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Supplementary Materials for

What Role for Short-Lived Climate Pollutants in Mitigation Policy?

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Supplementary Material

Modeling and Scenario Overview

We used the Magicc model v.6 (freely available for download at live.magicc.org) to assess the future temperature trajectories resulting from various greenhouse gas (GHG) emissions scenarios. The Magicc model is a reduced complexity climate model. The model has a hemispherically averaged upwelling-diffusion ocean coupled to an atmosphere layer and a globally averaged carbon cycle model. A full description of the model can be found at Meinhausen *et al*. (*17*). The only parameters we changed from the default version (other than the input emissions scenarios described below) was the runtime, which was extended from 100 to the maximum of 400 years (2000–2400). The model was run using the medium (3°C) climate sensitivity. CO_2 emissions scenarios were based off the RCP6 scenario provided in the Magicc software package [derived from Meinhausen *et al*. (*18*)], with only CO_2, CH_4, and black carbon (BC) emissions altered as described in detail below.

RCP6 is not a "business-as-usual" (BAU) scenario. We did not use a BAU reference scenario because the focus of this Policy Forum is on how to prioritize emissions reductions of different GHGs relative to each other, not relative to taking no mitigation actions. Black carbon reference emissions were derived from Ramanathan and Xu (*1*), and the CH_4 reference emission scenario is described below. For CH_4 and BC, the RCP6 scenario could not be used as a reference due to the strong emissions reductions for both gases embedded in RCP6. Use of RCP6 as a reference, with CH_4 and BC reductions already embedded, would have minimized the influence of short-lived climate pollutant (SLCP) reductions reflected in the mitigation scenario and would not have illustrated the trade-offs between emission reduction strategies.

As stated in the figure caption, for simplicity, we did not alter hydrofluorocarbon (HFC) or sulfate aerosol emissions from the reference RCP6 trajectories. The RCP6 scenario assumes strong regulation of sulfate emissions, with emissions declining rapidly despite rising CO_2 emissions. There are eight different HFCs included in the RCP6 scenario. Emissions of some are predicted to rise and others to decrease quickly. Inclusion of modified HFC and sulfate aerosol emissions in this sensitivity analysis would likely alter the shape of some of the plotted temperature trajectories but would be unlikely to significantly impact the pattern of their climate influence over time, which is the focus of this policy forum.

Although the model was run from 2000 to 2400, we have only plotted timelines from 2000–2200 for two reasons: the temperature response curves change very little between 2200 and 2400 and extending the *y* axis obscures the dynamics between 2000–2100 without adding much valuable information; second, our confidence in emissions scenarios extending far into the future decreases at these long time scales. However, this reason alone should not deter us from looking at model results at these time scales. If we assume GHG mitigation will occur within the next 100–150 years, the long-term trend in the temperature trajectories out to 200 or 400 years is primarily controlled by differences in emissions scenarios during this time, not differences between lower-level emissions in the far future. The goal of this modeling analysis is to present a comparison between the temperature trajectories over short and long time scales that could result from hypothetical feasible reductions in emissions of either CO_2, SLCPs, or both (hybrid climate mitigation, HCM), relative to a scenario in which mitigation occurs on a slightly delayed time scale (modified reference RCP6).

The absolute temperatures, as well as the temperature differences between the scenarios, are highly dependent on the choice of reference scenario and precise emissions reductions. However, comparisons between the time scales of the temperature responses are relatively insensitive to these assumptions. In each of our emissions reductions scenarios we used the same time scale for primary reduction efforts: 2010–2050, in order to highlight the influence that different near-term emissions choices will have on near-term and long-term climate change.

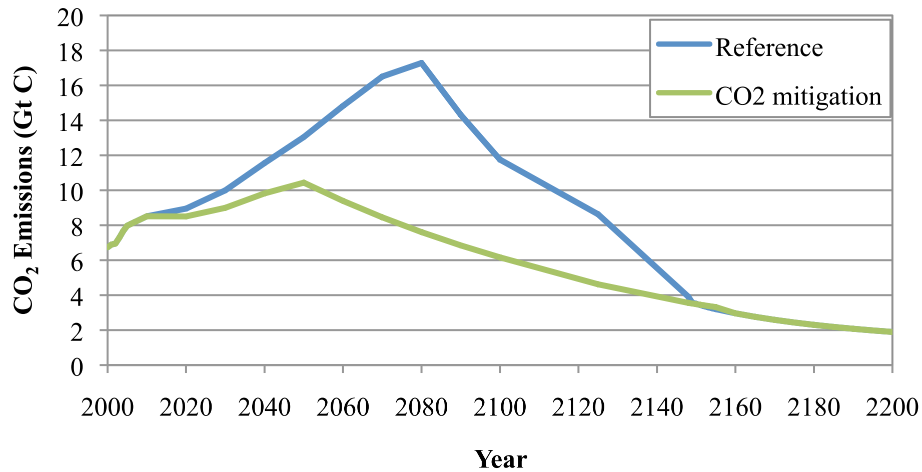
Scenarios
In the following figures, we show the emissions trajectories for CO_2, CH_4 and BC that were used to create the Reference, SLCP mitigation, CO_2 mitigation, and HCM scenarios displayed in Figure 1 of the manuscript. Descriptions of the scenarios are provided in text below followed by the figures.

Fig. S1. CO_2 emissions scenarios.
Reference: Emissions follow the RCP6 CO_2 emissions scenario. This "reference" CO_2 emissions trajectory is also used in the SLCP reduction scenario.
CO_2 Mitigation: CO_2 emission reductions (the difference between Reference and Mitigation scenarios) grow by 0.5% per year from 2010 to 2050, at which point mitigation scenario emissions are 80% of reference emissions. After 2050, emissions are assumed to decline approximately linearly until they intercept the reference RCP6 scenario at 2150. This emissions trajectory is also used in the HCM scenario.

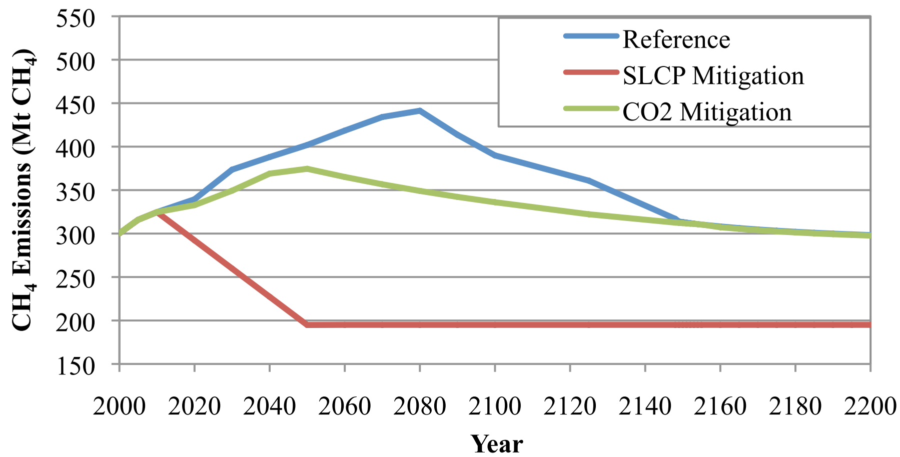
Fig. S2. CH_4 emissions scenarios.
For CH_4 emissions we have created three hypothetical emissions trajectories: a middle-of-the-road (not BAU) reference emissions scenario to compare with the reference RCP6 CO_2 scenario, a dramatic reduction scenario similar to that proposed in Shindell *et al*. (*4*), and an intermediate scenario that takes into account coreductions from CO_2 mitigation efforts.
Reference: We divided CH_4 emissions into two bins: fossil fuel–derived emissions and everything else. Based on present-day CH_4 emissions (*14*), 245 Tg CH_4/year is derived from non–fossil fuel–related anthropogenic sources, and fossil fuel–related emissions account for 80 Tg CH_4/year. We assume non–fossil fuel emissions increase from 2010 levels by 15% by 2040 and level off. The fossil fuel component of CH_4 emissions is assumed to track CO_2 emissions [from the "Reference" CO_2 emissions scenario) consistent with the proportion between the two emission estimates in (*4*)].
SLCP mitigation: Consistent with Shindell *et al*. (*4*), CH_4 emissions are reduced by 40% by 2050 relative to 2010 levels (10% per decade). This trajectory is also used in the HCM scenario.
CO_2 mitigation: This scenario follows the formula described for the "Reference" CH_4 emission scenario. Non–fossil fuel emissions increase by 15% by 2040 and stabilize, and the fossil-fuel component tracks CO_2 emissions from the "CO_2 mitigation" scenario. We did not take into consideration potential changes in this ratio, such as might be expected to result from increased reliance on natural gas, which could result in higher ratios of CH_4:CO_2 emissions from the fossil-fuel sector.

Fig. S3. BC emissions scenarios.
Reference: BC emissions are assumed to increase by 15% relative to 2010 levels by 2040 and stabilize, consistent with Ramanathan and Xu (*1*).
SLCP Mitigation: BC emissions are reduced by 80% relative to 2010 levels by 2050 (20% per decade), consistent with (*4*). This trajectory is also used in the HCM scenario.
CO_2 Mitigation: BC emissions are reduced by 20% relative to 2010 levels by 2050 (5% per decade) with these reductions attributed to strong efforts to reduce CO_2 emissions, particularly emissions from diesel engines [based roughly on BC emissions estimates from Bond and colleagues (*19*)].

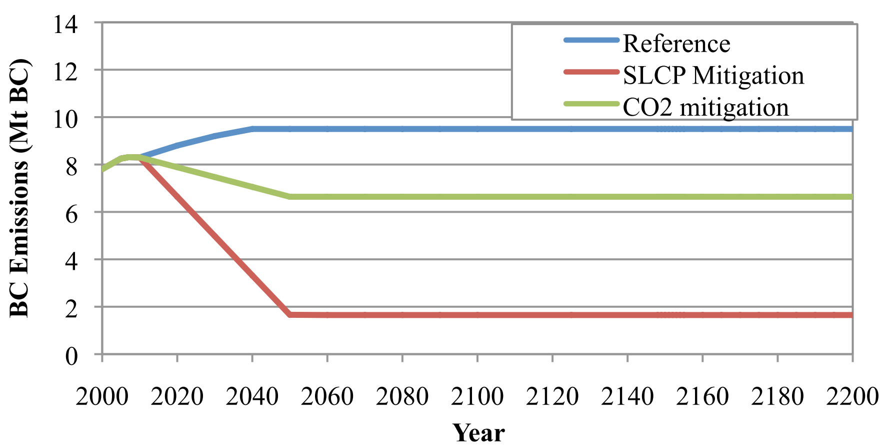
CO_2 Emissions Scenarios



CH_4 Emissions Scenarios



BC Emissions Scenarios



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