Analysis of impact of national carbon market on thermal power and renewable energy development

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Abstract. At the end of last year, the national carbon emission market of China was officially launched, and the power industry became the first industry included in the national carbon market. Participating in the national carbon market will increase the cost of power generation in the thermal power industry by adding carbon prices to the cost of power generation, thereby limit the total emissions of the thermal power industry. At the same time, the carbon market will also result in improving the competitiveness of renewable energy. Therefore, the carbon market will cause a profound impact on the entire power industry.

1. Introduction

The carbon emissions trading market is an important policy tool of China to control greenhouse gas emissions and fulfill the Paris Agreement's emission reduction commitments. China's carbon emission market started with pilot markets from the year 2013. In 2016, the National Development and Reform Commission proposed that the national market will cover eight key emission industries, including electricity (power generation and power grids); While in July 2017, it was proposed to launch the national market with three industries in advance, including power generation, cement, and electrolytic aluminum; For now it was finalized that the power generation industry (including cogeneration) will take the lead.

For the construction path of the national carbon market, it has steadily progressed in phases, gradually expanding from a single industry to multiple industries and transitioning from pilots to the whole country. The policy issued[1] proposed to advance the construction of the carbon market in stages and steps without affecting the steady and healthy development of the economy. The development of national market would be divided into three stages, including infrastructure construction period, simulated operation period and deepening improvement period. It is expected that the quota trading between the power generation companies will start in 2020, as shown in Figure 1. In the future, it will gradually cover other key emission industries. The initial stage of the national carbon market will coincide with the existing pilot markets for a period of time. Power generation companies that meet the threshold should be integrated into the national carbon market and the pilot markets should be gradually integrated into the national carbon market.
2. Power generation companies in the carbon market

From the perspective of participating entities, the power generation industry is comprehensively covered. Power plants with annual emissions of 26,000 tons of carbon dioxide equivalent (comprehensive energy consumption of approximately 10,000 tons of standard coal) and above (including self-produced power plants) have been included in the market. This threshold for the integration of power generation companies into the carbon market is not high. Taking a coal-fired power plant as an example, power generation company or self-produced power plant with an installed capacity of 10 MW will be included, covering almost all power generation companies. According to a preliminary statistic, more than 1,700 power generation companies will be included in the initial period, with emissions exceeding 3 billion tons, accounting for about 30% of the country's total emissions in 2016[2].

In the aspect of distribution of quotas, quotas are allocated to power generation enterprises according to unified emission standards, and most of the quotas will be obtained free of charge at the initial stage. The quota allocation methods for the power industry in each pilot market are different, and the national carbon market will implement a unified distribution method for the power generation industry. It is expected that the baseline method will be adopted, that is, the quotas will be issued according to the uniform emission standards for the individual unit types. The main factors taken into account are the actual power generation and the carbon emission level per unit of power generation. Judging from the international experience and the trial practice of the seven pilots, the initial allocation of free quotas is usually adopted, and the proportion of paid allocation of quotas will continue to increase. Gradually, the auction method will be used.

3. Impact of the national carbon market on power industry

The carbon market is a policy market. The state controls the total amount of carbon emission quotas and limits the number of emission allowances of power generation companies. If the actual emissions of enterprises are lower than the quotas, surplus allowances can be sold and gain profit in the carbon market, and vice versa. In order to meet the request of emission reduction goal, enterprises can choose form purchasing quotas from the market or cutting emission through technical or management methods. Through market mechanisms, enterprises are encouraged to save energy, reduce emissions, and promote low-carbon transition.

3.1. Impact on thermal power companies

The cost of purchasing carbon quota (carbon price cost) is included in the overall cost of power generation. In the short-term, the impact on the industry as a whole is small, but the cost of individual companies will increase significantly. At the initial stage of the carbon market, considering a smooth start and avoiding fierce impact on the industry, the quota will not be too tight and the impact of carbon prices cost on thermal power costs will be limited. There are differences in the changes of the
cost of various companies. Enterprises whose emission levels exceed the benchmark value more will have a bigger quota gap, and they will need to purchase more quotas or implement serious emission reductions, which will increase the cost to a greater extent. Because only one industry is included, it is basically the internal balance of the industry. There are a number of quota gaps and a corresponding surplus.

According to a preliminary calculation, when quota transactions carried out in real terms in 2020, assume that 10%, 15% and 20% quotas cap will occur at the low, medium and high scenarios respectively. With reference to the carbon price level of the current pilot markets, the carbon price is expected to be 50-70 yuan/ton. When purchased from the market, the average cost of power generation will be increased by $3.05 \times 10^{-3}$ yuan/kWh, $5.49\% \times 10^{-3}$ yuan/kWh and $8.54 \times 10^{-3}$ yuan/kWh respectively, as shown in Table 1.

In the long run, the total allowance of carbon emissions will gradually be tightened up, and the rising carbon prices will increase the cost of thermal power significantly. With the improvement of market construction, in order to achieve the goal of reaching carbon emission’s peak in 2030, the total amount of carbon emission quotas will be tightened year by year. The cost of further reduction of thermal power will increase, and the level of carbon prices will increase accordingly, thereby increasing the cost of thermal power. With reference to the overseas mature carbon market price level, the carbon price is expected to be 100-150 yuan/ton in 2030. If the 10%, 20% and 30% quotas are purchased from the market and some of the quotas are paid for, the carbon price will bring a rise of the average cost of electricity by $6.10 \times 10^{-3}$ yuan/kWh, $18.30 \times 10^{-3}$ yuan/kWh and $34.93 \times 10^{-3}$ yuan/kWh, as shown in Table 1.

### Table 1. The increase of cost of electricity per kWh in different scenarios

| Phase     | Scenario | Average carbon price (yuan/ton) | Percentage of quota gap | Percentage of free quota | Auction price (yuan/ton) | Increase of cost of electricity per kWh ($10^{-3}$ yuan/kWh) |
|-----------|----------|---------------------------------|-------------------------|--------------------------|---------------------------|-------------------------------------------------------------|
| 2020      | Low      | 50                              | 10%                     | 100%                     | ---                       | 3.05                                                        |
|           | medium   | 60                              | 15%                     | 100%                     | ---                       | 5.49                                                        |
|           | High     | 70                              | 20%                     | 100%                     | ---                       | 8.54                                                        |
| 2030      | Low      | 100                             | 10%                     | 100%                     | 125                       | 6.10                                                        |
|           | medium   | 120                             | 20%                     | 95%                      | 150                       | 18.30                                                       |
|           | High     | 150                             | 30%                     | 90%                      | 175                       | 34.93                                                       |

3.2. **Impact on the development of renewable energy**

In the short term, the national carbon market has no obvious effect on the promotion of renewable energy. Due to the low carbon price in the initial stage of the market, the cost of thermal power has not changed significantly and its market competitiveness is still strong, as shown in Figure 2. The initial trading products did not include Chinese Certified Emission Reduction (CCER), so renewable energy power generation projects could not obtain additional benefits from the carbon market. When wind and photovoltaic power generation are issued with policy subsidy and the renewable energy quota trade is implemented, the cost may be lower than some inefficient and high-emission thermal power units, and more power generation and profits will be obtained from the market.
Figure 2. Cost of carbon price added in the cost of power per kWh in different scenarios in 2020.

In the long run, with the increase of carbon prices and the reduction of renewable energy generation costs, the competitiveness of renewable energy power generation will be significantly enhanced and will further accelerate development. According to the 2030 high scenario in Figure 3, the carbon price is 150 yuan/ton, and the cost of thermal power will be close to 0.30 yuan/kWh. In 2030, the cost of wind power and photovoltaic power generation is expected to be reduced to 0.325 yuan/kWh[3], and the gap between renewable energy and thermal power costs is already very small. If the carbon price increases to more than 200 yuan/ton, considering the benefits of CCER when traded in carbon market, as well as renewable energy quota trading, the cost of wind power and photovoltaic power generation will be equivalent to the cost of thermal power. Therefore, there will be a further improvement in the amount of new energy generated and its profitability.

Figure 3. Cost of carbon price added in cost of power per kWh in different scenarios in 2030.
Based on the above analysis, under the background of carbon emission amount control in the power industry, carbon emission rights have become scarce resources. The space for thermal power development has gradually tightened, and carbon emission cost will gradually increase the cost of thermal power, prompting power generation companies to invest in renewable energy. Future power supply structure and layout will change significantly.

3.3. Impact on the development of grid
The carbon market will affect the power supply structure and the development of renewable energy, which in turn will have an impact on the future grid layout. After the national carbon market is fully functional, other key emission industries such as iron and steel, non-ferrous metals, building materials, and chemical industries will also be included, which will have an impact on the structure and layout of electricity consumption. After analysing the future changes in power supply layout and power flow, the grid investment layout and planning should be adjusted adaptively.

4. Conclusions
The electric power industry is a crucial source of carbon emissions. The carbon emissions of the power industry account for about half of the total carbon emissions in China[4], and therefore it is also a key area of carbon emission reduction. With the power industry being fully integrated into the national carbon market, the power industry is facing the dual pressure of supporting economic growth and carbon emission reduction. It requires a vigorous development of non-fossil energy generation and the improve of overall efficiency of the power system. The carbon market will have a major impact on the cost of power generation, and investment structure of power generation companies. It will also have a certain impact on the planning and construction of the power grid and its operation.

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