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Stabilization and global climate policy

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Abstract

Academic and political debates over long-run climate policy often invoke "stabilization" of atmospheric concentrations of greenhouse gases (GHGs), but only rarely are non-CO_2 greenhouse gases addressed explicitly. Even though the majority of short-term climate policies propose trading between gases on a global warming potential (GWP) basis, discussions of whether CO_2 concentrations should be 450, 550, 650 or perhaps as much as 750 ppm leave unstated whether there should be no additional forcing from other GHGs beyond current levels or whether separate concentration targets should be established for each GHG. Here, we use an integrated modeling framework to examine multi-gas stabilization in terms of temperature, economic costs, carbon uptake and other important consequences. We show that there are significant differences in both costs and climate impacts between different "GWP equivalent" policies and demonstrate the importance of non-CO_2 GHG reduction on timescales of up to several centuries.

Keywords: Climate; Greenhouse effect; Model; Policy; Methane; Carbon dioxide

1. Introduction

The stated goal of Article 2 of the UN Framework Convention on Climate Change (UN FCCC) is the "stabilization of greenhouse gas (GHG) concentrations in the atmosphere" at a level that would "prevent dangerous anthropogenic interference with the climate system". The 1997 Technical Paper III of the Intergovernmental Panel on Climate Change (IPCC) attempted to clarify the Convention's stabilization goal (Schimel et al., 1997). Sensitivity to small deviations in other GHG emissions was evaluated and the study revealed that in the short-term these deviations could have significant impact. The Technical Paper also noted that, since pre-industrial times, the contribution of these 'other' substances to radiative forcing is comparable to that of CO_2. But in academic papers, control of other gases is at best usually relegated to footnotes or asides (Dai et al., 2001a; Nordhaus, 2001; Arnell et

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al., 2002; Hoffert et al., 2002; O'Neill and Oppenheimer, 2002). Question 6 of the Synthesis Report to the IPCC Third Assessment Report (TAR) asks what the consequences are of stabilizing concentrations in carbon dioxide equivalents, but the text then only addresses CO_2, and the stabilization scenarios are analyzed with only one projection of other greenhouse gases, namely the unconstrained SRES A1B scenario (Watson and Core Writing Team, 2001). The U.S. National Assessment Report on Climate Change Impacts relies heavily on the CGCM1 and HADCM2 models, both of which use CO_2 as a surrogate for other greenhouse gases (National Assessment Synthesis Team, 2001).

While most stabilization proposals only explicitly address carbon dioxide stabilization, shorter-term climate policies often include the possibility of trading among greenhouse gases by using the global warming potentials (GWPs) established by the IPCC in order to reach more economically efficient solutions than relying on CO_2 reduction alone would allow. Indeed, the Kyoto Protocol allows for precisely this sort of trading across greenhouse gases, using a 100-year GWP as the 'exchange rate'.

Trading schemes that rely on constant GWPs will not generate stabilization of concentrations or radiative forcing, as trading a reduction of a gas with a short lifetime for an increase of a long-lived gas will inherently lead to reductions in radiative forcing in the near term and increases in radiative forcing in the long-term (and vice versa). Stabilizing radiative forcing would require trading concentration levels of one GHG for another, which would imply that in terms of emissions, emissions paths for each GHG be specified over at least the lifetime of the longest lived of the two. Other studies equate a CO_2 stabilization level with a forcing value, such as a recent Hadley Centre analysis (Mitchell et al., 2000). These studies model varying CO_2 concentrations and assume the concentrations of all other gases stay constant, but acknowledge that, in reality, society might choose a different allocation between other GHGs and CO_2 that add up to the same total forcing level. For a given CO_2 equivalent stabilization target, the actual level at which CO_2 will need to be stabilized is therefore likely to be significantly lower and, moreover, such studies provide no direct guidance on the emissions paths that would be consistent with stabilization of radiative forcing. The question of stabilization of multiple greenhouse gases is inevitably linked to how to compare greenhouse gases, and thus the inadequacy of GWPs (e.g. Reilly et al., 1999). One approach is to set a specific climate or radiative forcing target and endogenously estimate the optimal control path of different gases (e.g. Manne and Richels, 2001). Work in this vein has relied on highly stylized climate and atmospheric chemistry relationships, so there is some assurance that a single optimal path exists or that it is numerically feasible to solve for it. Absent in these efforts are important relationships among methane, the hydroxyl radical, and tropospheric ozone (and its precursors).

In this study, we use the MIT Integrated Systems Model (IGSM) to examine several different ways in which a stabilization target might be interpreted. Economic projections were made for the coming century under different policy constraints to develop emissions scenarios and also to examine economic impacts. The natural systems model was used to determine the climate impacts of the various emissions scenarios. The inclusion of chemistry, terrestrial ecosystem, and other components in the coupled natural system model enables examination of processes such as ozone generation and the carbon cycle on both 100-year and several century timescales. Previously, different components of the MIT IGSM have been used to examine the economics of non-CO_2 gas abatement (Hyman et al., 2003), the Kyoto protocol (Prinn et al., 1999; Reilly et al., 2002) and the climate impacts of reductions in non-CO_2 gases (Reilly et al., 2003). The unique contribution of this study is an examination of the complex relationships among physical climate system components as they affect stabilization. By extending the model to consider periods well beyond 2100, we examine the limits of the 2100 horizon often used in the literature for stabilization discussions. More generally, this study is designed to bring the definitional issues involved in stabilization policy discussions into sharper focus. While the results of the model runs depend on several assumptions, comparisons between the various policies give indications of the magnitude of the economic and climatic importance of these definitions.