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Overview of research on China's transition to low-carbon development: The role of cities, technologies, industries and the energy system

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ABSTRACT

China is experiencing a transition to low-carbon economic development. This paper assesses the current literature on the potentials of and barriers to China's transition to low-carbon development, identifying promising fields of action and suggesting a research agenda that systematically addresses the shortcomings. Through a broad literature review, we select three main research areas of interest: low-carbon cities, low-carbon technologies and industries, and the transition of China's energy system. As an innovative work, we also summarize some specific issues discussed more in Chinese journals but less in English language ones. Some elements of a more comprehensive research agenda that can improve the understanding of China's ability to enter a low-carbon development pathway are suggested.

1. Introduction

China's crucial role as an emitter of greenhouse gases has long been recognized in the debate about global climate change mitigation. Researchers have emphasized both the need for a significant reduction in China's emissions and the potential for accomplishing this if the Chinese government agrees to a fundamental policy shift. More recently, it has become increasingly acknowledged that this policy shift has already started to occur, even though it may be a side effect of China's domestic energy issues rather than a direct result of a global climate agreement. However, the economic, political and institutional preconditions that would enable China to begin a transition to a low-carbon development pathway are still poorly understood. Whereas some researchers have overestimated the steering and implementation capacities of a central government in a planned economy [142], others have underestimated the societal dynamics that might promote such a transition at a rate faster than that in other countries. This paper therefore assesses the current literature on the potentials of and barriers to China's transition to low-carbon development. Through a broad literature review, we selected some of the best covered topics. Although we omitted a number of topics, we believe that we have covered those most relevant to the overall question of low-carbon development in China. The objective of this review paper is to combine existing literature from various disciplines to systematize current knowledge about the most important challenges of low-carbon development in China and to

discuss the implications of the findings for finding promising routes to strengthen low-carbon strategies and develop research on this topic further. Obviously the literature covers a wide range of – sometimes incompatible – methodologies. For the sake of transparency, we mention these methodologies, but it is beyond the scope of this review paper to discuss in depth their respective underlying assumptions and epistemological starting points. As this is a review paper in nature, it cannot directly contribute to the reduction of GHG emissions, but we hope to improve the understanding of how such strategies are – or are not – leading to emission reductions in the long run. The paper is organized as follows: in the remainder of this introduction, we explain the preconditions for low-carbon development in China and deduce the three strands of literature on low-carbon development in China that have been most intensely researched in the past years. Chapters 2–4 follow the three themes we have identified: Chapter 2 summarizes the literature on low-carbon cities in China, Chapter 3 focuses on the literature about low-carbon technologies and industries, and Chapter 4 reviews the literature on the transition of China's energy system. While these three chapters focus on research publications in Anglophone mainstream journals, we add a brief fifth chapter on the literature published in Chinese journals. Chapter 6 summarizes our findings and draws some conclusions.

What are the preconditions for low-carbon development in China? Even though China's per capita CO₂ emissions remain below those of other industrialized countries, at 6.7 t (2010–2014), its total CO₂

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emissions have grown enormously in recent decades, thus making China the world's largest single national emitter [108]. China's energy system is mostly based on coal [91], and the majority of its coal-fired power plants operate at relatively low efficiency levels. Energy security has become a pressing issue in terms of both domestic and international strategies [42,43]. Domestic problems connected to energy consumption are becoming increasingly important. At the same time, there is pressure from rural areas because China still suffers from rural energy poverty and from large metropolitan areas, where the population suffers from poor and sometimes dangerous urban air quality. As a reaction to all these pressures and in an attempt to become a more active player in international climate negotiations, China's government has recently made a voluntary commitment to lowering its CO₂ emissions per unit of GDP by 60–65% by 2020 (compared with 2005 levels) and to increasing the share of non-fossil fuels in its primary energy mix (UNFCCC 2015; [81]). Another recently established goal is that the share of non-fossil fuels used in primary energy consumption should be increased to 15% by 2020 [82]. China has also issued a series of national strategies for energy conservation and emission reductions; these are presented in the 12th Five-Year Plan.¹ Policies and measures such as emissions trading have been introduced in several provinces [18,39]. The societal preconditions required for implementing such policies effectively and for achieving ambitious mitigation targets are therefore a pertinent research topic.

This article seeks to contribute to the above-mentioned research area and provides a literature review, on the basis of which research gaps will be identified. Our main focus is on mainstream peer-reviewed journals in English, but we also examine relevant debates in peer-reviewed journals in Chinese. A review of research papers in relevant journals² revealed three main research areas of interest: low-carbon cities, low-carbon technologies and industries, and the transition of the national energy system from one based on fossil fuels toward one based on renewable and nuclear energy sources. The three research areas resonate with three important economic and social dynamics currently affecting China: rapid urbanization, rapid technological development and industrialization, and an ongoing increase in energy demand. We assess these three strands of literature consecutively, summarizing recent findings and identifying research gaps. The final chapter therefore identifies what appears from the literature as promising approaches to low-carbon development in the Chinese context and suggests elements of a more comprehensive research agenda that can improve the understanding of China's ability to enter a low-carbon development pathway.

2. Current research on low-carbon cities in China

As densely populated and resource-intensive regions, cities have always been hotspots of innovation. Since the beginning of industrialization,

however, cities have been under intense environmental pressure because of their high concentrations of industry, infrastructure and population. They have also been regarded as the world's main sources of greenhouse gas emissions and the primary contributors to global warming and climate change [14]. According to UN Habitat [96], approximately 40–78% of global GHG emissions are estimated to originate in cities. Moreover, the proportion of greenhouse gas emissions from cities is increasing continuously because of ongoing urbanization [65]. In many parts of the world, urban sprawl and energy-intensive development patterns are still seen as pathways to urbanization [1,75]. This phenomenon is particularly true for some developing countries, whose energy consumption and GHG emissions are expected to continue to increase significantly along with rising living standards and material affluence [22,78].

As the world's largest developing country, China is experiencing urbanization on an unprecedented scale. China's urbanization rate has increased from approximately 36% in 2000 to nearly 53% in 2012 [74]. Migration, urban expansion, and the emergence of new cities near existing cities all indicate that urbanization in China will exert continuing acute pressure on infrastructure, economic growth, land development, urban resource demands, and pollution [9]. China's 35 largest cities contain approximately 18% of the country's population and contribute 40% of the country's energy usage and CO₂ emissions [14,44]. This percentage continues to grow along with China's high-speed urbanization.³ A low-carbon urban development strategy would therefore offer a high GHG emission-reduction potential for China. At the same time, China's cities are extremely vulnerable to the impacts of climate change because of their high population densities, concentrated economic activities and scarce natural resources. Cities in northern and western China tend to experience droughts, dust storms, and smog, which have been particularly serious in recent years, whereas the eastern and southern cities often suffer from floods and extreme rainstorms. Liu and Deng have shown that the mean annual precipitation is expected to decrease by 2–10% in drought-prone northern China but increase by more than 20% in flood-prone southern China [65]. A strong dust storm attacked the northwest provinces in April of 2014, including some important cities such as Lanzhou City in Gansu Province and Wulumuqi City in Xinjiang Province. Some eastern cities, such as Shanghai, and southern cities, such as Guangzhou, suffer from rainstorms almost every summer. It can be assumed that the immense scale of urbanization will increase public pressure and therefore lead to a bolder and more aggressive decarbonization strategy for both national and regional policy makers.

Which low-carbon city initiatives have been started in China, and what can we learn about them from the existing literature? An initial low-carbon city program was implemented by China's Ministry of Construction and the Worldwide Fund for Nature in 2008. In August 2010, China's National Development and Reform Commission (NDRC) launched a low-carbon city experimental project that was implemented in eight cities: Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding⁴ [16]. The concept of the low-carbon city, which integrates elements of both a low-carbon economy and a low-carbon society, has been found to be a new path by which China can achieve its goals of sustainable urbanization, ecological civilization and scientific development [106,14]. Therefore, these “low-carbon cities” are intended to develop low-carbon economies and to promote low-carbon lifestyles. Specifically, a low-carbon city is characterized by reduced pollution, low emissions, and high energy efficiency [65].

So far, however, low-carbon cities in other countries have been little more than an inspiring guiding principle for city administrators and citizens. Even if policies promoting low-carbon cities abound, it would

¹ The Five-Year Plans, as an important part of Chinese domestic economic plans, are a series of social and economic development initiatives that mainly focus on carrying out major national construction projects, mapping strategies for economic development, setting growth targets and launching reforms. The first Five-Year Plan began in 1953. The 11th Five-Year Plan covers the period 2006–2010, and the 12th covers 2011–2015.

² Using the SCI and SSCI network databases, we searched with the key words “low-carbon” and “China” to identify related articles published during the 2004–2016 period. The total number of articles identified was 16926. Because we are focusing primarily on the effects of low-carbon policies on China's economy and society from the perspectives of management and economics, papers focusing on technologies from purely natural science or technological perspectives were excluded from our list. For similar reasons, papers about low-carbon agriculture were also beyond the scope of our review because that field is another vast and complex research area closely related to chemistry, biology, geology, etc. Moreover, by using Bibexcel software, we also analyzed the frequency of key words appearing in the 6000+ articles we identified. In addition to obvious words such as “China”, “carbon dioxide”, “low-carbon”, and “climate change”, key words closely related to content included issues such as “low-carbon economy”, “energy consumption”, “renewable energy”, “energy efficiency”, and “low-carbon city”. Therefore, our paper is divided into reviews centered on the concepts of “low-carbon city”, “low-carbon technologies and industries in China”, and “the transition of China's energy system”.

³ By 2014, China's urban population had grown to 54% of the country's total population (World Bank: <http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS>).

⁴ Source: <http://www.worldbank.org/en/news/feature/2012/05/03/sustainable-low-carbon-city-development-in-china>.

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