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The impact of near-term climate policy choices on technology and emission transition pathways

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ABSTRACT

This paper explores the implications of delays (to 2030) in implementing optimal policies for long-term transition pathways to limit climate forcing to 450 ppm CO_2e on the basis of the AMPERE Work Package 2 model comparison study.

The paper highlights the critical importance of the period 2030–2050 for ambitious mitigation strategies. In this period, the most rapid shift to low greenhouse gas emitting technology occurs. In the delayed response emission mitigation scenarios, an even faster transition rate in this period is required to compensate for the additional emissions before 2030. Our physical deployment measures indicate that the availability of CCS technology could play a critical role in facilitating the attainment of ambitious mitigation goals. Without CCS, deployment of other mitigation technologies would become extremely high in the 2030–2050 period. Yet the presence of CCS greatly alleviates the challenges to the transition particularly after the delayed climate policies, lowering the risk that the long-term goal becomes unattainable.

The results also highlight the important role of bioenergy with CO_2 capture and storage (BECCS), which facilitates energy production with negative carbon emissions. If BECCS is available, transition pathways exceed the emission budget in the mid-term, removing the excess with BECCS in the long term. Excluding either BE or CCS from the technology portfolio implies that emission reductions need to take place much earlier.

1. Introduction

Technological implications of climate change mitigation policies have been an important area of research for the integrated assessment modeling (IAM) community. Previous studies focused on the role of technology, particularly the influence of technology availability on the cost of climate change mitigation policies [1–5]. A few model inter-comparison studies, such as ADAM [6], RECIPE [7], and EMF27 [8], also explored the role of technology across a wide suite of IAMs, based on a coordinated set of technology assumptions. They examined the nature of energy system transformation under climate change mitigation policies and the influence of technology availability on mitigation costs and on the feasibility of meeting ambitious climate goals.

The IAM studies agree that technology is indeed one of the key components of climate change mitigation and directly affects the attainability of low climate stabilization [6–8]. They suggest that more and better performance of the technology options available for mitigation leads to lower cost of mitigation and a higher likelihood of achieving

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ambitious climate targets. It has also been shown that limiting climate change will undoubtedly require major changes to the global energy system, which takes the form of extensive deployment of new and existing low-carbon technologies [1,7–9]. Thus the availability of technology has the effect of shaping the optimal time path of emission mitigation, that is, the relative degree of near-term and longer-term emission reductions, which in turn influences the cost of achieving the climate targets [4,8].

Technological aspects of long-term mitigation policies are receiving renewed attention as current national emission reduction pledges are not consistent with the reductions required to meet the 2 °C target in a cost-minimizing way [10]. Although previous studies have shown that a delay in climate policy can result in substantial increases in mitigation costs and even infeasibilities [7,11–16], there exists no single model inter-comparison study that systematically explores the role of technology under weak near-term climate policies that are consistent with what is currently being discussed in the international climate policy arena.

This study employs AMPERE WP2 scenarios to explore this research gap [17]. Nine different IAMs with varying representation of the energy–economy–climate system and unique strengths participated in this study. All models use coordinated assumptions about technology availability and harmonized near- and long-term emission budgets and population and economic developments to allow for a comprehensive, relatively robust characterization of the role of technology in achieving meaningful climate stabilization in the long term under weak near-term policies. We hypothesize that weaker-than-optimal near-term actions imply that subsequent emission mitigation and energy system transformations will be forced to accelerate in subsequent years with the responsiveness depending on the available emission mitigation technology options.

The objective of this study is to investigate what near-term climate policies may imply for technology deployment and longer-term emission pathways that achieve the 450 ppm CO_2e target[1] in 2100 under alternative technology availability setups. The three sets of research questions include:

1. How do less-than-optimal near-term emission mitigation policies affect mid-term and long-term emission mitigation requirements to achieve an end-of-century goal? How are the resulting pathways affected by technology availability? We will examine whether these variables become particularly sensitive when specific technologies are excluded and whether there is a critical set of technologies required to achieve the long-term stabilization goal.
2. What are the physical requirements of the transitions described in questions 1? For example, what are the land requirements; how many power plants need to be built; and what is the rate of capacity expansion? Are such transformations constrained by resource limits and how do they compare to historical technology deployment rates?
3. How do specific IAM characteristics affect the above questions? We will attempt to explain the results by identifying specific technologies on which different IAMs rely for mitigation and the abilities of the IAMs to do large technology upscaling or early retirement.

The paper is organized as follows. Section 2 provides a brief background on the study design and scenario set-up. Section 3 explores long-term CO_2 emission pathways toward the 450 ppm CO_2e target after the period of optimal or delayed mitigation actions under various technology availability scenarios. Section 4 then examines the transformation of the energy system with a particular emphasis on the characteristics of technology deployment. Section 4.1 then discusses the physical implications of such technology deployment, and Section 4.2 offers conclusions.

2. Study design and scenario set-up

In this study, we employ a subset of AMPERE WP2 scenarios that is generally consistent with a concentration target of 450 ppm CO_2e (2.6 W/m^2) in 2100, corresponding to a cumulative emission budget over the period 2000 to 2100 of 1500 $GtCO_2$.[2] We combine this with two alternative near-term climate policies through 2030 and five technology sensitivity experiments.

The two near-term climate policies are:

1. Optimal short-term emissions (*OPT*) and
2. Emissions limited to 60.8 $GtCO_2e$ per year in 2030 (*HST*[3]).

Note that the OPT pathways are model-specific and that the HST scenarios are calculated in terms of Kyoto greenhouse gases [17].[4] After the year 2030, models have full

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[1] The 450 ppm CO_2e target is broadly consistent with limiting long-term temperature change below 2 °C compared to pre-industrial levels [44], which is called for by the UN Framework Convention on Climate Change [45] and also regarded as a reasonable benchmark to avoid dangerous climate change [46]. This is apparently an aspirational target as a globally appropriate agreement with binding emission constraints to achieve the target is not likely to be reached anytime soon. To allow for various analyses related to mitigation costs and feasibility of achieving long-term targets, the AMPERE exercise also includes scenarios achieving 550 ppm CO_2e, which represents lower climate ambition [17]. In this paper, however, we chose to focus on the cases with the aspirational but meaningful target to highlight the influence of near-term mitigation action on required long-term emission mitigation and energy-system transformation, which tend to amplify as the target gets more stringent.

[2] The use of a cumulative CO_2 emission budget reduces the uncertainty that would be introduced if each modeling team were to employ its own simple climate model and facilitates participation by groups that do not have in-house atmosphere–climate models.

[3] HST indicates “high short-term target,” which is the low-ambition extrapolation of global greenhouse gas emissions levels from the pledges by 2020 under the 2010 Cancún Agreements [47].

[4] To meet aspirational warming goals, we need deep emission reductions not only of Kyoto greenhouse gases—CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs—but also of some non-Kyoto air pollutants—black carbon aerosols and tropospheric ozone precursors. Reducing black carbon emissions in particular, which could also be achieved from local air-quality measures, would help decrease short-term net radiative forcing and thus result in lower global warming for a few decades [49]. In the AMPERE exercise, however, we do not examine the issue of accelerated action on air pollutants as a major near-term strategy of achieving the long-term 450 ppm CO_2e stabilization target. One important consideration for this was that only five models out of the nine participating models represent full greenhouse gases and radiative agents, although eight models represent full Kyoto gases. So, we set the high short-term target of 60.8 $GtCO_2e$ for those eight models with full Kyoto gases. For the other two models, POLES and IMACLIM, that represent only fossil and industrial CO_2 emissions, the target has been set to 44.2 $GtCO_2$ in 2030.

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