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The value of a clear, long-term climate policy agenda: A case study of China's power sector using a multi-region optimization model

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HIGHLIGHTS

- This study assesses the value of a timely outcome of the long-term climate policy agenda.
- A multi-period multi-region optimization model for China's power sector is developed.
- Clear policy signals of long-term climate agenda mitigate the impacts of a carbon lock-in and reduce mitigation costs.
- Air pollution control targets help reduce the extra cost of a delayed mitigation agenda.

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ABSTRACT

This study uses China's power sector as the target of a case study to assess the value of a timely outcome of the long-term climate policy agenda. It examines the question of how much extra cost will be incurred if hypothetical post-2020 carbon mitigation targets are not acknowledged and considered by the sector before 2020. This paper develops a multi-period multi-region optimization model for China's power sector while developing and applying regional differences and analyzing connections. The results estimate that when compared to the 2010 level, the 2030 carbon intensity mitigation target of 30% would be a total of 84.9 G CNY. The current local air pollution control targets, which are currently priorities in China's power sector emission control, may contribute slightly to the decrease of carbon intensity in the power sector by about 15.5 gCO_2/kW h in 2020 and reduce the impact of a delayed post-2020 carbon mitigation target. The study suggests that clear and certain pre-consideration of long-term carbon mitigation policy should be taken as early as possible to avoid carbon lock-in investment. Control policies of LAP and CO_2 mitigation could be combined in advance in the power sector in China in order to incentivize a cost-effective method of sustainable development.

1. Introduction

Currently, no legal outcome has been agreed upon concerning carbon mitigation targets after 2020 and heated negotiation is ongoing at the Durban Platform with a hope of sealing a deal before 2015. Taking into account procrastinated decision making in Copenhagen and Doha, where the deadlines for certain climate negotiation tasks have not been met at all or were not met until the last moment, it is difficult to tell if the same situation will be faced at the Durban Platform. This casts great uncertainty on the future climate policy agenda. It has already been shown that investors tend to delay low-carbon technology investments to make more informed decisions as time passes when there are large policy or market uncertainties [1]. Procrastinating on providing a clear long-term climate policy agenda aligned with international agreements may cause delays in low-carbon technology investments, strengthening the "carbon lock-in" of technologies and resulting in greater carbon abatement costs in the future when the climate policy agenda is finally settled and investments have to be made in a short time.

As the largest CO_2 emitter and energy supplier for the fast growth of the second largest economy in the world, China's power sector is one of the most important energy systems to be studied.

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Accounting for approximately half of the national energy-related CO_2 emission and still expanding fast, China's power sector is identified as the key sector with great CO_2 mitigation potential because of the fact that most of its massive emissions are centralized from power plants and relatively easier to control than other sectors with distributed emissions [2]. However, the predominance of coal in the energy resource structure, the current fast expansion speed, decades' lifecycle of generation units and large capital investments also contribute to the great "carbon lock-in" potential in China's power sector if a clear long-term climate policy agenda is delayed.

Meanwhile, so far China's power sector is making great efforts towards the emission control of local air pollution (LAP). Targets for mitigating total SO_2 emissions have been set since the late 1990s and NO_X emission mitigation targets have just been included in the 12th five-year plan starting from 2011. The 12th Five-Year Plan for China's Industrial Energy-Saving [3] also proposed targets for reducing 16% of SO_2 emission and 29% of NO_X emission from thermal power in 2015 compared to the levels in 2010. LAP control policies can lead to significant impacts on technology trends, and the potential synergies or trade-offs of CO_2 caused by LAP mitigation measures has been discussed and studied [4–9]. If the current LAP control targets indicate larger synergy mitigation effects than trade-off effects bringing net synergy carbon mitigation potential, it may help ease the "carbon lock-in" in terms of technology structure and costs caused by the delay of a clear long-term carbon mitigation agenda.

The motivation of this study is to assess the value of a timely outcome of the long-term climate policy agenda. Taking China's power sector as the targeted sector of the case study, we try to estimate how much extra cost will be needed in the sector if the post-2020 carbon mitigation targets aren't acknowledged and considered in the sector development until 2020, compared to what is currently known. Furthermore, we investigate the impacts on this extra cost caused by the LAP control targets, which are policy priorities at the moment. We investigate emission pathways that are similar, but differ in the timing of information about 2030 emission targets. While there are many studies that analyze different timing of emission reductions (e.g., [10–12]), very few analyze the same emission pathways which differ in information about long-term policies. In the following sections of the paper, we will first describe in detail the analysis framework and modeling methodology, followed by a brief introduction of the input data and assumptions. Next we will conduct and discuss a scenario analysis of China's power sector development between 2010 and 2030 under various LAP and CO_2 emission control targets. Lastly, we will provide policy implications and conclusions.

2. Methodology

2.1. Scenario analysis approach

We consider 2010–2030 to be the total planning horizon, and divide the period in half, with 2010–2020 as phase A and 2020–2030 as phase B. Six scenarios are developed in this study to indicate the development situations of China's power sector. These scenarios are as follows: (1) no emission control policy during the whole planning horizon (NC Scenario); (2) an emission control policy of LAP control targets during the whole planning horizon (LC Scenario); (3) post-2020 CO_2 control targets only known to the sector in phase B (OC Scenario); (4) post-2020 CO_2 control targets known and considered in the power sector development in phase A (AC Scenario); (5) the same as the OC Scenario with LAP control targets added during the whole planning horizon (SQ Scenario); (6) the same as the AC Scenario with LAP control targets added during the whole planning horizon (AD Scenario). Detail scenario settings are shown in Table 1. Two ten-year planning horizons are used for the NC, LC, SC and SQ Scenarios, while a twenty-year planning horizon is used for the AC and AD scenario. Energy saving targets concerned with the standard coal consumption of electricity generation are considered in all scenarios from 2010 to 2030.

Table 1
Scenario settings.

Scenario	LAP control targets (2010–2030)	CO_2 control targets (2020–2030)	Clear information about post-2020 CO_2 control targets during 2010–2020
NC	–	–	–
LC	Y	–	–
OC	–	Y	–
AC	–	Y	Y
SQ	Y	Y	–
AD	Y	Y	Y

If the post-2020 carbon intensity mitigation targets are known and considered in phase A, only one optimization will be done during the whole 2010–2030 period, as the power sector will take into account the future carbon constraint in their investment decision. If post-2020 carbon intensity mitigation targets are only known and considered in phase B, two optimizations will be done. The first one will be done during the whole period of 2010–2030 without carbon constraint, while the second one will be done from 2020 to 2030 to update the previous optimization due to post-2020 carbon control targets.

By comparing the results of the SQ and AD Scenarios, we can assess the "carbon lock-in" effect in China's power generation technology structure before 2020 if no clear sign of post-2020 carbon mitigation targets are known or considered in the sector, together with the potential extra cost generated. This reveals the value of a clear long-term climate policy agenda, which is what this study is primarily concerned with. By comparing the results of scenarios with LAP control targets against those without, we can observe the interactions between the current policy priorities of LAP emission control in China's power sector and CO_2 emission control, assessing LAP control's impact on the "carbon lock-in" versus the value of a clear long-term climate policy agenda.

2.2. A multi-region Bottom-up Optimization Model for China's Electricity Sector (BOMCES)

To fulfill such a modeling task, a powersector planning model that considers both LAP and CO_2 emission control is needed. China's power sector is divided into six regional power grids, shown in Fig. 1 and Table 2, with growing yet limited inter-connection and divergent differences in various aspects including energy resources and fuel features. Based on the fact that regions with sufficient, and often clean energy resource are usually not the electricity load centers, as well as the growing inter-connections among regions due to the Strong Smart Grid plan in China, a power sector model without consideration of inter-regional power transmissions may not be valid in capturing the great mitigation potential and may bias the future emissions trajectory projections.

Multi-period, multi-region optimization models have been proposed and used for power sector analysis since the late 1980s, mainly due to the inter-connection of power grids and inter-regional or international electricity trading in North America and Europe. Roges and Rowse [13] developed a multi-region optimization model to analyze inter-regional electricity trading in Canada, with the energy structure and power supply cost as the major concerns. Hoster [14] and Voorspools and D'haeseleer [15] further developed a multi-region model of the power sector