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Estimate of China's energy carbon emissions peak and analysis on electric power carbon emissions

WANG Zhi-Xuan [a,*], ZHANG Jing-Jie [b], PAN Li [a], YANG Fan [a], SHI Li-Na [a]

[a] China Electricity Council, Beijing 100761, China
[b] North China Electric Power University, Beijing 102206, China

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Abstract

China's energy carbon emissions are projected to peak in 2030 with approximately 110% of its 2020 level under the following conditions: 1) China's gross primary energy consumption is 5 Gtce in 2020 and 6 Gtce in 2030; 2) coal's share of the energy consumption is 61% in 2020 and 55% in 2030; 3) non-fossil energy's share increases from 15% in 2020 to 20% in 2030; 4) through 2030, China's GDP grows at an average annual rate of 6%; 5) the annual energy consumption elasticity coefficient is 0.30 in average; and 6) the annual growth rate of energy consumption steadily reduces to within 1%. China's electricity generating capacity would be 1,990 GW, with 8,600 TW h of power generation output in 2020. Of that output 66% would be from coal, 5% from gas, and 29% from non-fossil energy. By 2030, electricity generating capacity would reach 3,170 GW with 11,900 TW h of power generation output. Of that output, 56% would be from coal, 6% from gas, and 37% from non-fossil energy. From 2020 to 2030, CO_2 emissions from electric power would relatively fall by 0.2 Gt due to lower coal consumption, and relatively fall by nearly 0.3 Gt with the installation of more coal-fired cogeneration units. During 2020–2030, the portion of carbon emissions from electric power in China's energy consumption is projected to increase by 3.4 percentage points. Although the carbon emissions from electric power would keep increasing to 118% of the 2020 level in 2030, the electric power industry would continue to play a decisive role in achieving the goal of increase in non-fossil energy use. This study proposes countermeasures and recommendations to control carbon emissions peak, including energy system optimization, green-coal-fired electricity generation, and demand side management.

Keywords: Energy consumption; Growth rate; Carbon emissions peak; Electric power development

1. Estimates of energy consumption and carbon emissions peak

1.1. The U.S.–China Joint Announcement on Climate Change

On November 12, 2014, China and the U.S. issued the U.S.–China Joint Announcement on Climate Change in Beijing. Under the agreement, “China intends to achieve the peaking of CO_2 emissions around 2030 and to make best efforts to peak early and intends to increase the share of non-fossil energy in primary energy consumption to around 20% by 2030. Both sides intend to continue to work to increase ambition over time.” The Announcement focused on four key

* Corresponding author.
E-mail address: wangzhixuan@cec.org.cn (WANG Z.-X.).
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points that were relevant to this study. First, China's carbon emissions (hereinafter carbon emissions) will peak around 2030 and China will make best efforts to peak early, which means the peaking should occur no later than 2035, even could be prior to 2030 with effort. Second, although the exact value of emissions peaking was not defined in the Announcement, it will not be randomly increased because the peaking of carbon emissions will reflect a goal of approximately 20% non-fossil energy in primary energy consumption by 2030, and because actions to combat climate change contained in the Announcement will facilitate peaking ahead of schedule.

1.2. Estimates of carbon emissions peak

The high carbon content of China's energy resources contributes significantly to carbon emissions. According to The People's Republic of China Second National Communication on Climate Change (DCCNDRC, 2013), not including land use, land use change and forestry (LULUCF), China's greenhouse gas emissions from energy production in 2005 were approximately 5.769 Gt CO_2-eq, accounting for 77.3% of national total greenhouse gas emissions. Because the production of steel and cement will peak before 2020 (Zhang, 2015; Gao, 2013) and carbon emissions from LULUCF have relatively low impacts, the peak value of China's carbon emissions will be determined almost entirely by energy consumption. Therefore, this study would analyze China's carbon emissions peak from energy consumption.

Because carbon emissions from energy consumption are influenced by a number of factors such as economy, social trends, energy, and environment, accurate forecasts of the trends in carbon emissions are difficult. Nevertheless, on the basis of current economic development trends and energy plans and policies already proposed by the government, future carbon emissions and the uncertainty could be reasonably estimated and analyzed.

In this study, factors used to estimate carbon emissions peak fell into two categories. The first category was based on China's National Plan on Climate Change (2014–2020) (NDRC, 2014) and the Energy Development Strategy Action Plan (2014–2020) (SCPRC, 2014). In the two plans, a cap of approximately 4.8 Gtce was established for China's energy consumption for 2020 with a cap on coal consumption set at 4.2 Gt. By 2020, the share of coal consumption in the total primary energy mix would be reduced to below 62%, and the share of non-fossil energy would increase to 15%. Accordingly, for the purpose of forecasting and analysis, this study chose 5 Gtce for primary energy consumption, 61% for coal consumption, and 10% for natural gas consumption in the total primary energy mix.

The second category included the following hypothetical propositions for forecasting and analysis proposed by the authors on the basis of our understanding of existing research: a) economic growth from 2020 to 2030 would be moderate and stable, and the annual growth rate of both the economy and the energy consumption would continue to decrease; b) by 2030, the share of natural gas in the total energy mix would increase to 14%, while the share of oil and coal would be reduced to 11% and 55%, respectively; c) non-fossil energy would be defined as carbon-free energy; and d) the emission coefficient will remain unchanged because the continuous technological advances in power industry of China in the past ten-odd years has tapped most of the potential of further increasing energy efficiency.

Using 2020 carbon emissions as the benchmark of 100, the average annual growth rate in gross energy consumption and carbon emissions from 2020 to 2030 were estimated on the basis of shares of non-fossil energy, coal, natural gas, and oil outlined above. The formulas are presented in Equations (1) and (2).

$$Q_E^{'} = \frac{Q_C^{'} \times \sum_{i=1}^{3} a_i^{'} b_i}{Q_C \times \sum_{i=1}^{3} a_i b_i} \times 100, \tag{1}$$

$$\text{where } Q_C^{'} = Q_C \times \left(1 + \frac{c}{100}\right)^{10}. \tag{2}$$

$Q_E^{'}$: 2030 carbon emissions assuming 2020 carbon emissions as 100; $Q_C^{'}$: gross primary energy consumption in 2030 (Gtce); Q_C: gross primary energy consumption in 2020 (Gtce); $a_i^{'}$: percentage of fossil energy i in the total 2030 energy consumption; a_i: percentage of fossil energy i in the total 2020 energy consumption; b_i: carbon emissions coefficient of fossil energy i, including coal, oil, natural gas, etc; c: average annual growth rate (%) of gross energy consumption from 2020 to 2030.

The results of these formulas are presented in Fig. 1.

As shown in Fig. 1, the average annual growth rate of energy consumption has a nearly linear relation with carbon emissions. In the absence of LULUCF, if the annual growth of energy consumption was zero, China's 2030 carbon emissions would be 92% of its 2020 level. This means carbon emissions would have peaked in 2020. If the annual growth of gross energy consumption averaged approximately 0.8%, China's carbon emissions in 2030 would be on a par with 2020 level. Carbon emissions would peak slightly later than 2020. Or, if the average annual growth rate of energy consumption were capped at 0.8% (taking other measures of carbon emissions reduction into account, this rate can be capped at 1%), the carbon emissions peak would be achieved. If the annual growth rate of GDP averaged 6%, and the average annual energy consumption elasticity coefficient was 0.30 (reflecting an annual energy consumption growth rate of approximately 1.8% and continued declines to below 1% in 2030), carbon emissions in 2030 would be approximately 110% of its 2020 level. For the purpose of this study, we defined this as the Relatively Ideal Scenario. When considering the effect of carbon sink, early peaking might be achieved and the peak value might be lower. If the assumptions in the Relatively Ideal Scenario, are applied in Equation (1), emissions of coal, natural gas, and oil, and overall energy consumption would be expressed as presented in Fig. 2.

If the annual growth rate of energy consumption averaged 1.8% during 2020–2030 and declined from 2.8% in 2021 to