China’s energy carbon emissions peak and its relation to thermal power development

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Abstract. In this paper, the future carbon emissions in the energy industry and the power industry were both calculated by 2035, and the peak values were obtained. Based on the carbon emission calculation, the relationship between the two kinds of carbon emission peak was analysed, and the influence of carbon emission peak to the thermal power development was also studied. Results show that, the energy industry carbon emissions will reach peak between the year 2025 and 2030, and the peak time for carbon emissions of power industry will be later for 1 to 3 years than that of energy industry. The coal-fired generator installation capacity is expected to reach peak before 2030, about 1.2 billion kilowatts.

1. Introduction
In response to global climate change, countries around the world have to adjust the development strategy to develop a new low-carbon economic development mode, beginning a transition to low-carbon economy strategic action. In 2015, China submitted to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) a self-contribution document on climate change, "Strengthening Climate Change Action - China's National Independent Contribution", which proposed by 2030, the unit GDP of CO2 emissions compared to 2005 Year decline of 60% -65%, CO2 emissions peak around 2030 and strive to reach the peak as soon as possible, non-fossil energy accounted for about 20% of the primary energy consumption and so on. Thermal power is the primary source of energy consumption and carbon emissions. According to the International Energy Agency statistics, in 2014, CO2 emissions of China's coal-fired power plant accounted for about 45% of the total emissions of greenhouse gas emissions. The purpose of this paper is to study the development trend and peak time of carbon emissions in China's energy industry and power industry, and to explore the relationship between carbon emissions peak of energy industry and the development of thermal power in China.

2. Carbon emissions accounting method
In this paper, we use the carbon emission coefficient method given by Intergovernmental Panel on Climate Change (IPCC) and calculate the carbon emissions from energy consumption activities in China. Table 1 shows the value of the carbon emission coefficient used in the research and development of government policies or scholars in recent years. Although different researchers have different values for carbon emission factors, the difference in the value of carbon emissions has little effect on the calculation of carbon emissions.
Table 1. Domestic carbon emission coefficient.

| Data source                  | Data year | Coal  | Oil   | Gas   |
|------------------------------|-----------|-------|-------|-------|
| National Development and Reform Commission [1] | 2014      | 2.64  | 2.08  | 1.63  |
| Wang [2]                     | 2014      | 2.66  | 2.11  | 1.63  |
| BP                           | 2014      | 2.79  | 2.04  | 1.74  |
| Fan [3]                      | 2013      | 2.77  | 2.15  | 1.64  |

3. Prediction and analysis of China’s energy industry carbon emissions

3.1. China’s primary energy demand forecast

Based on the judgment of future economic and energy development and related policy considerations, the use of scenario analysis was adopted. Taking into account the uncertainty of the affecting factors such as long-term factor investment, structural adjustment, industrial transfer, energy and technological progress and energy policy, two scenarios of energy and power development were designed: the baseline scenario and the energy revolution scenario (corresponding to high and low schemes), reflecting the energy and power development status under the conditions of structural adjustment and economic growth mode of change from slow to fast. Considering energy efficiency, energy price, environmental constraints and energy policy, we use medium and long term energy demand forecasting model [4], combing with empirical analysis, to forecast the "three five" and long-term primary energy demand, as shown in Table 2 and 3.

3.2. Prediction and analysis of carbon emission peak

According to the trend of the total energy consumption forecasted in the previous section, by multiplying the energy consumption by the carbon emission coefficients given in section 2, the trend of the total energy carbon emission in China under different scenarios is calculated, as shown in Figure 1.

Table 2. Energy consumption and proportion for various kinds of primary energy-low scheme (unit:10^8 ton coal equivalent).

| Year | Energy varieties | Total | Coal | Oil | Gas | Non-fossil energy |
|------|------------------|-------|------|-----|-----|------------------|
| 2020 | consumption      | 48.1  | 28.4 | 8.1 | 4   | 7.6              |
|      | proportion       | 100%  | 59.0%| 16.8%| 8.3%| 15.8%            |
| 2025 | consumption      | 51.8  | 28.2 | 8.5 | 5.1 | 10               |
|      | proportion       | 100%  | 54.4%| 16.4%| 9.8%| 19.3%            |
| 2030 | consumption      | 54    | 26.5 | 8.7 | 6.1 | 12.7             |
|      | proportion       | 100%  | 49.1%| 16.1%| 11.3%| 23.5%           |
| 2035 | consumption      | 55.3  | 24.5 | 8.7 | 7.1 | 15              |
|      | proportion       | 100%  | 44.3%| 15.7%| 12.8%| 27.1%           |
Table 3. Energy consumption and proportion for various kinds of primary energy-high scheme (unit:10⁸ ton coal equivalent).

| Year | Total | Coal | Oil | Gas | Non-fossil energy |
|------|-------|------|-----|-----|-------------------|
| 2020 | consumption | 51   | 30.5| 8.7 | 4.1               | 7.7               |
|      | proportion  | 100% | 59.8%| 17.1%| 8.0%             | 15.1%             |
| 2025 | consumption | 57   | 31.7| 9.7 | 5.3               | 10.3              |
|      | proportion  | 100% | 54.6%| 17.0%| 9.3%             | 18.1%             |
| 2030 | consumption | 60   | 31.5| 10  | 6.2               | 12.3              |
|      | proportion  | 100% | 52.5%| 16.7%| 10.3%            | 20.5%             |
| 2035 | consumption | 62.5 | 29.8| 10.3| 7.3               | 15.1              |
|      | proportion  | 100% | 47.7%| 16.5%| 11.7%            | 24.2%             |

Figure 1. Energy carbon emission in China under different scenarios

According to the results of the two schemes, the future energy carbon emissions will reach peak in 2025 ~ 2030, with the peak level of 10 to 11.4 billion tons. In the high scheme, energy carbon emission will reach peak in 2029, with the peak level of about 11.4 billion tons, increasing by 22% compared to carbon emissions in 2015, which is about 2.1 billion tons. In the low scheme, energy carbon emission will reach a peak in 2025, four years earlier than the high scheme to achieve carbon emission peak, with the peak level of about 10 billion tons, 1.4 billion tons lower than the high scheme, increasing by 7% compared to carbon emissions in 2015, which is about 700 million tons.

4. Trend and peak analysis of carbon emission in China's electric power industry

This section analyses the trends and peaks of carbon emissions in the power sector based on power optimization schemes. The determination of the power supply planning scheme is based on the clean energy decision support model with multi-regional power planning module including the new energy as the core [5]. The model idea is: taking the total cost of the whole society in the planning period as the goal to build optimization problem. The energy base development potential and development conditions such as coal-fired power, hydropower, wind power and so on are considered. There are constraints on energy supply capacity, power balance, peak load balance, the system operation, and
environmental space. We can obtain the installed capacity, layout and construction timing for various types of power generators form the results.

High scenario setting - hydropower, nuclear power, wind power, and solar power have reached the expected scale of national planning.

Low scenario setting - low demand, hydropower, nuclear power, wind power, solar power generation have a slight reduction than the expected development, coal, gas and other conventional thermal power have a larger proportion of reduction.

Table 4  China’s national power supply-high scheme (unit: ten thousand kW).

| Year | Installed capacity | Hydropower | Pumped storage | Nuclear power | Wind power | Gas power | Coal-fired power | Solar power | Biomass power |
|------|-------------------|------------|---------------|---------------|------------|-----------|-----------------|------------|---------------|
| 2015 | 150673            | 29666      | 2271          | 2717          | 12830      | 6637      | 91294           | 4158       | 1100          |
| 2020 | 207451            | 34732      | 4938          | 5820          | 24027      | 8519      | 112430          | 15285      | 1700          |
| 2025 | 245400            | 40300      | 7100          | 8200          | 33000      | 13000     | 118000          | 23000      | 2800          |
| 2030 | 283017            | 43000      | 8913          | 13199         | 40000      | 19305     | 118600          | 35000      | 5000          |
| 2035 | 348437            | 47000      | 15261         | 15000         | 60000      | 26052     | 117000          | 62000      | 6124          |

Table 5  China’s national power supply-low scheme (unit: ten thousand kW).

| Year | Installed capacity | Hydropower | Pumped storage | Nuclear power | Wind power | Gas power | Coal-fired power | Solar power | Biomass power |
|------|-------------------|------------|---------------|---------------|------------|-----------|-----------------|------------|---------------|
| 2015 | 150673            | 29666      | 2271          | 2717          | 12830      | 6637      | 91294           | 4158       | 1100          |
| 2020 | 200239            | 33400      | 3566          | 5800          | 21000      | 10973     | 112000          | 15285      | 1700          |
| 2025 | 240320            | 40300      | 7100          | 8200          | 33000      | 13000     | 117800          | 23000      | 2800          |
| 2030 | 265693            | 42000      | 8400          | 13000         | 40000      | 16000     | 116520          | 35000      | 5000          |
| 2035 | 312500            | 49000      | 13000         | 23000         | 55000      | 23000     | 115000          | 62000      | 6124          |

Under the two kinds of electricity demand scenarios, we can obtain China’s national power supply for both high and low schemes, as shown in Table 4 and 5. In which, thermal power generation which dominates the carbon emission of power industry can be calculated. Applying the coal and gas consumption rate for power generation, the power generation can be converted to the primary energy consumption, and then China's power industry carbon emissions can be calculated as shown in Figure 2.
Figure 2  Carbon emission of power industry under different scenarios.

In the high scheme, in 2020, the power industry carbon emissions will reach 4.89 billion tons, of which 4.8 billion tons come from coal-fired power, accounting for 97.7%, and 100 million tons come from gas power, accounting for 2.3%. After the year 2020, with the growth of coal-fired power into the saturation period, the power industry carbon emissions growth slows down, up to peak about 2032, about 5.56 billion tons, of which coal-fired power emissions are 5.29 billion tons, accounting for 95.1%, and gas power carbon emissions are 270 million tons, accounting for 4.9%. In 2035, the industry carbon emissions fall to 5.45 billion tons, of which 5.1 billion tons come from coal-fired power, accounting for 93.6%, and gas power carbon emissions of 350 million tons, accounting for 6.4%.

In the low scheme, the power structure adjustment accelerates, new energy has a rapid development, and coal-fired power installation reaches a peak earlier. In 2020, the power industry carbon emissions are about 4.2 billion tons, of which 4.1 billion tons come from coal-fired power. Carbon emissions reach peak about 2026, six years earlier than the high scheme, with peak value of about 4.79 billion tons.

5. The relationship between the carbon emission peak and development of thermal power
From the carbon emission peak time, the power industry emission will reach peak later than the energy industry for 1 to 3 years. From the contribution of power industry carbon emission to the energy carbon emission, in the two schemes, the contribution rates of power industry carbon emission are 47.1% and 47.7%.

Reducing the power industry carbon emissions depends on reducing coal power generation. The scale of coal-fired electricity development should be in adaption with the growth of demand as well as the scale of new energy development. Coal power generation should be under strict control. According to the situation of our study, China's coal power installed capacity is expected to peak about 1.2 billion kilowatts, coal-fired electricity peak in 500 to 600 million kWh. From now to year 2020, China's coal installed capacity will have about 200 million kilowatts of growth space. Comparing to the past five years, the increase is basically the same, but the growth rate drops significantly.

6. Conclusions
China's energy industry is expected to reach peak for carbon emissions between 2025 and 2030, and the peak level is among 10.0 and 11.4 billion tons. China's power industry is expected to reach peak for carbon emissions between 2026 and 2032, with the peak level among 4.8 and 5.6 billion tons. The contribution rate of carbon emissions in the power industry to energy industry is about 47%, and the carbon emission peak time for power industry will be one to three years later than that of the energy industry.
industry. Controlling coal-fired generation has key influence for carbon emission to reach peak, and coal-fired generation should reach peak before 2030, and the growing space ought to be less than 2000 billion kWh.

References
[1] Information on http://hzs.ndrc.gov.cn/newzwxx/201401/t20140110_575400.html
[2] Zhixuan Wang 2014 Estimate of China’s energy carbon emissions peak and analysis on electric power carbon emissions[J] Advances in Climate Change Research 181-188
[3] Xing Fan 2013 Calculation of carbon emissions and research on the reduction path in China [D] Liaoning University
[4] Minjie Xu, Zhaoguang, Hu and Xiandong Tan 2012 Scenario analysis on mid-long term energy and electricity demand and carbon emission in China[J] Electric Power 45(4) 101-104
[5] Lu Cheng and Lu Xing 2016 Analysis of requirement and impact of power development under the peak carbon emissions in 2030 [J] Electric Power 49(1) 174-177