CLIMATE POLICY NOTE

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MULTI-GAS STRATEGIES AND THE COST OF KYOTO

A multi-gas control strategy that includes abatement of all greenhouse gases and sink enhancement significantly reduces the cost of the Kyoto Protocol

Most discussion of how to address global warming has focused on one single greenhouse gas (GHG), carbon dioxide, from fossil fuel use only. Yet, other GHGs and carbon sinks also affect the atmosphere's "radiative budget." The Kyoto Protocol allows credit for enhancing sinks and reducing five classes of other greenhouse gases—methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride—in a multigas emissions limit. Several studies at MIT address the cost implications of the Kyoto Protocol's multigas approach.

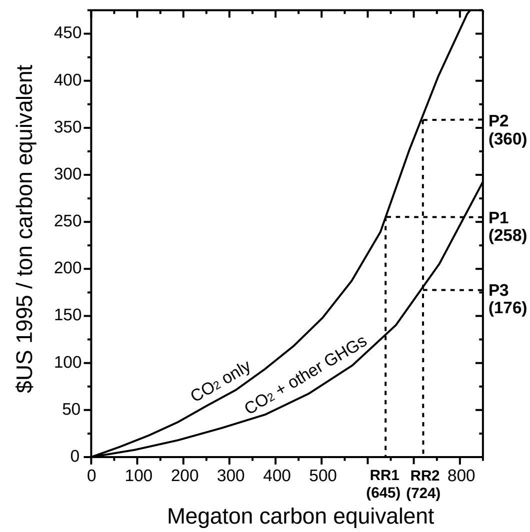

Figure 1. Marginal abatement curves for CO_2 in the USA and total GHGs (further explained below).

Effect of Expanded Credit Options

The emission limits proposed in the Kyoto Protocol apply not to individual GHGs, but to a "multigas" limit in which each gas is "weighted" according to its contribution to radiative forcing over some time period relative to carbon dioxide (CO_2)—its global warming potential (GWP). The inclusion of the non-CO_2 gases has two effects: it increases the carbon-equivalent abatement required at the same time that more opportunities for abatement are made available.

Abatement options are expanded further by the inclusion of carbon sink enhancements; however, the qualifying sinks are limited to human-induced efforts initiated after 1990. Indirect sink enhancement from increased plant growth due to both elevated atmospheric CO_2 and deposition of industry-emitted nitrogen is excluded, as are increases in natural land sinks, despite terrestrial ecosystems' importance in balancing the carbon budget.

Figure 1 illustrates the net effect of the Protocol's multi-gas features. The two curves are marginal abatement cost (MAC) schedules, which can be derived from models or built independently for each GHG. Any point along either curve indicates the cost of the last increment for a given amount of abatement; the area under the curve up to that point represents the total cost of abatement. The "CO_2 only" curve represents abatement opportunities and associated costs for CO_2 emissions alone. The "CO_2 + other GHGs" curve indicates abatement and sink enhancement opportunities, expressed in carbon equivalents, for all six classes of Kyoto GHGs and sink enhancements; it is formed by adding horizontally at every price the amounts of abatement from each of the six classes of gases, appropriately weighted by its GWP, and the amount of sink enhancement.

If the Kyoto limit had defined a fossil CO_2-only target, widening the scope of creditable actions to recognize other gases and sinks would have reduced cost unambiguously. However, the other gases are included in the target. Lines *RR1* and *RR2* in **Figure 1** indicate the required reduction if the Kyoto percentage is applied to CO_2 only and to all Kyoto gases, respectively. The net effect of the Protocol's more comprehensive treatment is depicted by the change in emission limit from *RR1* to *RR2* and by the shift in abatement opportunities from the CO_2-only MAC to the other MAC.

Meeting the Kyoto multi-gas limit with CO_2-only abatement would cost almost twice as much

Economic Results for Three Policy Cases

Three cases depict the net balance of these effects:

- **Case 1.** *Fossil CO_2 target and control:* Only CO_2 is considered in determining allowable emissions, as has been assumed by much of the research to date on cost control, and only CO_2 reductions are counted.
- **Case 2.** *Multi-gas target but CO_2-only control:* The target includes the six classes of gases included in the Kyoto Protocol, but control actions are limited to CO_2 emissions from fossil fuels.
- **Case 3.** *Multi-gas target and control:* The target is the same as in Case 2, but sinks and abatement of the other gases are included among the control options.

The intersection of *RR1* with the CO_2-only MAC represents Case 1. The total cost for meeting this target with this set of abatement opportunities is indicated by the area under the CO_2-only curve, to *RR1*; the marginal cost of carbon is *P1*. Increasing the abatement target to *RR2* while limiting abatement opportunities to CO_2-only emissions control (Case 2) increases the marginal cost to *P2* and adds the area beneath the CO_2-only MAC, between *RR1* and *RR2*, to total cost. Case 3 (intersection of *RR2* with the multi-gas MAC) expands abatement opportunities. Associated marginal and total costs will always be lower than Case 2, but comparisons with Case 1 depend on the relative magnitudes of the increased limit and expanded opportunities.

This illustration is based on data for the USA; the same results do not necessarily apply to other countries, as **Table 1** below illustrates. The distance from *RR1* to *RR2* depends on the baseline share of other gases and their growth through 2010 relative to CO_2; the distance between the two curves depends on other-gas abatement and sink opportunities available. Countries with relatively high growth in other-gas emissions between 1990 and 2010 and relatively few abatement opportunities will likely be worse off under a multi-gas strategy; those with relatively low growth in other-gas emissions and greater abatement or sink opportunities will do better.

Table 1. Total annual abatement cost in 2010 (billions of 1995 $US) for the six Annex B regions in MIT's EPPA model.

	USA	JPN	EEC	OOE	EET
Case 1: CO_2 target and control	61	14	29	12	0
Case 2: Multi-gas target, CO_2 control	86	19	45	24	0.2
Case 3: Multi-gas target & control	43	13	27	7	0.1

Comparing Cases 1 and 3 reveals the net effect of the Kyoto Protocol's multi-gas features. For all but one region (excluding the former Soviet Union, which remains unconstrained), the added cost-reducing opportunities outweigh the additional constraint. For Annex B as a whole, the total cost is reduced 22% ($90 billion vs. $116 billion) by including sinks and other GHGs in the Protocol.

While the comparison of Case 1 with Case 3 indicates the effect of expanded Kyoto definitions, comparing Case 2 with Case 3 is at least as important, for it reveals the cost of failing to develop other-gas abatement opportunities and sink enhancements. Meeting the Kyoto multi-gas limit with CO_2-only abatement would incur total costs of $174 billion for Annex B—almost twice as much as fully utilizing the expanded opportunities. Early attention to all gases and sinks is thus a crucial aspect of any response to Kyoto-type emissions targets.

Sources: J. Reilly, M. Mayer, and J. Harnisch, "Multiple Gas Control Under the Kyoto Agreement." Extended abstract in the Proceedings of the 2[d] Intl. Symposium on Non-CO_2 Greenhouse Gases (J. van Ham, A.P.M. Baede, L.A. Meyer, and R Ybema, eds.), Kluwer Academic Publishers, Dordrecht, Netherlands (forthcoming). Earlier work was published in J. Reilly, R. Prinn, J. Harnisch, J. Fitzmaurice, H. Jacoby, D. Kicklighter, J. Melillo, P. Stone, A. Sokolov, C. Wang, "Multi-gas Assessment of the Kyoto Protocol," *Nature* **401**, 7 October 1999 (pp. 549-55), based on Joint Program Report #45 <http://web.mit.edu/global change/www/reports.html>.