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Potential impacts of China's climate policies on energy security

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ABSTRACT

Energy security, as an indispensable constituent of economic security, has long been a top research priority, and the dynamics of energy security become particularly complicated with the involvement of climate change. In this work, we combined a one-sector integrated assessment framework with a series of well-proposed energy security metrics to extensively explore the unidirectional consistency between climate policy and energy security from the national perspective. Implementation of climate policy is generally beneficial for improving energy security. Specifically, climate policy helps to reduce the systematic risk of China's energy system according to the metrics of energy (oil) intensity, energy (oil) expenditures and per capita energy (oil) consumption independent of time scale options. As observed from the perspective of energy diversity, co-benefits arising from climate policy primarily emerge in the first half of this century, and they may gradually decline as emission constraints and the phasing out of fossil fuels are enhanced. Additionally, the macroeconomic costs required to reach China's committed carbon-peaking target might be far lower than the costs required to fulfill the emission budgets under the global 2-degree warming rise threshold. If the co-benefits of energy security are considered, the economics of climate policy is expected to significantly improve.

1. Introduction

As one of the core aspects of economic safety, energy security has long received considerable attention from both governments and scientific communities. Conventionally, security primarily refers to the security of supply (SOS), particularly oil supply (Alhajji, 2007; Gupta, 2008). As the fluctuation risk of energy prices increases, resources scarcity grows significantly, and the imbalance of energy supply and demand within and across regions is prominently enhanced, energy security is given a much richer and more extensive meaning that involves affordability, availability and accessibility (Kruyt et al., 2009).

The background of global climate change makes the issue of security more complicated: Climate change may worsen the spatial imbalance of energy supply and demand, and cause the conventional energy market to fluctuate more frequently and extensively, which would heavily increase the cost risks of the entire economic system. In addition, climate change affects the resilience of the energy system itself and energy-related infrastructures, which, in turn, makes the energy system more vulnerable (Farrell et al., 2006; Jewell et al., 2016). As a result, energy security further features its added acceptability, given the increasingly stringent situation of global warming (Sovacool and Brown, 2010). Here, acceptability should be better understood as the influences of climate change on security risks.

On these grounds, the scientific communities always define the updated energy security as "low vulnerability of vital energy systems" (Jewell et al., 2013). Vital energy systems could be widely referred to the total primary energy supply system, or specific energy supply systems such as petroleum, nature gas and electricity. Geographic energy systems could also be included from the perspective of having specific global, national or sector boundaries (Cherp and Jewell, 2014). Regarding the vulnerability of energy systems, we primarily discuss the degree of risk exposure and the capacity of responding to risks (resilience) (Stirling, 1994; Jewell et al., 2013). Vulnerabilities also cover the disruptive risks of conventional energy fuels and the economic risks resulting from energy costs and market fluctuations (Greene, 2010). Consequently, both the traditional security risks and the low vulnerability of vital energy systems are considered to contribute to the long-term and dynamic assessment of future energy security with the intervention of climate change (Cherp and Jewell, 2014).

Traditional assessment methods are no longer suitable for studying the vulnerability of vital energy security. First, the conventional approaches are used to investigate supply risks of fossil fuels based on the historical and current energy market information. However, the status of fossil energy will undoubtedly decline. Thus, the emphasis on the so-

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called vital energy system may largely be on future non-fossil energy. Particularly, the intensive involvement of primary renewables and second electricity will produce a new requirement for integrated system method of energy security assessment (Cherp and Jewell, 2014). Second, risks of global warming make the vital energy systems more vulnerable, and as regions with high climate sensitivities, climate change may significantly influence the affordability, availability and acceptability of energy services (Jewell et al., 2013). For example, the rise in global average temperatures intensifies the use of air-conditioners and other cooling facilities, which may bring new challenges to current power supply systems and increase the relevant energy costs of the economic system. Moreover, frequent and irregular heatwaves will also aggravate the contradiction between energy supply and demand within or across regions. Additionally, climate-related disasters can accelerate human-made energy capital depreciation and damage energy infrastructures, which may cause new-added energy security risks.

Consequently, research on long-term and dynamic interactions between climate policy and energy security based on integrated assessment models (IAMs) has aroused great concern. Bollen et al. (2009) discuss the potential relationships among climate change, local air pollution and energy security by employing the MERGE model, and stress that energy policy alone will not reduce global total oil demand, but rather delay its peak for a couple of years. For Europe, the considered climate policy mix may promote the attainment of its emission control goal and bring remarkable co-benefits such as the decrease of mortality associated with air pollution. Climate policies could lower the risks of vital energy security. First, climate policies are likely to reduce global energy trades, resource exploitation and energy imports of leading economies. Second, climate policies are beneficial for increasing the diversity of energy systems (Jewell et al., 2013). Take the US for example, the reach of the low-carbon target is heavily consistent with the diversity of power supply systems. Specifically, given the low-carbon goal, the supply of electricity becomes more diversified (Grubb et al., 2006). Climate policies help to decrease the cost competitiveness of conventional energy, accelerate the diffusion of non-fossil technologies and diversify the energy system (Schumacher, 2017), which contributes significantly to guaranteeing energy security (McCollum et al., 2013). Additionally, the positive impacts of climate policies include the decline of the total energy supply, decrease in the dependence on the energy mix and fossil fuels trade and growth in the gross domestic product (GDP) (Cherp et al., 2016). However, the influence of climate policies on energy security closely relates to the considered time scales. The potential benefits of climate policies primarily occur in the short- and medium-term, specifically before the first half of 21 century, while from the long run, these effects tend to decrease gradually until they become completely negative (Jewell et al., 2014; McCollum et al., 2014; Cherp et al., 2016).

The relationships between climate change and energy security are not bidirectional. The intense control of emissions could largely reduce energy imports, i.e., the implementation of climate policies brings the co-benefits of security (McCollum et al., 2011). Meanwhile, energy policies alone, such as the proactive control of energy imports for reaching energy independence, play a negligible role in emission reduction, not to mention the achievement of the global 2-degree warming-limit target (McCollum et al., 2014; Jewell et al., 2016). Thus, the insignificant climate co-benefits could not provide supportive evidence for political advocates to introduce intended energy independence policies. Additionally, much attention is also paid to the cost analysis of specific climate and energy policies. Based on the GCAM model, Iyer et al. (2015) studied the possible paths of the abrupt transition of the global energy system and estimated the corresponding policy costs under the 2 °Ctemperature-stabilizing target. These authors note that it is unwise to delay climate actions due to the remarkably positive impacts of short-term energy restructuring and mitigation behaviors on the attainment of energy security and climate targets, as well as on the relevant policy costs. Indeed, it is prominently cost-saving to consider the goals of climate change, energy security and local air pollution simultaneously. The corresponding policy costs are much lower than the sum of the separated costs that would be incurred to achieve the different targets in isolation (McCollum et al., 2011; Jewell et al., 2016). More specifically, if the co-benefits associated with climate policies are fully considered, the cumulative policy costs would decrease by 0.1–0.7% of the GDP in 2030 (i.e., 100–600 billion US dollars) (McCollum et al., 2013).

Lessons learned from the existing studies reveal that there are unidirectional relationships between climate change and security, i.e., the implementation of climate policies brings considerable energy security co-benefits, particularly during the first half of this century (McCollum et al., 2011). From the literature analysis, we also found that the current relevant research primarily focuses on the global or regional scale, and little focus has been on the national level. This disparity if particularly true for developing countries such as China, which has been explicitly emphasized as one of the primary open questions of McCollum et al. (2014) and Cherp et al. (2016). The limitation of the conventional IAM framework may largely tell the story: the majority of the existing IAMs are global or multi-regional, which directly leads to the resulting focus of related research on interactions between climate policy and energy security (Jewell et al., 2014). Support at the country-scale for IAMs is, therefore, indispensable for us to extend the relevant study to the national level. As a result, our well-developed, one-sector energy-economy-environmental (3E) integrated model of China fits well within this requirement and allows us to investigate the possible interaction between China's climate policy and long-run energy security.

As the largest greenhouse gas (GHG) emitter and energy consumer, China is facing more overwhelming and pressing challenges in climate change and energy security than any other country, which enhances the high importance of studying the possible relations between China's climate policy and energy security. Theoretically, we first incorporated the possible emission budgets across various emission allocation principles under the 2-degree warming-limit target into a 3E-integrated model. Then, we developed a systematic simulation and analysis framework by examining a series of energy security metrics. Empirically, our emphasis is primarily on exploring the potential unidirectional consistency between climate change and energy security that has been found at the global level, i.e., investigating the dynamic long-term impacts of climate policies on security. Additionally, one of our research goals was to analyze the macroeconomic costs and energy security co-benefits of climate policies.

The remainder of this work is organized as follows: Section 2 includes the introduction of the model methods and involves brief descriptions of our 3E-integrated model and well-developed metrics of energy security. Section 3 designs the scenarios, i.e., introduces emission budgets according to representative emission allocation plans under the 2-degree temperature-limit threshold. The primary results and related analyses are provided in Section 4, and the last section summarizes our conclusions.

2. Methodologies

2.1. The basic integrated assessment model

The implementation of the entire empirical simulation, which includes the outputs of energy, economy and emissions, and the consideration of climate policies, primarily depended on the Chinese one-sector 3E-integrated assessment model, CE3METL. This model is a Chinese version of the global E3METL (**E**nergy-**E**conomy-**E**nvironmental **M**odel with **E**ndogenous **T**echnological change by employing **L**ogistic curves), which is lead-developed in 2013 by *H. duan*. This model features innovative multiple technological diffusion mechanisms, i.e., the policy-driven multi-logistic curves (Duan et al., 2013). With these new mechanisms at hand, we could better describe