transportation                  | -0.1%        | 0.2%       | 0.2%         | -1.0%      | -0.3%        | -0.5%      |
| Services                        | -0.0%        | 0.2%       | -0.4%        | -0.3%      | -0.6%        | 0.4%       |

**Table 6: OECD Stabilization Without Permit Trading**

|                           | United States | Japan  | Australia | Other OECD |
|---------------------------|---------------|--------|-----------|------------|
| <b>2005</b>               |               |        |           |            |
| Permit price              | --            | --     | --        | --         |
| Carbon emissions          | 1.4%          | -3.3%  | 1.6%      | -2.3%      |
| Coal consumption          | 1.0%          | -0.6%  | 1.1%      | -0.7%      |
| Oil consumption           | 3.1%          | -5.9%  | 3.7%      | -4.1%      |
| Gas consumption           | 2.2%          | -2.3%  | 0.9%      | -2.0%      |
| GDP                       | 0.5%          | -0.4%  | 5.6%      | -0.4%      |
| Investment                | 7.4%          | -5.0%  | 5.5%      | -6.1%      |
| Exchange rate             | 13.7%         | -23.4% | 17.9%     | -26.0%     |
| Net foreign assets (Bil.) | -\$306        | -\$65  | -\$35     | \$267      |
| GNP                       | 0.3%          | 0.0%   | -0.3%     | -0.3%      |
| <b>2010</b>               |               |        |           |            |
| Permit price              | \$60          | \$205  | \$105     | \$213      |
| Carbon emissions          | -25%          | -21%   | -37%      | -30%       |
| Coal consumption          | -46%          | -24%   | -55%      | -57%       |
| Oil consumption           | -4%           | -15%   | -3%       | -15%       |
| Gas consumption           | 1%            | -6%    | -2%       | -6%        |
| GDP                       | 0.0%          | -1.5%  | -0.4%     | -1.7%      |
| Investment                | 6.2%          | -6.2%  | -6.8%     | -9.4%      |
| Exchange rate             | 11.8%         | -23.7% | 27.9%     | -24.4%     |
| Net foreign assets (Bil.) | -\$842        | \$54   | -\$101    | \$662      |
| GNP                       | -0.4%         | -0.8%  | -5.3%     | -1.6%      |
| <b>2020</b>               |               |        |           |            |
| Permit price              | \$67          | \$237  | \$128     | \$264      |
| Carbon emissions          | -37%          | -31%   | -53%      | -44%       |
| Coal consumption          | -60%          | -31%   | -75%      | -78%       |
| Oil consumption           | -9%           | -24%   | -12%      | -24%       |
| Gas consumption           | -1%           | -8%    | -7%       | -10%       |
| GDP                       | 0.1%          | -1.4%  | -1.7%     | -1.9%      |
| Investment                | 5.4%          | -6.4%  | -2.1%     | -9.2%      |
| Exchange rate             | 14.3%         | -23.1% | 11.9%     | -24.4%     |
| Net foreign assets (Bil.) | -\$838        | \$92   | -\$249    | \$965      |
| GNP                       | -0.2%         | -0.3%  | -6.1%     | -1.8%      |

**Table 7: OECD Stabilization With Permit Trading**

|                            | United States | Japan  | Australia | Other OECD |
|----------------------------|---------------|--------|-----------|------------|
| <b>2005</b>                |               |        |           |            |
| Permit price               | --            | --     | --        | --         |
| Annual permit sales (Bil.) | --            | --     | --        | --         |
| Carbon emissions           | 1.2%          | -3.3%  | 1.6%      | -2.5%      |
| Coal consumption           | 0.9%          | -0.6%  | 1.1%      | -0.8%      |
| Oil consumption            | 2.9%          | -6.0%  | 3.5%      | -4.6%      |
| Gas consumption            | 2.3%          | -2.3%  | 0.9%      | -2.3%      |
| GDP                        | 0.5%          | -0.3%  | 0.9%      | -0.4%      |
| Investment                 | 7.5%          | -5.1%  | 5.6%      | -6.7%      |
| Exchange rate              | 13.5%         | -24.2% | 17.8%     | -29.0%     |
| Net foreign assets (Bil.)  | -\$312        | -\$68  | -\$34     | \$292      |
| GNP                        | 0.3%          | 0.1%   | -0.4%     | -0.4%      |
| <b>2010</b>                |               |        |           |            |
| Permit price               | \$91          | \$91   | \$91      | \$91       |
| Annual permit sales (Bil.) | \$30          | -\$4   | -\$1      | -\$25      |
| Carbon emissions           | -41%          | -11%   | -32%      | -14%       |
| Coal consumption           | -70%          | -11%   | -48%      | -25%       |
| Oil consumption            | -9%           | -11%   | -2%       | -9%        |
| Gas consumption            | -1%           | -4%    | -2%       | -4%        |
| GDP                        | -0.4%         | -1.3%  | -0.1%     | -1.1%      |
| Investment                 | 4.8%          | -4.5%  | -6.0%     | -7.2%      |
| Exchange rate              | 10.9%         | -25.2% | 27.6%     | -28.5%     |
| Net foreign assets (Bil.)  | -\$864        | \$52   | -\$100    | \$750      |
| GNP                        | -0.8%         | -0.7%  | -3.2%     | -0.9%      |
| <b>2020</b>                |               |        |           |            |
| Permit price               | \$108         | \$108  | \$108     | \$108      |
| Annual permit sales (Bil.) | \$64          | -\$8   | -\$2      | -\$55      |
| Carbon emissions           | -62%          | -16%   | -44%      | -19%       |
| Coal consumption           | -96%          | -15%   | -62%      | -33%       |
| Oil consumption            | -18%          | -15%   | -10%      | -12%       |
| Gas consumption            | -3%           | -6%    | -6%       | -6%        |
| GDP                        | -0.3%         | -1.0%  | -1.3%     | -1.1%      |
| Investment                 | 4.1%          | -5.1%  | -1.3%     | -7.3%      |
| Exchange rate              | 15.8%         | -24.4% | 11.7%     | -28.3%     |
| Net foreign assets (Bil.)  | -\$830        | \$82   | -\$240    | \$1052     |
| GNP                        | -0.7%         | 0.1%   | -5.6%     | -1.1%      |

# Towards a Successful International Greenhouse Gas Emissions Trading

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**Abstract** - The inclusion of emissions trading in the Kyoto Protocol reflects an important decision to address climate change issues through flexible market mechanisms. In this paper, we have addressed a number of policy issues that must be considered in designing and implementing an international greenhouse gas (GHG) emissions trading scheme. These include how much of a Party's assigned amounts of GHG emissions can be traded internationally; emissions trading models; competitiveness concern in the allocation of emissions permits; banking and borrowing; accountability; emissions trading system enlargement; and bubbles. Although our focus has been exclusively on emissions trading, we have discussed its relationship with the clean development mechanism, joint implementation and bubbles wherever necessary. By providing some new insights, the paper aims to contribute to the design and operationlization of an international emissions trading scheme.

**Keywords:** Bubbles, carbon tax, clean development mechanism, emissions trading, greenhouse gases, international competitiveness, joint implementation, Kyoto Protocol

**JEL Classification:** Q25, Q28, Q48

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## 1. Introduction

In Kyoto in December 1997, 160 countries reached a historical agreement on limiting greenhouse gas emissions. In comparison with the United Nations Framework Convention on Climate Change (UNFCCC) at the Earth Summit in June 1992 that only committed Annex I countries to “aim” to stabilize carbon dioxide (CO<sub>2</sub>) and other greenhouse gases at their 1990 levels by 2000, the so-called Kyoto Protocol sets legally binding emissions targets and timetables for these countries. Together, they must reduce their emissions of six greenhouse gases by at least 5% below 1990 levels over the commitment period 2008-2012, with the European Union, US and Japan required to reduce their emissions of such gases by 8%, 7% and 6% respectively (UNFCCC, 1997). This Protocol will become effective once it is ratified by at least 55 parties representing at least 55% of the total CO<sub>2</sub> emissions of Annex I Parties in the year 1990.

As a reflection of the underlying principles in Article 3.3 of the UNFCCC, which states “policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost”, the Kyoto Protocol has incorporated a variety of provisions for cooperative implementation mechanisms (see Box 1). It is generally acknowledged that the inclusion of cooperative implementation mechanisms in the Protocol reflects an important decision to address climate change issues through flexible market mechanisms. Article 6 authorizes the transfer or acquisition of “emission reduction units” (ERUs) from joint implementation (JI) projects among Annex I Parties while Article 12 establishes the so-called “clean development mechanism” (CDM) through which Annex I countries can obtain the “certified emission reductions” (CERs) from JI projects with non-Annex I countries. Pushed by the US, the Kyoto Protocol also accepts the concept of emissions trading in principle under which one Annex B country will be allowed to purchase the rights to emit greenhouse gases (GHG) from other Annex B countries that are able to cut GHG emissions below their assigned amounts (i.e. their targets). Although Annex B to the Kyoto Protocol and Annex I to the UNFCCC are now identical in nature, this change from Annex I into Annex B potentially allows a developing country to engage in emissions trading if it voluntarily adopts an emissions target and is inscribed in Annex B. Because the emissions trading proposal was adopted at the very end of the Kyoto negotiations, designing “the relevant principles, modalities, rules and guidelines” governing emissions trading has been deferred to subsequent conferences. No doubt, such design of a workable emissions trading scheme is essential to the success of emissions trading. The market-based emissions trading approach, pioneered in the US Acid Rain Program (cf. Ellerman *et al.*, 1997), can achieve significant cost reductions in cutting GHG emissions while also allowing flexibility for reaching compliance only if it is structured effectively.

**Box 1: Mechanisms of Cooperative Implementation under the Kyoto Protocol****Article 4.1**

“Any Parties included in Annex I that have reached an agreement to fulfil their commitments under Article 3 jointly, shall be deemed to have met those commitments provided that their total combined aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of Article 3. The respective emission level allocated to each of the Parties to the agreement shall be set out in that agreement.”

**Article 6.1**

“For the purpose of meeting its commitments under Article 3, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy...”

**Article 12.2**

“The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.”

**Article 17**

“The Conference of the Parties shall define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading. The Parties included in Annex B may participate in emissions trading for the purpose of fulfilling their commitments under Article 3. Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under that Article.”

*Source: UNFCCC (1997).*

In this paper, we address a number of policy issues that, although far from comprehensive, must be considered in designing and implementing an international GHG emissions trading scheme.<sup>2</sup> These include how much of a Party's assigned amounts of GHG emissions can be traded internationally; emissions trading models; competitiveness concern in the allocation of emissions permits; banking and borrowing; accountability; emissions trading system enlargement; and bubbles. Although our focus is exclusively on emissions trading, we discuss its relationship with the CDM, JI and bubbles wherever necessary. By providing some new insights, the paper aims to contribute to the design and operationlization of an international emissions trading scheme.

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<sup>2</sup> A comprehensive discussion of all the design issues related to emissions trading well goes beyond the scope of the paper. We recommend readers to consult UNCTAD (1998) in this regard.

## 2. How Much Can Be Traded Internationally?

How much of a Party's assigned amounts of greenhouse gas emissions can be traded internationally is a very important issue in the current international debate on emissions trading. In accordance with Article 17 of the Kyoto Protocol that specifies that emissions trading "be supplemental to domestic actions", some countries have called for imposing a percentage limitation on the use of international emissions trading to meet one Annex I Party's Kyoto commitments (cf. United Kingdom, 1998).

*How much trading?*

Restricting trades interferes with the operation of an inter-source trading market. If Annex B governments elect to allocate the assigned amounts to individual sub-national legal entities and authorize them to trade on the international emissions permits market, no country would know up-front what a percentage of its obligations would have been fulfilled via emissions trading unless all transactions require to be pre-approved by the government or the endorsed agency. In the latter case, no legal entity is guaranteed up-front whether its transactions fall below the national threshold, although the government is sure that its allowed percentage limitation on the use of emissions trading is met. Clearly, this rule would raise transaction costs and inhibit trades, which would limit the effectiveness of emissions trading. Moreover, because the fundamental integrity of the Kyoto Protocol relies on the accountability of a Party for ultimately matching its actual GHG emissions with its assigned amounts, this approach to compliance explicitly suggests that no one means of meeting the emissions commitments is superior to, or more valid than, any others, provided that actual reductions in GHG emissions occur (Environmental Defense Fund, 1998).

It is important to bear in mind that incorporating the provision for trading to be supplemental to domestic actions was to prevent the trading in the "hot air" and to provide the incentive for technical innovation.<sup>3</sup> Imposing a general restriction to solve a limited concern runs the risk of throwing out the baby

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<sup>3</sup> When emissions trading were allowed, a country whose legally binding GHG emissions limits set by the Kyoto Protocol exceed its actual or anticipated emissions requirements would be able to trade these excess emissions, thus creating the "hot air" that would not have had otherwise. The "hot air" problem is particularly acute in Russia whose emissions are not expected to rise to its 1990 level until 2008. The "hot air" forms a "reservoir" from which some advanced Western countries, if not all, can simply buy emissions permits to make up any shortfall, instead of taking any serious domestic actions. This is one of the reasons why some countries have called for imposing a percentage limitation on the use of emissions trading. However, it should

with the bath water. A ceiling on trading on the fixed, arbitrary and once-for-all basis proposes a permanent solution to a transition problem. Moreover, setting a ceiling makes it even more difficult to set stringent emissions targets for the subsequent commitment periods beyond 2012. It is the lack of the post-2012 targets that restricts the choice of the compliance mechanisms and tools and that creates some divergence of views in assigning liability.

*relevant to*  
Instead of imposing a percentage limitation on the use of emissions trading, one possible resolution to the “hot air” concern would be to require the Parties to demonstrate adequate domestic actions according to a set of criteria against which such actions can be measured. Such criteria should be defined by the Conference of the Parties. Unlike a ceiling on trading, this option refers to process rather than to outcomes.

*↓*  
Another option involves imposing a transaction tax on trades involving “taxable” allowances, with the tax rate to be set by the Conference of the Parties (Zhang, 1998). Such a tax could be imposed only on the buyer side and could differ to reflect the direction of emissions trading flows, with zero or low rate for transactions within the advanced OECD countries themselves but high rate for transactions between them and countries with economies in transition. In order to prevent countries from attracting more trades by setting even lower transaction tax rate, the low rate should be uniformly imposed on trading within the OECD countries, and the high rate on those transactions with non-OECD countries. Moreover, the differentiated rate could become the uniform rate until the trading in the “hot air” would not be a big issue anymore.

Such a transaction tax should be internationally imposed but nationally administrated and collected by buyer countries. Buyer countries could use the proceeds from such a tax to strength their research, development and diffusion of low-cost climate friendly technologies, to subsidize transfer of such technologies to non-Annex I countries, or to buy and retire a portion of their allowed emissions permits from the market. They could also be used to retire the “hot air”.

Although imposing a transaction tax raises the cost of meeting their allowed emissions limits, it is much less trade-restrictive than imposing a percentage limitation on the use of emissions trading, because legal entities avoid the risk of being bumped over the national threshold. It alleviates to some extent the concern

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be pointed out that although emission trading makes the “hot air” problem explicit, the problem is related to targets setting, not to emissions trading per se.

about the “hot air” trading, because legal entities in the advanced OECD countries face higher transaction tax rate when engaging in trading with their counterparts in other Annex I countries. It also provides the incentive to search for cleaner technologies, particularly when the proceeds from such tax are used as buyer countries’ R&D investments in climate friendly technologies and as their payments for buying and retiring a portion of their allowed emissions permits from the market.

Finally, it should be pointed out that a transaction tax differs from a carbon tax. A carbon tax is a mandatory tax for firms emitting carbon emissions. Therefore, it is expected that there are the great political difficulties of introducing such a tax in some countries. In contrast, a transaction tax leaves firms the freedom to determine how to meet their emissions limits. Firms that elect to meet their emissions limits only by taking domestic actions have no obligations to pay such a tax.

### 3. Emissions Trading Models

*Who trades?* In terms of whether sub-national entities are eligible for trading, two types of emissions trading models can be distinguished: 1) Inter-governmental emissions trading; and 2) Inter-source trading.

In the first model, governments elect not to allocate the assigned amounts to sub-national entities, and retain the sole right to trade. As such, inter-governmental emissions trading takes place on a government-to-government basis. The legal basis for such trading has been provided by Article 17, which unambiguously states that the Parties included in Annex B to the Kyoto Protocol are eligible for emissions trading. It should be pointed out that inter-governmental emissions trading differs from joint implementation (JI) as specified in Article 6 of the ~~Kyoto Protocol~~, at least for two reasons. First, inter-governmental emissions trading separates the issue of the financing from the source of generating allowances, whereas ERUs to be transferred and acquired are always tied with specific JI projects. Second, under normal conditions, no specific approval is needed to take the transactions in inter-governmental emissions trading, whereas any JI projects need the approval of both the host and investor Annex I countries. Moreover, inter-governmental emissions trading differs from the “bubble” approach as specified in Article 4 of the Kyoto Protocol because the latter pre-

determines the transfers and acquisitions of assigned amounts within the voluntarily-formed group prior to the beginning of the commitment period.

In the second model, governments elect to allocate the assigned amounts to individual sub-national entities, and authorize them to trade on the international emissions permits market. The great advantage over the first model is that it limits the governments to setting the rules rather than undertaking emissions trading themselves, and leaves individual companies the freedom to choose how to comply with their limits. By incorporating sub-national entities into an international emissions trading scheme, the companies that actually have control over emissions would be able to profit directly from emissions reduction activities, thus providing them with strong incentives to exploit cost-effective abatement opportunities. This would potentially increase the total amount of transactions in the international scheme, meaning greater capital flows to selling participants and greater cost reductions for buying participants. By increasing the number of trades, it would also improve market liquidity and reduce the potential for abuse of market power. The latter might occur in inter-governmental trading if one country or bloc holds a significant proportion of the total number of permits. Moreover, individual companies which have information on their technical options and costs can choose their efficient emissions level by comparing marginal costs and the international permit price, whereas, in the inter-governmental trading model, national governments can make errors in their decisions of how many permits to buy or sell because they possess only global and imprecise information about greenhouse gas emission reduction options and their marginal cost.<sup>4</sup>

If emissions trading among sub-national entities is authorized, the next issue is how these governments allocate the assigned amounts within their countries. The allocation of permits depends on the structure of national emissions trading systems. Such systems could be modelled as either “*upstream*” or “*downstream*” or “*hybrid*” systems (Zhang, 1998). An “*upstream*” trading system would target fossil fuel producers and importers as regulated entities, so would reduce number of allowance holders to oil refineries

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<sup>4</sup> We argue here that sub-national legal entities are the best entities to trade emissions permits. However, there are some potential drawbacks of including private companies in the trading scheme. One is increased administrative complexity; another is that because inter-source trading would impact the assigned amounts of the Parties, the Parties might feel a loss of control over the level of their assigned amounts and thus their ability to meet their Kyoto obligations.

and importers, gas pipelines, LNG plants, coal mines and processing plants (Hargrave, 1998). For example, if such a system would be implemented in the US, the total number of allowance holders would be restricted to about 1900 as shown in Table 1. Even with such a relatively small number of regulated sources, market power would not be an issue. In the above upstream system for the US, the largest firm has only a 5.6 percent market allowance share. Firms, with each having less than one percent share, would hold the lion's share of allowances (Cramton and Kerr, 1998).

Implemented effectively, an upstream system would capture virtually all fossil fuel use and carbon emissions in a national economy. Firms would raise fuel prices to offset the additional cost. In an upstream system the number of firms that has to be monitored for compliance is relatively small, thus it is easier to administer. Moreover, existing institutions for levying excises on fossil fuels, which exist in most industrialized countries, can be used to enforce the scheme (Zhang and Nentjes, 1998). However, one of the drawbacks of an upstream system is that it provides no incentive for energy end-users to develop disposal technologies, the aspect that is deemed critical in searching the long-term solutions to solving climate change problems.

In contrast, a “*downstream*” trading system would be applied at the point of emissions. As such, a large number of diverse energy users are included. This would offer greater competition and stimulate more robust trading, thus leading to increased innovation. However, such a system would be more difficult to administer, especially concerning emissions from the transportation sector and other small sources. On the other hand, it would avoid that some energy users do not respond to the price signal, which might occur in an upstream system because of market imperfections such as high transaction costs, high discount rates and imperfect information, although the extent depends on the degree of competition and price elasticities whether price increases are actually passed on to the consumers (U.S. Office of the President, 1998).

**Table 1 Number of Regulated Entities in an Upstream Trading System in the US**

| Industry            | Point of regulation       | Number of regulated entities |
|---------------------|---------------------------|------------------------------|
| Oil                 | Refinery                  | 175                          |
| Oil                 | Refined product importers | 200                          |
| Natural gas         | Pipeline                  | 150                          |
| Natural gas liquids | Processing plant          | 725                          |
| Coal                | Preparation plant         | 550                          |
| Coal                | Mine                      | 100*                         |
| Total               |                           | 1900                         |

\* Although there are approximately 2100 mines in the US, the number of mines actually required to hold allowance probably would be less than 100. This is because mines would be required to hold allowances only for coal not sent to preparation plants. This occurs at a relatively small number of mines, principally located in the West.

Source: Hargrave (1998).

To keep a downstream trading system at a manageable level, regulated sources could be limited to utilities and large industrial sources. Governments could then address uncapped sources through other regulatory means such as carbon taxes. In doing so, however, the governments need to establish additional programs. This would be administratively burdensome, let alone the political difficulties of introducing carbon taxes in some countries. Moreover, the actual achievements in reductions of CO<sub>2</sub> emissions by a proposed carbon tax remain uncertain because of imperfect knowledge of the price elasticities of demand and supply for fossil fuels, especially for the large price increases caused by carbon taxes for major emissions cutbacks (Cline, 1992). This would put the governments at risk of non-compliance with the emissions commitments.

Alternatively, national trading systems could be modelled as “*hybrid*” systems (Zhang and Nentjes, 1998). A hybrid system is similar to a downstream trading system in the sense that regulated sources at the levels of energy users are also limited to utilities and large industrial sources. On the other hand, like an upstream trading system, a hybrid system would require fuel distributors to hold allowances for small fuel

users and to pass on their permit costs in a mark-up on the fuel price. As such, small fuel users are exempted from the necessity (and transaction costs) of holding allowances. Yet the rise in fuel price will motivate them to reduce fuel consumption or to switch from fuels with a high carbon content, such as coal, to fuels with a low carbon content such as natural gas.

No matter what national trading systems are adopted, importers and domestic producers of fossil fuels should be treated equally in obtaining emissions permits under the “like product” provisions in the World Trade Organization (WTO) (Zhang, 1998). Moreover, regardless of whether individual countries choose to empower private trading, the ultimate responsibility for fulfilling the Kyoto Protocol commitments would, however, remain with the national government as a Party to the Protocol.

#### **4. Competitiveness Concern in the Allocation of Permits**

The Kyoto Protocol has set the caps on aggregate GHG emissions for Annex I countries. If emissions trading among sub-national entities is authorized, the next issue is how these governments allocate the assigned amounts within their countries. The allocation process itself represents the establishment and distribution of private property rights over emissions, and itself lies outside the mandate of the WTO (Vaughan, 1997). Given the great concern about international competitiveness, however, the allocation of permits does have the potential to bring parties into conflict with the WTO provisions. Some fear, for example, that governments could allocate the permits in such a manner to favour domestic firms against foreign rivals. This will violate the WTO principle of non-discrimination. The allocation of permits could also be designed in such a manner to advantage certain sectors over others and further enhance their existing imperfect market competition. This makes the unequal treatment explicit, which can be much easier hidden from the general public if the conventional command-and-control regulations are used. This in turn will have a similar price distortion effect as a subsidy, and would be in conflict with the WTO rules that prohibit the use of export subsidies for such a purpose. All this clearly indicates that the manner in which countries allocate

their assigned amounts should be compatible with these WTO principles and should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade.<sup>5</sup>

However, it should be pointed out that although grandfathering is thought of as giving implicit subsidies to some sectors, grandfathering is less trade-distorted than the exemptions from carbon taxes. To understand their difference, it is important to bear in mind that grandfathering itself also implies an opportunity cost for firms receiving permits: what matters here is not how you get your permits, but what you can sell them for - that is what determines opportunity cost. Thus, relative prices of products will not be that distorted and switching of demands towards products of those firms whose permits are awarded gratis (the so-called substitution effect) not be induced by grandfathering. This makes grandfathering different from the exemptions from carbon taxes. In the latter case, there exist substitution effects. For example, the Commission of the European Communities (CEC) proposal for a mixed carbon and energy tax provides for exemptions for the six energy-intensive industries (i.e., iron and steel, non-ferrous metals, chemicals, cement, glass, and pulp and paper) from coverage of the CEC tax on grounds of competitiveness. This not only reduces the effectiveness of the CEC tax in achieving its objective of reducing CO<sub>2</sub> emissions, but also makes the industries which are exempt from paying the CEC tax to improve their competitive position in relation to those industries which are not. There will therefore be some switching of demand towards the products of these energy-intensive industries, which is precisely the reaction that such a tax should avoid (Zhang, 1997).

With the great concern that a government that grandfathers permits to a domestic firm could give it a competitive advantage over similar firm in another country where permits are not awarded gratis, some thought that there is the need for the harmonisation of allocation of permits. However, we think that individual governments should be left free to devise their own ways of allocating permits on the following grounds. First, we think this is not necessarily the case, because even if a firm obtains emissions permits by auction, if necessary, its government still can protect its international competitiveness by means of recycling the revenues raised through auctioned permits to lower other pre-existing distortionary taxes, such as taxes on labour and capital.

<sup>5</sup> See Zhang (1998) for a detailed discussion on GHG emissions trading and the world trading system.

Second, although auctioning at least part of the assigned amounts to sub-national legal entities alleviates to some extent the concern about international competitiveness, any attempts to produce an agreement on a common rate are likely to run into concerns about national sovereignty and thus would encounter significant political difficulties. Take the above CEC proposal for a carbon/energy tax as an example. National sovereignty considerations to some extent explain why the CEC proposal for a carbon/energy tax failed to gain the unanimous support of its member states, partly because some member states opposed an increase in the fiscal competence of the Community and thus opposed the introduction at a European level of a new tax on grounds of fiscal sovereignty (Bill, 1997). This failure is also because some member states are loath to restrict themselves to the common CEC-specified policy and measure design to stabilise CO<sub>2</sub> emission and way how to do it.

③ Third, given great differences in national circumstances, setting a uniform rule of allocation will restrict the rights of individual governments to select the option which is best suited to their own national circumstances. With second-best considerations, it is conceivable that some countries whose economies are heavily distorted would decide to auction permits, and that the revenues generated through auctioned permits can then be used to reduce pre-existing distortionary taxes, thus generating overall efficiency gains. Parry *et al.* (1997), for example, show that the costs of reducing US carbon emissions by 10% are four times more costly under a grandfathered carbon permits case than under an auctioned case. This disadvantage reflects the inability to make use of the revenue-recycling effect in the former case.

u Fourth and importantly, leaving individual governments the freedom to devise their own ways of allocating assigned amounts to sub-national entities would ensure that any individual government maintains its right to determine the domestic policies and measures that would be taken to meet its Kyoto obligations. For example, a government that wants to use taxes or regulations for domestic emissions control could retain the sole right to trade. Alternatively, a government could allocate its assigned amounts to private entities to trade.

## 5. Banking and Borrowing

Banking offers a greater degree of intertemporal flexibility, thus lowering the cost of abating GHG emissions. There has been heavy use of banking in the US Acid Rain Program (cf. Ellerman *et al.*, 1997), which has led to early reductions and substantially lower overall costs of compliance.

In an international GHG emissions trading scheme, three types of banking can be distinguished. The first type of banking has built into Article 12.10 of the Kyoto Protocol. It specifies that CERs obtained under the CDM during the period 2000-2008 can be banked for later use in meeting Annex I country's commitments during the first commitment period 2008-2012. This banking clause provides the incentive for private firms in Annex I countries to invest in emissions reductions in developing countries prior to the beginning of the first commitment period.

The second type is similar to the banking element built in the US Acid Rain Program. Once an emissions trading scheme, either domestic or international, is established among Annex B countries, permit holders are allowed to bank their unused permits to offset future emissions or to sell them to others. If property rights to permits during the commitment period are well defined, banking would encourage permit holders to go further with reducing emissions than their required emission limits in early years if it were more cost-effective for them to do so.

The third type of banking extends the second mechanism by including emissions reductions achieved within the jurisdiction of Annex I countries prior to the beginning of the first commitment period as well. In comparison with the first type of banking under the CDM, it also provides a similar incentive for private firms within Annex I countries to take early actions at home rather than shop around abroad. Currently, the type of banking has not been an option under the Kyoto provisions but warrants special attention. We propose that potential use of the option is contingent on the following two conditions. The first is conditional on ratification of the Kyoto Protocol (Kopp *et al.*, 1998). The option might only be authorized from the year in which the Protocol is ratified onwards. This would provide a strong incentive for Annex I countries to ratify the Protocol earlier than what otherwise would be the case. The second is conditioned on the stringency of overall assigned amounts of emissions. The countries that are supposed to sell the "hot air" should be not allowed to use the option. Thus, it alleviates to some extent the concern about the "hot air" trading, because it provides the incentive for legal entities in the advanced OECD countries to take abatement actions at home. If authorized,

the option will accelerate the process of implementing a domestic emissions trading scheme by dealing with all technical issues associated with it. However, triggering the green light for the option requires amendment to the Kyoto Protocol because the total emissions of one Annex I country during the commitment period will exceed its assigned amounts if pre-2008 emissions reductions banked are awarded to offset the post-2008 emissions targets. If such an amendment were made, the next question is that those countries that are eligible for pursuing the option have to negotiate internationally accepted national baselines for the pre-2008 period. As the negotiations leading up to the Kyoto targets have shown, this task will not be that easy.

*Early Goals*

An alternative option to allow the banking of Annex I country's own early reductions is that any credits one Annex I country awards its sub-national legal entities for pre-2008 reductions are drawn from the assigned amounts of the country in question. On the one hand, this option would give these "first-movers" a competitive advantage over those not undertaking early actions (Environmental Defense Fund, 1998). On the other hand, since the credits awarded to early movers would be otherwise allocated to those entities not undertaking early actions, with limited supply of early credits, the option amounts to government encouragement of uneconomic rent-seeking (Fischer *et al.*, 1998).

No matter what degree of flexibility is allowed in banking, governments should not confiscate banked permits even if the latest scientific evidence suggests that further emission reductions are necessary. A more acceptable approach would be to reduce the issue of new permits proportionally from the year for which the stricter emissions cap applies. This suggests that an emissions trading scheme would have to be designed from the outset to be flexible enough to facilitate any changes that might be required in the overall emission limits.

*Banking*

If an Annex I country starts with a very strict limit on GHG emissions, bottlenecks could be prevented by allowing the borrowing of a limited amount of future permits provided that a premium is paid. By taking into account the turnover of capital stock, the prospect for low-carbon or carbon-free backstop technologies, and time discounting, borrowing would allow total abatement costs to be minimised while keeping to an overall emissions budget. Therefore, as with banking, borrowing is another way to increase flexibility and lower the cost of abating GHG emissions (Richels *et al.*, 1996).

*gates from banking*

Although banking is relatively uncontroversial, borrowing is much more controversial (cf. Matsuo, 1997; Mullins and Baron, 1997; Zhang and Nentjes, 1998). Opponents fear that borrowing would make it more difficult to check whether emission sources are in compliance with their emission limits. If borrowing is allowed, firms facing bankruptcy have an incentive to borrow without being able to meet their future commitments. Borrowing could conceivably even discourage trading among individual emission sources, thus reducing market liquidity. Borrowing could also undermine the incentive to search for cleaner technologies. To some extent, the delayed response will mean additional committed warming.

In case the Conference of the Parties deems it desirable to allow some but not complete borrowing, some safeguards could be developed to allow borrowing in such a way that it does not undermine the environmental objectives. Such safeguards could include:

- limiting the contribution of borrowing to meeting an emission target;
- restricting borrowed permits to own use, rather than sale to others;
- restricting borrowing to special circumstances, such as insufficient availability of allowances on the international market;
- making borrowing of the allowance contingent on the stringency of overall emission limits (perhaps postponing its adoption until more stringent limits for the subsequent commitment periods are agreed). In any case, borrowing should not be allowed for the countries that are supposed to sell the “hot air”; and
- restricting how far into the future permits can be borrowed. For example, borrowing in the current period should not go beyond the subsequent commitment period.

## **6. The Rules for Accountability**

The question of which Party - the buyer, the seller or both - is liable for non-compliance by the seller who over-sells its permits and then fails to comply with its commitments is one of the most important issues in designing a workable emissions trading scheme. Article 6 of the Kyoto Protocol allows Annex I countries to

transfer to, or acquire from each other, ERUs resulting from JI abatement projects, but rules governing such transfers and acquisitions as well as emissions trading have not been defined. No matter how emissions trading takes place on a government-to-government basis or on a fully-fledged emissions market, such rules are essential to the success of emissions trading.

*Seller liability*

In addressing essential design features underling the transfers and acquisitions of allowances, we begin with Article 6.4. Under the Article, if one Annex I country is found non-compliance with the relevant provisions of Article 8, any ERUs acquired by the buyer country can not be used to meet its commitments under Article 3 until the question of compliance by the seller country is resolved. Put another way, Article 6.4 specifies in vague terms that the buyer country is only at risk if the question is raised regarding the seller country' compliance with reporting provisions, but does not hint anything suggesting that such ERUs acquired by the buyer country would be invalidated. So some observers think that Article 6.4 implicitly means that trading ERUs rests on the so-called "seller beware" liability (Rolfe, 1998). Under a "seller beware" regime, any ERUs or allowances acquired by the buyer is valid regardless of whether the seller is in compliance with its commitments under the Protocol. Because buyers bear no risk under the "seller beware" liability, they are more likely to become active in the market. This would stimulate the development of a more robust trading market. This is essential to the successful function of emissions trading, particularly in the initial start-up stage when few potential buyers, if any, have any trading experiences.

"Seller beware" works well in domestic emissions trading scheme, such as the US Acid Rain Program whose built-in effective enforcement mechanisms make non-compliance very expensive and unattractive. However, an international "seller beware" trading scheme will be problematic, given the fact that enforcement at the international level often proves to be more difficult and less likely to be effective than at the national level because of the absence of an institution with the international jurisdiction to enforce policy. As such, the "seller beware" liability could lead to a regime of weak compliance because the lack of strong enforcement at the international level would provide few disincentive for buyers to acquire from sellers who take a lax attitude to compliance.

To remove the built-in flaws, one option is to use eligibility to trade as an enforcement mechanism. The approach assumes that trading is a privilege, not a right. Initially, trading is only allowed to those

“eligible” parties whose domestic monitoring and enforcement systems have met certain “minimum quality” criteria (Zhang and Nentjes, 1998). By precluding those Annex B countries that do not meet the criteria from engaging in emissions trading until such time as they bring their domestic monitoring and enforcement systems up to the threshold eligible for trading, the eligibility criteria would ensure that there is no significant risk to buyers. Therefore buyers are more likely to become active in the market. The more stringent are the criteria, the greater is the assurance that traded tons of emissions represent real reductions, and hence the less risk there is to buyers. From the environmental perspective, the more stringent criteria are preferred. On the other hand, this would lead to reduced scope of participation in the trading market than do the less stringent ones, thus undermining the effectiveness of emissions trading in lowering the cost of abating GHG emissions. Clearly, a compromise needs to be reached between the desirability of assigning the seller responsibility for the validity of acquired allowances and the “appropriate” eligibility threshold.

Another option to assign the responsibility for the validity of acquired allowances could rest on the so-called “buyer beware” liability. The principle stipulates that the buyer, be it a country or a firm, is liable for non-compliance by the sellers. In this case, the allowances acquired by the buyers become invalidated or are discounted if the sellers are found not in compliance with their commitments. This would provide the strong incentive for risk-averse buyers to ensure that any allowances acquired are valid.

*invalidation of allowances*

If, at the end of the commitment period, it turns out that the seller has exceeded its assigned amounts, then the allowances acquired by the buyers could either be discounted in proportion to the degree of the seller’s overage or become invalidated on a “last-in, first out” (LIFO) basis. Operationalization of the LIFO system entails certain vintage of allowances so that the last allowances acquired could be identified. In so doing, the Parties that wished to trade are required to serialize their allowances at least by their country of origin and year of origin, with the transfers and acquisitions of allowances being mandated to start with lower numbers. In the event of non-compliance by the seller, the acquired allowances to be voided is on the basis of the last that has acquired would be the first to become voided. The process of taking back the seller’s overage continues until the seller is brought into compliance. The LIFO approach is preferred to the simple discounting approach because the former can distinguish buyers who acquire allowances from sellers when no implementation problems are on the horizon from those buyers who do so when serious implementation

problems have arisen in the seller country (Goldberg *et al.*, 1998). It also corrects the serious drawback of discounting that is unable to decide who, all buyers or just the marginal buyer, is liable for non-compliance by the seller whose allowances are sold to several countries.

However, one drawback of including a “buyer beware” liability is that the allowances are not fungible, with each one representing a unit with reference to the country where it originated. This might complicate the transfer and acquisition process and could add substantial transaction costs. With modern information technology, however, a regime of the “buyer beware” liability is probably not as complicated as it sounds. Another major drawback of assigning a “buyer beware” liability is that it erodes the commodity nature of allowances by allowing them to be retroactively devalued, thus creating uncertainty over their value until the end of commitment period. This drawback becomes even more serious because in this Protocol there is only one very long commitment period. The long length means that compliance is not determined until the end of the commitment period because, in principle, both the seller and buyer responsibility regimes do not require any interim evaluation of implementation before the end of the commitment period. As a result, we know whether the seller is in compliance only at the end of the commitment period. At that time, it might be too late to bring the seller back into compliance, although a “true-up” period of several months at the end of the commitment period is allowed for the seller finding itself in non-compliance to acquire additional allowances to cover its excess tons of emissions.

To prevent that unwanted outcomes from an early date, it is desirable to assign the buyer-seller hybrid responsibility by introducing a process of evaluating Parties’ efforts towards implementation during the commitment period. This includes annual reporting of the progress of each Party in meeting its assigned amounts. If in a given year a Party’s actual emissions did not exceed by a certain margin its annualized assigned amounts, the seller’s tons acquired by the buyers would be valid. After the year when the seller is found to go beyond that tolerance margin, however, the buyers become liable for potential non-compliance by the seller. As such, the allowances acquired prior to that year would not be discounted, thus avoiding the imposition of retroactive liability for the buyer.

Article 12 provides that Annex I countries can acquire the certified credits obtained from joint implementation abatement projects with developing countries under the CDM. In view of this, some suggest

that the transfers and acquisitions of allowances in an international emissions trading scheme could be envisioned along this line. Any extra allowances to be sold first have to be verified and certified prior to trading. In comparison with the pre-verification trading scheme, the post-verification one would increase certainty surrounding the validity of acquired allowances. In the mean time, however, it could significantly reduce the volume of trades, particularly in the multi-year compliance system in which transfers and acquisitions of allowances are expected to take place when it is approaching to the end of the commitment period. It is presumably assumed that the concern about the validity of acquired allowances prevails at the beginning of setting up an international emissions trading scheme. So the post-verification trading scheme, although not the first-best choice, could be considered in the first commitment period in case there are a large of countries sceptical about the accountability of a pre-verification trading scheme. Whether it continues or using other options to ensure certainty over the validity of acquired allowances could be reviewed at the end of that period. In any case, only certified credits from joint implementation projects with developing countries can be incorporated into an international emissions trading scheme.

## **7. Emissions Trading System Enlargement**

Given the fact that the costs of abating GHG emissions differ significantly among countries and there are a great deal of low-cost abatement options in developing countries (cf. IPCC, 1996), it is generally acknowledged that broadening an international emissions trading scheme to include developing countries creates a source of obtaining low-cost abatement options, thus increasing potential of efficiency gains. This is one of the reasons why some OECD countries insist on bringing non-Annex I countries into an emissions trading scheme. On the other hand, Russia, the country widely regarded as the biggest seller of emissions permits among Annex I countries once emissions trading takes place, would not welcome the addition of non-Annex I countries, such as China and India, to the scheme because these new entrants would raise the supply of overall permits on the market and depress the prices of those permits held by Russia. Although these are

Mod. for new entrants

just political speculations, they underline the importance to establish clear rules of procedure about admitting new entrants before emissions trading begins.

There are two avenues to establish such rules of procedure. One is based on voting to admit new entrants. So far any decisions made by the Conference of the Parties to the UNFCCC have been generally adopted by consensus. If admitting new entrants requires unanimous assent by all current Annex B countries eligible for emissions trading, this confers on Russia a *de facto* power of veto. Thus, if avenue to admit new entrants rests on voting, a three-fourth majority vote of the current Annex B countries present and voting at the meeting could be adopted to prevent exploitation of market power.

The second avenue rests on automatic phase-in once one prospective country meets pre-determined criteria. In our view, the second is superior to the first avenue. Such criteria should include the conditions under which any new entrant could be incorporated into the emissions trading scheme. Once such criteria are set, they should remain stable in the short-run, although in the long-run adjustments in the criteria might be normal as greater information and experience is gained.

By the same token, broadening an emissions trading scheme to cover all greenhouse gases under Annex A to the Kyoto Protocol increases the cost savings. On the other hand, a workable emissions trading scheme requires that emissions of whatever a pollutant to be included have to be measured with reasonable accuracy. This requirement implicitly precludes including all gases in the initial trading scheme. However, limiting trading to a subset of gases is not likely to be effective unless the Protocol is further amended to partition the assigned amounts into two categories—tradable and non-tradable gases with separate goals being assigned for each. Without a separation of categories, it seems to be lack of a legal basis to reject the legitimate claim from those countries that use the flexibility inherent in the equivalence process to substitute freely among the gases, because Article 5.3 of the Protocol has authorized that the global warming potentials are used to translate non-CO<sub>2</sub> greenhouse gases into carbon equivalent units in determining each Annex I Party's compliance with its assigned amounts.

## 8. Bubbles

In addition to Article 17, on the insistence of the EU, the Kyoto Protocol incorporates the “bubble” concept into the final text (Article 4). It allows a group of Annex I countries to jointly fulfil their commitments under Article 3, provided that their total combined aggregate GHG emissions do not exceed their assigned amounts. The “bubble” approach is often termed as “trading without rules” because it sets few restrictions on trading between Parties. This makes it a potentially attractive instrument. Given great differences in environmental monitoring and enforcement infrastructures among Annex I countries, if it turns out to be too difficult to agree on the common rules and guidelines for a full-fledged emissions trading scheme, the “bubble” approach at least opens the possibility of trading emissions permits within the voluntarily-formed group. In addition to the current EU bubble, the US has reached a conceptual agreement with Australia, Canada, Japan, New Zealand, Russia and Ukraine to pursue an umbrella group to trade emissions permits (USDOS, 1998). However, the approach presents some drawbacks. First, it requires to set a cap on overall emissions for the group as a whole and to work out a specific cap for each member country within the group in an agreement, the terms of which must be notified to the UNFCCC Secretariat at the time of ratification of the Protocol. Once the agreement has been registered with the Secretariat, the commitments agreed on cannot be revisited during the commitment period in question.

Second, it narrows the scope of efficiency gains in comparison with inter-source trading, because it restricts where firms or countries comply with their caps and because it is likely to have frightening transaction costs.

Third, in the case of the current EU bubble, because the European Community (EC) itself as a Party to the Protocol, in addition to its member states, has the legitimate responsibility for reporting on the performance of the EU as a whole and ensuring its declared targets as a whole under the notified agreement are met, the potential advantages of offering double coverage of reporting obligations and double assurance for abatement obligations could be hindered by the need to have complete and early information from individual member states (OECD, 1998). In the event that the EC as a whole would fail to meet its own targets and if a non-compliance procedure would be established, the EC, together with those individual member states that have not achieved their own targets set out in the agreement, would thus be faced with sanctions under

Article 4.6. In this case, who bears the responsibility of the EC itself? As such, some clarification for the clear division of responsibility in the terms of that agreement is needed in the case where a regional economic integration organization itself is a party to the Protocol.

Fourth, although originally conceived as a way of allowing the EC as a regional economic integration organization (REIO) to accommodate the internal burden sharing of the Kyoto commitments among its member states, the final wording under Article 4 is framed in general terms. This might create potential loopholes in meeting the Kyoto obligations. In the case of a REIO bubble, each REIO member and the organization itself are held accountable for the failure to achieve the required reductions for the REIO member. Under the terms of the agreement notified to the UNFCCC Secretariat, the incentive for non-compliance is offset by the joint responsibility of both the individual members and the regional organization. In contrast, in the case of a non-REIO bubble, the absence of a formal regional organization with enforcement powers means that the seller countries are solely responsible for their own non-compliance. As discussed in Article 17 trading, these countries may have an incentive to fall short of compliance. To ensure the environmental integrity of the Kyoto Protocol, it is thus desirable to assign some form of joint responsibility for non-REIO bubbles too. However, the countries concerned within a non-REIO bubble should be left free to work out an arrangement to bring the whole group into compliance.<sup>6</sup>

## **9. Concluding Remarks**

The Kyoto Protocol is the first international environmental agreement that sets legally binding GHG emissions targets and timetables for Annex I countries. Its Article 17 authorizes emissions trading between Annex B countries. If properly designed, emissions trading can effectively reduce their abatement costs while assisting Annex I countries in achieving their Kyoto obligations.

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<sup>6</sup> Goldberg *et al.* (1998), for example, suggest that one possible approach to assigning the joint responsibility within a non-REIO bubble would be to hold the economically stronger members accountable, in part, for the failure of the weaker members to meet their agreed emissions targets.

Aimed at contributing to the design and operationalization of an international GHG emissions trading scheme, this paper has discussed how much of a Party's assigned amounts of GHG emissions can be traded internationally; emissions trading models; competitiveness concern in the allocation of emissions permits; banking and borrowing; accountability; emissions trading system enlargement; and bubbles. The following conclusions emerge from that discussion.

First, no ceiling on the use of international emissions trading should be imposed on countries eligible for emissions trading, on grounds of both economic efficiency and environmental effectiveness. We think that setting a ceiling on trading on the fixed, arbitrary and once-for-all basis proposes a permanent solution to a transition problem, interferes with the development of financial markets for allowances, and makes it even more difficult to set stringent emissions targets for the subsequent commitment periods beyond 2012.

Second, we propose to impose a transaction tax on trades involving "taxable" allowances as one possible resolution to the "hot air" concern that motivated the placement of supplemental norm in the Kyoto Protocol. Such a tax differs from a carbon tax because firms that elect to meet their emissions limits only by taking domestic actions have no obligations to pay such a transaction tax. It could be imposed only on the buyer and could differ to reflect the direction of emissions trading flows. Another approach to addressing the supplemental norm requirement would be to require the Parties to demonstrate adequate domestic actions according to a set of criteria to be defined by the Conference of the Parties.

Third, companies are the best entities to trade emissions permits. Allocating permits to individual sub-national legal entities will facilitate private participation in emissions trading. Such an allocation depends on the structure of national emissions trading systems. Such systems could be modelled as either "*upstream*" or "*downstream*" or "*hybrid*" systems, depending on national circumstances.

Fourth, the allocation of permits has the potential to bring parties into conflict with the WTO provisions, raising concerns about international competitiveness. Although such concerns are not limited to trading where allowance allocation can make unequal treatment explicit, they can be much more easily hidden from the general public if conventional command-and-control regulations are used. Auctioning at least part of the assigned amounts to sub-national legal entities alleviates to some extent the concern about international competitiveness. However, any attempts to produce an agreement on a common rate are likely to run into

concerns about national sovereignty and thus would encounter significant political difficulties. With this in mind, we argue that individual governments should be left free to devise their own ways of allocating assigned amounts. This would ensure that any individual governments maintain their right to determine the domestic policies and measures that would be taken to meet their Kyoto obligations.

Fifth, banking offers a greater degree of intertemporal flexibility, thus lowering the cost of abating GHG emissions. The Protocol allows CERs obtained under the CDM prior to the beginning of the first commitment period to be credited for later use, and seems to place no restrictions on the use of banking during the post-2008 commitment periods. However, banking of Annex I country's own early reductions prior to the beginning of the first commitment period has not been an option under the Kyoto provisions. If authorized, this type of banking would provide a strong incentive for Annex I countries to ratify the Protocol earlier than what otherwise would be the case. It alleviates to some extent the concern about the "hot air" trading, because it provides the incentive for legal entities in the advanced OECD countries to take abatement actions at home. As with banking, borrowing is another way to increase flexibility and lower the cost of abatement. However, borrowing is much more controversial. If allowed, a number of safeguards should be added to avoid possible abuses of the option.

Sixth, the rules for accountability are essential to the success of emissions trading. In general, a "seller beware" liability works well in a strong enforcement environment where the built-in effective enforcement mechanisms make non-compliance very expensive and unattractive. In the Kyoto Protocol, however, a "seller beware" liability may not always work because there is only one very long commitment period and, as of now, no additional commitment periods have been defined, and because enforcement at the international level has proved to be less likely to be effective than at the national level. This may create a need for some form of a "buyer beware" liability under which acquired allowances that are tainted could not be used to satisfy the buyer's assigned amount requirements. This would provide the strong incentive for risk-averse buyers not to acquire allowances from sellers who appear to be headed towards non-compliance. If the Parties decide that "buyer beware" liability is needed to complement traditional compliance procedures, the "last in, first out" approach is preferred to the simple discounting approach in taking back the seller's overage, because the former can distinguish buyers who acquire allowances from sellers when no implementation

problems are on the horizon from those buyers who do so when serious implementation problems have arisen in the seller country. Furthermore, we argue that, in order to prevent non-compliance from an early date, it is desirable to assign the buyer-seller hybrid responsibility by introducing a process of evaluating Parties' efforts towards implementation during the commitment period. If in a given year a Party's actual emissions did not exceed by a certain margin its annualized assigned amounts, the seller's tons acquired by the buyers would be valid. After the year when the seller is found to go beyond that tolerance margin, however, the buyers become liable for potential non-compliance by the seller. As such, the allowances acquired prior to that year would not be discounted, thus avoiding the imposition of retroactive liability for the buyer.

Seventh, the Protocol itself, the eligibility criteria and the measurement capability considerations initially preclude including all the countries and greenhouse gases in an international emissions trading scheme. However, broadening a coverage of such a scheme will induce more cost-effective abatement options and further increase the cost savings. Therefore, it is very important to establish clear rules of procedure to facilitate admitting new entrants and including gases that are not covered initially before emissions trading begins.

Finally, although originally conceived as a way of allowing a REIO to accommodate the internal burden sharing of the Kyoto commitments among its member states, the final wording of joint fulfilment under Article 4 is framed in general terms. If it turns out to be too difficult to agree on the common rules and guidelines for a full-fledged emissions trading scheme, the "bubble" approach at least opens the possibility of trading emissions permits within the voluntarily-formed group. Moreover, in order to ensure the environmental integrity of the Kyoto Protocol, just as a REIO bubble has built-in joint responsibility of both the individual members and the regional organization, it is desirable to assign some form of joint responsibility in the case of non-REIO bubbles, although the countries concerned within a non-REIO bubble are left free to work out an arrangement to bring the whole group into compliance.

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