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Life cycle greenhouse gas emissions from power generation in China's provinces in 2020

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HIGHLIGHTS

- Most provinces have carbon intensities between 500 and 700 g CO_2/kWh in 2020.
- Most provinces show trends of decline in carbon intensity between 2015 and 2020.
- Coal is still a major growth contributor to power generation in most provinces.
- Renewable energy sources can help reduce the carbon intensity of power generation.

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ABSTRACT

Carbon intensity of power generation is an important indicator to show the direct competitiveness of electricity against the combustion of fossil fuels. In this study, we estimate the carbon intensities of power generation in China's provinces. Most provinces are likely to have a carbon intensity per unit of power generation between 500 and 700 g CO_2/kWh in 2020, which justifies the progress of electrification from the power generation perspective. With the growing share of low carbon power generation, most provinces show trends of decline in carbon intensity between 2015 and 2020. However, some provinces are expected to see increase in carbon intensity due to increasing share of coal power generation in their power mixes. Coal is still a major growth contributor in most provinces, despite significant growths of low carbon energy sources. Furthermore, renewable energy sources can help reduce the carbon intensity of power generation, but a better coordination among provinces is required, alongside with strong government support and direction.

1. Introduction[1]

Low carbon electricity technologies have become more readily available from financial, technical and institutional perspectives. It has made electrification of the energy system a popular choice in the process of decarbonisation. Fossil fuels used for heating purposes and in transportation system can be replaced by electricity that is produced by renewables and other low carbon technologies, which in turn reduce CO_2 emissions, changing the fuel mix without compromising security of supply [1–3]. Such transition would require electricity generation to be at least carbon emission competitive comparing to the conventional technologies, therefore the benefits of electrification can be justified.

In a previous study, Kennedy et al. [4] discuss the low-carbon infrastructure strategies for global cities. The authors argue that electrification of the transportation system can become carbon competitive once carbon intensity of power generation drops to 600 tonnes of CO_2 equivalent (CO_2-e) per gigawatt hour (or 600 g CO_2-e per kilowatt-hour). In a following study, Kennedy [5] addresses the significance of achieving a short-term target of below 600 g/kWh by 2020, which is essential to achieve the 2 °C emission target in the longer term. Certainly, it is a short-term goal but it can be considered as a first step towards more ambitious targets of reducing CO_2 emissions per unit of electricity by 90% by 2050, as proposed by the IEA [6].

Since 1990, global average carbon intensity of electricity generation had been relatively stable varying between 506 and 546 g CO_2 per kWh (see Fig. 1). However, there have been large variations in carbon intensity of power generation in different countries, influenced by a range of factors. Resource endowments and investment in these resources can affect the selection of power generation technology. Countries with significant hydropower potential can produce electricity of lower

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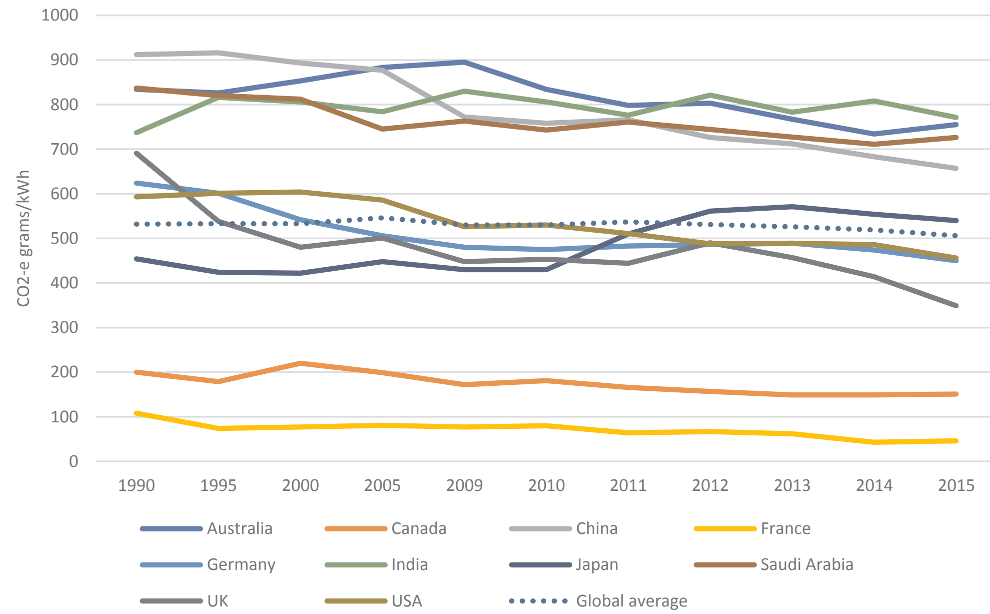

Fig. 1. Carbon intensity of electricity generation in selected countries and at global average level.
Source: [8]

carbon intensity (such as Canada); by contrast, countries that have large fossil fuel reserves (such as oil in Saudi Arabia and coal in Australia) tend to produce electricity of higher carbon intensity. Equally, regions that face lack of availability of energy resources may choose to import forms of energy that are easily accessible but environmentally and financially damaging. At the same time, relevant government policies on energy and climate usually lead to a transition towards decarbonisation.[2] For example, the UK has introduced a carbon floor price [7], which is much higher than the price of EU ETS emission allowances. It has resulted in higher marginal costs for coal-fired stations than natural gas; therefore competitiveness loss. A significant decline in carbon intensity of power generation has happened in the UK. The country also introduced incentives to promote the conversion of existing coal-fired power plant to biomass (such as the case of Drax power station). Furthermore, demand growth can also affect technology selection. For countries with lower level of demand growth, building low-carbon intensive power technologies is capable to satisfy the demand. It is more convincing to phase out carbon intensive power plants and replace them with renewables when there is no demand growth pressure.

As can be seen from Fig. 1, China has shown a fast decline in carbon intensity of power generation, which had dropped to 657 CO_2 g/kWh in 2015 from 912 CO_2 g/kWh in 1990 [8]. Further reduction on carbon intensity per unit of power generation can be beneficial to China, since electrification has become an important component in China's energy transition. Fossil fuel combustion for heating, transportation and other purposes are not sustainable and need to be replaced with other technologies. There is no easy alternative within those areas, which makes electrification a popular choice [9,10]. Recent policies on China's electricity industry and its associated emission intensity has shown ambitious targets. For example, policy on controlling greenhouse gas (GHG) emissions in the 13th Five-Year period has stated a target of electricity supply from major power generators to reach 550 g/kWh [11]. However, historical data and recent trends in power supply emissions showed that even if a regional industrial shift occurs [12], the target may have overestimated the capability of achieving lower emission levels from China's power generation.

Furthermore, even though there are benefits in policy implementation through a central government [13] or a government controlled system [14] for a country as large as China, it is important to understand the carbon intensity in power generation at sub-national level. Power generation in China's provinces shows a large variation in terms of both volume and fuel mix. In 2015, for example, Shandong was the largest electricity-producing province. Its total power generation reached 461.9 TWh, with fossil fuels and wind power accounted for 97.6% and 2.1% of power supply respectively (the rest 0.3% was contributed equally by hydropower and solar power). Tibet is the smallest electricity-producing province with total power generation of 3.9 TWh. Hydropower dominated the supply mix, which accounted for 88.1% of the total production. The share of solar power was 6.2%, which was ahead of all non-hydro energy sources (2.8%) and fossil fuels (2.6%). Moreover, resource endowments encourage the growth of renewable energy sources in some provinces [15]. By the end of 2015, Inner Mongolia had larger wind power capacity (24 GW) than Spain which at 23 GW has the fifth largest wind capacity in the world. At the same time, five western and central provinces including Sichuan, Yunnan, Hubei, Guizhou and Guangxi accounted for over 70% of the total hydropower generation in China.

Understanding the future power mix and its emission intensity can be important to justify the transition towards electrification. This study estimates the carbon intensity of power generation by 2020 in China's provinces. A novel approach is used to include life cycle greenhouse gas emissions. The approach takes into account power generation capacity, operating hours and emission factors of eight power generation technologies to estimate the carbon intensity of power generation from a life-cycle perspective. The structure of this paper is organized as following: in Section 2, we introduce the background of China's power industry briefly with regards to the development plans during the thirteenth five-year period. Then, we introduce the data collection and the method to calculate carbon intensity in Section 3. Section 4 introduces the results of this study and Section 5 discusses the research findings. We conclude the study in Section 6.

2. China's power industry in the thirteenth five-year period

China's Five-Year Plans are a series of social and economic development initiatives. The most well-known five-year plan is the Five-Year Plan on Social and Economic Development [16], which provides

[2] The revival of coal mining industry in the US and its associated environmental impacts is regarded as a special case.