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Stranded on a low-carbon planet: Implications of climate policy for the phase-out of coal-based power plants

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ABSTRACT

Limiting global warming to 2 °C will likely entail the complete phase-out of coal-based electricity generation without carbon capture and storage (CCS). The timing and rate of this phase-out will depend on the stringency of near-term climate policy and will have important implications for the stranding of coal power plant capacity without CCS. The objectives of this paper are to better understand the relationship between near-term climate policy and stranded coal capacity (assuming a long-term goal of limiting warming to 2 °C) and to explore strategies for reducing stranded capacity. Our analysis suggests that strengthening near-term climate policy (i.e., lowering the global greenhouse gas emission target in 2030) generally reduces stranded coal capacity and its costs. An effective strategy for reducing stranded capacity is to minimize new construction of coal capacity without CCS, which can be accomplished by reducing electricity demand through energy intensity improvements and/or by keeping existing plants operating through lifetime extensions. Another strategy, providing emission exemptions for pre-existing coal plants (i.e., grandfathering), would eliminate stranded capacity, but also decreases the likelihood of achieving the 2 °C target. Finally, the ability of CCS retrofits to significantly reduce stranded capacity depends on how quickly the technology can be deployed.

1. Introduction

Limiting the increase in mean global temperature to 2 °C relative to the pre-industrial level[1] will likely entail transforming the global energy system from one that relies on fossil fuels for ~80% of its total primary energy supply (TPES) to a system supplied predominantly by low carbon technologies, such as renewables, nuclear, and biomass with carbon capture and storage (CCS) ([1] and [2,3] in this issue). Integrated assessment models (IAMs) and energy-economic models indicate that this transformation will require a phase-out of fossil-based electricity generation without CCS over the next century [4,5]. The timing and rate of this phase-out will depend on the implementation and stringency of climate policy and will have important implications for fossil-based power plant operators and utilities.

Given the large investments and long operating lifetimes (typically 30–50 years) associated with fossil-based power plants, the implications of climate policy for the stranding of fossil-based power capacity are particularly interesting. Stranded capacity is essentially the installed capacity that is not utilized when a plant is operating below the load factor for which it is designed. It generally occurs when the cost of electricity generation renders capacity uncompetitive in the electricity market. With climate policy, this can occur at fossil-based

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[1] This is roughly equivalent to achieving an atmospheric CO_2-equivalent (CO_2e) concentration of 450 ppm in 2100.

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plants when payments for CO_2 emissions increase operating costs. If severe, stranded capacity can warrant the premature retirement of existing power plants and can have significant financial implications for plant operators.

The risk of stranded capacity is particularly large for coal-based power plants without CCS as these carbon-intensive plants become uncompetitive in scenarios that limit warming to 2 °C and, thus, are phased out rapidly ([2,6] in this issue). However, coal currently accounts for ~40% of global electricity generation [1] and, without stringent climate policy, its use is expected to increase over the next two decades, particularly in China and India, where coal currently accounts for about 80% and 70% of electricity generation, respectively [7]. Thus, given less stringent climate policy over the next two decades, commitments to new coal capacity are expected to increase, resulting in more risk of stranded capacity once policy shifts to support the long-term goal of limiting warming to 2 °C. Furthermore, the risk of stranded capacity is expected to be concentrated disproportionately in China and India, which has implications for the willingness of these countries to participate in global climate agreements. Although Rogelj et al. [8] briefly examined the impact of different short-term 2020 greenhouse gas (GHG) targets on the premature retirement of coal-based power plants, no previous research has thoroughly explored the impacts of climate policy on stranded capacity and its associated costs.

In this study, we use the MESSAGE–MACRO integrated assessment model [9,10] and several climate policy scenarios, including a subset that was developed within the context of the AMPERE model inter-comparison project[2] ([3] in this issue), to explore the impact of the stringency of near-term climate policy on stranded power plant capacity. In particular, the paper focuses on conventional coal-fired power plants (i.e., coal combustion plants without CCS) since these plants have the largest carbon intensity and, thus, are the most likely to be stranded under policies seeking to remain below a 2 °C target.

The objectives of this paper are to better understand the relationship between near-term climate policy and stranded coal capacity assuming a long-term goal of limiting warming to 2 °C and to explore strategies for reducing stranded capacity. In Section 2, we describe the scenarios and technologies addressed in this paper and, in Section 3, explore when and at what rate coal-based power generation is phased out under different policy scenarios. In Section 4, we then quantify the magnitude and cost of the resulting stranded capacity in each scenario and, in Section 5, explore strategies for reducing stranded capacity. These strategies include: 1) focusing on energy intensity improvements (measured as final energy use per unit GDP); 2) extending the lifetime of existing power plants to reduce the need for new capacity; 3) providing emission exemptions for pre-existing plants (i.e., grandfathering) with an emphasis on the consequences for meeting the long-term 2 °C target; and 4) retrofitting plants with CCS.

2. Scenario implementation and technology descriptions

Scenarios with a range of GHG emission targets[3] in 2030 are used to explore the impact of near-term climate policy on stranded power plant capacity assuming a common long-term goal of limiting warming to 2 °C (Table 1). These scenarios represent seven discrete emission targets that span the range between the optimal and high short-term targets specified in the AMPERE project ([3] in this issue). The lowest (i.e., optimal) target represents a stringent policy scenario in which immediate action is taken to meet the specified long-term climate objective, while the highest target is consistent with a 2030 target extrapolated from implementation of only the low-ambition unconditional Copenhagen pledges for 2020 ([3] in this issue). Thus, higher near-term targets represent progressively less stringent climate policy (and mitigation) through 2030. However, it should be noted that even the least stringent near-term target (60.8 Gt CO_2e in 2030) still represents a 12% reduction in 2030 emissions relative to a scenario with absolutely no climate policy.

It should also be emphasized that all scenarios seek to achieve the same long-term objective, which is to limit the increase in global mean temperature relative to pre-industrial levels to below 2 °C in 2100. Thus, scenarios with less stringent near-term policy (i.e., reduced mitigation) until 2030 will require a more rapid transition to a low carbon energy system, and thus more aggressive mitigation after 2030, to meet the long-term objective ([2,6] in this issue). All scenarios also assume that all mitigation technologies represented in the model are available (i.e., no restricted portfolio cases are considered) and that all countries participate in climate mitigation efforts at the same time (i.e., no delayed participation [12] or non-participation by certain regions). In addition, a low energy intensity (LowEI) scenario is examined in which the future energy intensity improvement rate is increased by about 50% relative to the reference scenario (RefEI).[4] The LowEI scenario is only examined with the least stringent near-term policy and is intended to assess the extent to which energy efficiency improvements can reduce stranded capacity in a weak policy environment.[5]

In the remainder of this paper, scenarios are identified by a combination of their energy intensity assumption and short-term target (e.g., RefEI-56.8), as summarized in Table 1. By default, all scenarios assume a power plant lifetime of 30 years and no grandfathering (i.e. plants are prematurely retired when carbon prices become sufficiently

[2] AMPERE is an acronym for "Assessment of Climate Change Mitigation Pathways and Evaluation of the Robustness of Mitigation Cost Estimates". The AMPERE project explores several long-term GHG mitigation scenarios using a collection of IAMs with the objective of better understanding the uncertainties arising from differences among models. A major thrust of this project is to evaluate the impacts of various near-term GHG emission targets (for the year 2030) on the cost and feasibility of achieving long-term climate objectives ([3] in this issue).

[3] GHG emissions include all Kyoto gases (CO_2, CH_4, N_2O, and F-gases) emitted from fossil fuel and land-use sources. The global warming potentials used to translate non-CO_2 emissions to CO_2-equivalent (CO_2e) emissions are from the IPCC Fourth Assessment Report for a 100-year time horizon [11]. The newly added gas NF_3 is not included.

[4] Energy intensity improvement rates in the RefEI and LowEI scenarios are about 1.3%/year and 1.9%/year, respectively.

[5] Note that the GHG emission target in 2030 in LowEI-57.8 is less than the highest near-term target met by a RefEI scenario (60.8 Gt CO_2e/year). This is because, with low energy intensity, the largest emissions achievable in 2030 are 57.8 Gt CO_2e/year, even when the full century emission budget is unconstrained.