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China's electricity emission intensity in 2020 – an analysis at provincial level

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Abstract

In order to maintain the 2°C climate change target, global carbon intensity of electricity generation needs to achieve a short-term target of 600 g/kWh by 2020. This target is important for China, which has been the largest consumer and producer of electricity since 2011. China has set ambitious targets to reduce its electricity carbon intensity in the 13th five-year plan. For a country as large as China, the outcomes of these policies rely on the implementation strategies and effectiveness of each province. In this study, we estimate the carbon intensities of power generation in China's provinces by 2020. Results show that despite progress in renewable energy growth most provinces are expected to have carbon intensities well above 600 g/kWh by 2020. Renewable energy sources can help reduce carbon intensities in most provinces, but the magnitude of such impacts depends on the coordination among provinces. The over-dependence on coal power generation has made carbon capture and storage a necessity for China's provinces to reduce their carbon intensity for power generation. Therefore, government support should be addressed sooner rather than later.

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Keywords: carbon intensity, power generation, China, renewable energy

1. Introduction

The global carbon intensity of electricity generation had been approximately 900 g/kWh in the 1990s and started to decline in 2000s reaching about 800 g/kWh by 2011. Kennedy [1] argues that carbon intensity of electricity generation is an important index in achieving climate change targets. The author concludes that a short-term target of below 600 tonnes of CO_2 equivalent (CO2e) per GWh (or 600 g/kWh) by 2020 is essential to achieve the 2°C emission

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target. This target of 600 g/kWh by 2020 considers electrification as an important strategy to cut emissions since low carbon electricity technologies become more readily available from financial, technical and institutional perspectives. Fossil fuels used for heating and transportation 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 [2]. This is a significant challenge given that unlike other regions [3], China remains in a growth trajectory. Moreover, with economic growth, household demand, even in the emerging ICT domain becomes gradually important [4, 5]. As the growing efforts on reducing emissions globally, the target means that electrification will become more carbon competitive if the 600 g/kWh target is fulfilled. 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].

Such target is important to China for several reasons. First, China has been the largest producer and consumer of electricity since 2011. Given the over-dependence on coal, electricity generation accounts for more than half of the total CO_2 emissions in China and 15% of the total CO_2 emissions in the world. Any significant changes in China's electricity carbon intensity will have a series of effects on the global carbon and fossil fuel markets and renewable energy industry. Second, electrification has been an important component in China's energy transition. Fossil fuel combustion for heating, transportation, and other purposes are not considered sustainable and needs to be replaced with other technologies. There is no easy alternative within those areas, which makes electrification a popular choice [7, 8]. Third, recent policies on China's electricity industry and its associated emission intensity has shown aggressive targets. For example, policy on controlling GHG emissions in the 13th Five Year period has stated a target of electricity supply from major power generators to reach 550 g/kWh [9]. However, historical data and recent trends in power supply emissions showed that even if a regional industrial shift occurs [10] 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 system [11] for a country as large as China, it is important to understand the carbon intensity in power generation at provincial level. In fact, power generation in China's provinces shows a large variation in terms of both volume and mix. For instance, Jiangsu is the largest electricity-producing province. In 2014, it produced 435 TWh of electricity, with fossil fuels, nuclear power and wind power accounted for 94.3%, 3.9% and 1.3% of power supply, respectively (the rest 0.6% was supplied equally by hydropower and solar power). Tibet is the smallest electricity-producing province. In 2014, it produced 2.6 TWh of electricity. Hydropower dominated the supply mix, which accounted for 76.9% of the total production. The share of fossil fuels was 11.5%, which was ahead of solar power (6.9%) and other energy sources (5.4%). In addition, the resource endowment encourages the growth of renewable energy sources in some provinces [12]. For example, by the end of 2015, Inner Mongolia had a larger wind power capacity (25.7 GW) than Spain (23 GW) which owns the fifth largest wind capacity in the world.

In this study, we estimate the carbon intensity of power generation by 2020 in China's provinces under three scenarios. 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 discuss the research findings. We conclude the study in Section 5.

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† 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, which provides general guidance for economic development, sets growth targets, and proposes reforms at the beginning of each five-year period, with the 13th and last period being between 2016 and 2020. Specific plans on different industries and regions are usually issued by different national/regional government departments, following the general guidance from the Five-Year Plan on Social and Economic Development. For example, in this report, we refer to the 13th Five Year Plan on Electricity System Development and 13th Five Year Plan on Controlling Greenhouse Gas Emissions. These specific plans usually define more detailed tasks and targets to address topics like electricity and greenhouse gases.

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

The 13th Five Year Plan on Electricity System Development was announced by the National Energy Administration (NEA) in November 2016 [13]. The plan states that the government 'strives to control the total coal capacity within 1,100 GW by 2020'. It is based on a projected annual power demand growth between 3.6% and 4.8%, though demand growth in 2015 was negative. The plan also refers to the closure of 20 GW of inefficient coal power plants between 2016 and 2020, which is very little by comparison to what is being built. At the same time, the plan reveals capacity targets by 2020. Apart from the capacity target for coal, China plans to expand its power generation capacity with 110 GW of gas power, 340 GW of hydropower, 210 GW of wind power, 110 GW of solar power and 58 GW of nuclear power. Total non-fossil fuel capacity is expected to reach 770 GW, an increase of 250 GW from 2015 (Figure 1). It shows a significant trend of moving away from fossil fuels and transitioning into renewable energy and other low carbon technologies. This clearly will lead to a reduction in carbon intensity in China.

At the same time, China also announced policies on controlling emissions from electricity generation. The State Council [9] issued the 13th Five Year Plan on Controlling Greenhouse Gas Emissions in October 2016. It states that '*all major power generating companies need to control their electricity supply emission levels at 550 g/kWh*.' The target seems very ambitious, given the existing circumstances in China's power generation.

At provincial level, the targets of renewable energy development are shown in their 13th five year development plans, respectively. For example, Hebei, Shanxi and Inner Mongolia provinces each propose to have 12 GW of solar power installed by 2020. For wind power, Inner Mongolia plans to have 27 GW of installed capacity, which is followed by Xinjiang (18 GW) and Hebei (18 GW).

3. Data and method

We compile data for power generation capacity at provincial level from different sources. For example, for coal power, we use data from Endcoal [14]. It shows the provincial coal power capacity under construction by July 2016. For nuclear power, we use data from the World Nuclear Organization. It shows nuclear power plants that becomes operational by 2020. For wind and solar power, we use the information from the 13th Five Year Development Plan for Solar Power [15] as well as various provincial renewable energy development plans. The aggregated power generation capacity at provincial level is close to the national plan (see Figure 1).

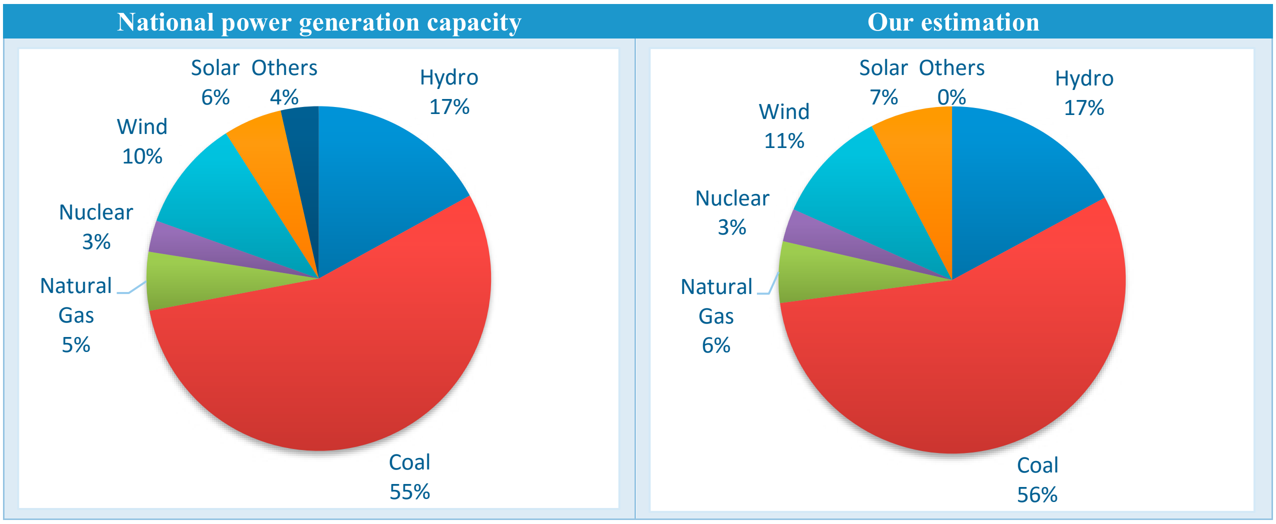

Figure 1 Share of power generation capacity in 2020

Source: Own calculation, data from [4], [6], [7], and various provincial renewable energy development plans

The capacity data is then converted to power generation by using the operating hours of each type of power generation technologies from each province in 2014. In fact, the operating hours of coal power has declined significantly in the last few years due to overcapacity. In 2016, the average operating hours for fossil fuels (mainly coal) were 4,165 hours, which was a decline of 199 hours in 2015 [16]. In 2014, the average operating hours of coal power were 4,730 hours. In the first scenario, we assume a 10% reduction in the operating hours of fossil fuel electricity generation by 2020 from the 2014 level. This assumption also considers the projected electricity demand (between 6,800 and 7,200 TWh) by the NEA which shows total power generation should be within the range of 6,800 and 7,200 TWh. In our calculation, the total power generation is 6,814 TWh with 10% reduction from coal power operating hours, which is within the range of demand projection by the NEA. This research does not address the changes of demand patterns, which represents the changes in socioeconomic conditions. Instead, we focus on the power generation fleet, which have been proposed by national and provincial governments.

Moreover, renewable energy operating hours have remained at low levels. This is due to the large-scale curtailment of renewable energy output in wind-rich provinces. For example, Gansu has over 10 GW of wind power capacity. The average curtailment rate in Gansu was above 40% during the last few years. Other wind-rich regions, such as Inner Mongolia, also experience significant curtailments. A well-connected grid network can help to reduce the curtailment rate, which in turn will increase operating hours of renewable energy. In this study, we use a second scenario to represent a 20% increase in renewable energy operating hours in 2020 comparing to the levels in 2014. The increase in renewable energy outputs is deducted from coal power generation so that total power generation in both scenario is identical. The third scenario takes a further 20% increase in renewable energy capacity. In the past few years, we have seen large gaps between planned renewable energy capacities and the real deployed capacities. With that in mind, in Scenario 2, we assume a 20% increase in renewable energy generation capacity by 2020 based on the adjusted operating hours in Scenario 2. Akin to Scenario 2, we deduct the amount of additional renewable energy generation coal power generation. A summary of scenarios is listed in Table 1.

Table 1 Three scenarios in this research

	Assumptions
Scenario 1	Coal power operating hours decline by 10%
Scenario 2	Scenario 1 + 20% increase in operating hours for renewable energy (wind and solar)
Scenario 3	Scenario 2 + 20% increase in installed capacity for renewable energy (wind and solar)

CO_2 emissions data from different power generation technologies are from Feng et al. [17]. The authors estimate life-cycle CO_2 emissions of 8 power generation technologies, using a hybrid life cycle analysis (See Table 2). We focus on life cycle emissions instead of direct emissions in this study. We understand that it is not ideal to apply a national average figure to each province. Some studies address the life cycle emissions of power generation in different provinces. For example, Ding et al. [18] compile the life cycle inventory for five types of power generation technologies (including thermal power, hydropower, solar PV, nuclear power and wind power) in thirty-one provinces. However, detailed data are only introduced for thermal and solar power. The study also neglect the wider emission impacts by focusing on the process life cycle inventories only. In comparison, Feng's results include the emissions from process life cycle analysis as well as the wider impacts by using a hybrid life cycle analysis. This method has also been used in addressing the emission impacts of power generation in China [19, 20]. We use the results from Feng's research here, but we will update the results as soon as detailed data becomes available.

Table 2. Life cycle CO2 emissions from different power generation sources

	Hydro	Coal	Natural Gas	Nuclear	Wind	Solar	Others
Life cycle emissions (g/kWh)	13	1230	856	17	46	76	97

Source: [17]

Carbon intensity is calculated as the total CO_2 emissions from different power generation sources divided by the total power generation in each province.

4. Results and discussion

We estimate the carbon intensity of power generation in China's provinces by 2020. As shown in Figure 2, the carbon intensities in most provinces are over 700 g/kWh by 2020. Very few provinces such as Hubei, Qinghai, Sichuan and Yunnan can fulfil the 600 g/kWh target by 2020. These provinces are mostly dependent on hydropower. For other provinces, Gansu is only able to fulfill the target with higher operating hours and more renewable energy capacities installed. At national level, carbon intensities vary between 861 and 821 g/kWh.

The growth of renewable energy sources with regards to higher operating hours (Scenario 2) and larger capacity (Scenario 3) can lead to a decline in carbon intensity. For example, in Inner Mongolia, Xinjiang and Gansu, the growth of renewable energy in terms of operating hours and capacity can lead to a reduction of approximately 100 g/kWh in carbon intensity. Most other provinces can also see declines, albeit minor, in their carbon intensity. Nevertheless, the growth of renewable energy can help the reduction of carbon intensity in most provinces, comparing to the 2014 levels. It is important to address that the additional generation from renewable energy sources will require sufficient grid infrastructure. In fact, China has proposed several cross-regional high voltage power transmission lines to link the regions that endowed with renewable energy sources to the demand centers. At present, renewable energy such as wind and solar only contributes to a minor proportion of the cross-regional power transmission. Better coordination among regions is needed to fully exploit the benefits of renewable energy development.

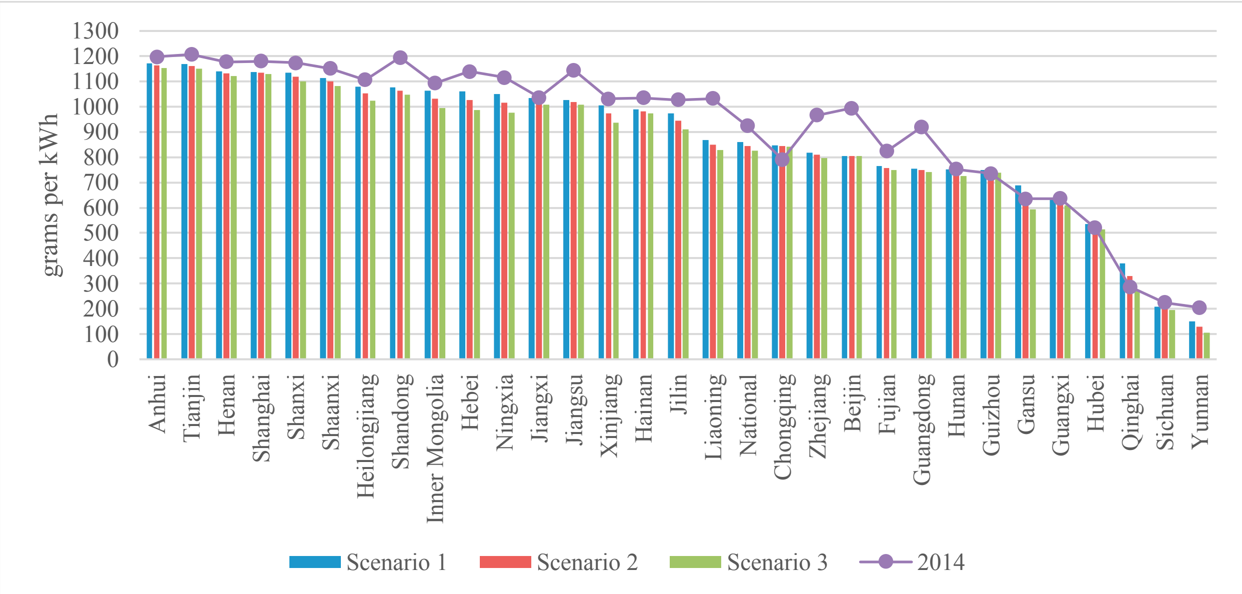

Figure 2 Carbon intensities in China's provinces by 2020 under different scenarios

The high carbon intensity is likely to continue due to the heavy dependence on coal power generation in most provinces. There is growing consensus in the scientific community and among policy makers that achieving the central aim of the Paris Agreement requires an early capping and then a rapid decline in global unabated coal-fired power generation. This implies shutting down many existing coal power plants, or retrofitting them with carbon capture and storage (CCS) equipment, and requiring (CCS) or similar abatement on new plants. In China, the growing demand of electricity might imply the operation of coal power plants in the near future so large-scale shutting down of coal power plants is not a straight-forward option. Therefore, CCS will need to play a central role in reducing carbon intensity in China in the longer term. Given the significance of CCS in addressing climate change targets in China, government support is necessary to encourage the research and development of CCS technologies, which should be implemented sooner rather than later.

Furthermore, we acknowledge that the rate of change in operating hours is not adequate. In this study, we compare the corresponding change in emissions in response to the change in operating hours and capacity growth. There is certainly scope in making province-specific adjustments. We are aware that data such as level of curtailments in different provinces can be used as a reference. However, such data is only available in few provinces. An update on results can be done, depending on the availability of new data.

Finally, there are various means to increase the operating hours and capacities of renewable energy in China. As discussed above, regional coordination through enhanced transmission planning can be necessary to fully perceive the benefits of renewable energy generation. At the same time, it is subject to the willingness of regional coordination, which has always been a problem under the current power system planning regime. In addition, China plans to establish a national carbon market. A well-defined carbon price can provide support to renewable energy development as well as discourage investment on carbon-intensive power generation. The key element is to ensure the carbon price can have an impact on the choice of power generation technologies (an effective example is the carbon floor price in the UK, which accelerate the phase-out of coal power generation due to lack of competitiveness). It is also important to set realistic emission standards with which utilities and power generation companies can be motivated to support the development of renewable energy sources. In the EU, for example, the Large Combustion Plan Directive and the Industrial Emission Directive set emission standards for power stations. Owner of power stations can opt to comply with these standards or opt out, in which case the plants would have to close. China also set emission standards for its major power generators to comply. At last, research and development on other renewable energy enabling technologies, such as energy storage system, is also necessary. The development of energy storage can assist the growth of renewable energy and improve emissions management [21] as well as boosting the local economy by creating new jobs and increasing local GDP.

5. Conclusion

In this study, we estimate the carbon intensities of power generation in China's provinces. Given that most provinces are dependent on coal power generation, their carbon intensity is not likely to achieve the 600 g/kWh benchmark as is mentioned in Kennedy's study. Renewable energy has become a significant player in the electricity system in several provinces in China. Although renewable energy sources can help reduce the carbon intensity of power generation, it requires a better coordination among provinces and relevant government support. Certainly, sustainable electricity sector planning needs to consider a wider range of parameters and embed effective climate change targets within it [22]. For China, CCS becomes a necessity to substantially reduce carbon intensities in the longer term. Therefore, research and development in CCS technologies should be encouraged and addressed in the future policy making.

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