The Research on Path of Power Industry to Reduce Haze

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Abstract. The study analyzed the environmental effect of measures for reducing emission in electric power industry. Designing scenario of ultra-low emissions, clean energy replacement and electricity replacement, we used air quality model to study the reduction effect on the whole country and some areas. The results show that impact of ultra-low emission on China's environment effect is limited to reducing haze in the future. The core of the optimization energy system is power, including improving the proportion of coal for power generation and reducing the scattered coal. The implementation of electricity replacement is the effective way to solve the problem of haze in China.

Introduction

With the comprehensive implementation of the air pollution prevention and control plan, the urban air quality in China has been gradually improved, and the concentration of major pollutants in the atmosphere has decreased. But some key areas of air pollution such as the Beijing-Tianjin-Hebei region are still relatively heavy, and different regional haze formation and complex features is prominent. The heavy pollution weather across the country is frequent, and heavy air pollution phenomenon has not been effectively curbed. The energy consumption structure dominated by fossil energy is an important cause of haze in China. How to optimize the energy system and the establishment of a clean modern energy system has become an urgent problem to be solved in the future.

At present, the efficiency of PM2.5 removal in power industry of China has reached over 99.75%, while the proportion of coal used in electricity generation is about 50%, far lower than that in developed countries such as the United States. Compared with the concentrated utilization of coal, decentralized utilization and management of inferior coal that is often high ash and sulfur is the key of preventing air pollution in some areas, which is lack of desulphurization and dust removal process. According to the pollution treatment experience of developed countries, the more large-scale coal is used to generate electricity and reduce the coal burning. The few studies are focused on quantitative environment impact of electricity replace on our country and the beijing-tianjin-hebei region, which the existing literature is mainly focused on technology selection of the emission reduction in thermal power industry [1-5].

This paper mainly analyzes the future trend of power industrial emission reduction. Using regional air quality model (CAMx), we research the environment improvement effect of implementing ultra-low emission measures, clean replacement and electricity replacement, the path of which is compared to reduce the haze. The result of the study will provide the reference for designing the path of reducing emissions in the power industry and building up clean energy system.

The Methods and Scenario Design

The Methods

The air quality model uses the principle of meteorology to simulate the concentration of pollutants from pollution sources to ambient air. CAMx is the third air quality mode which is developed by
ENviron company in the United States, which can be applied to simulate the multi-scale, photochemical smog and fine particulate matter air pollution in three-dimensional nested grid and is used to study the troposphere emissions of pollutants, such as transfer, chemical reaction and removal process. The physical basis of CAMx model is the continuity equation of pollutants:

\[
\frac{\partial c_i}{\partial t} = -\nabla \cdot (V_i c_i) + \left[ \frac{\partial (c_i \eta)}{\partial z} - c_i \frac{\partial}{\partial z} \left( \frac{\partial}{\partial t} \right) \right] + \nabla \cdot (\rho D \nabla (c_i)) + \frac{\partial c_i}{\partial t} \text{Chemistry} + \frac{\partial c_i}{\partial t} \text{Emission} + \frac{\partial c_i}{\partial t} \text{Removal}
\]  

(1)

\(c_i\) is the average concentration of species, \(Z\) is vertical topography with moving coordinates, \(V\) is horizontal wind vector, \(\eta\) is the rate of clamping in a vertical direction, \(K\) is turbulence diffusion coefficient. CAMx mode is to calculate in stages transmission of air pollution emission, chemical conversion, dry, wet sedimentation and so on in the process of updating the concentration field calculation, and end up with the concentration of all kinds of air pollutant.

This simulation system first provides the meteorological background field that system requires by using meteorological model WRF, and secondly provides natural gas emissions sources by use of terrestrial ecosystems estimate model MEGAN, which will form emission source files with anthropogenic source that is dealt with by model SMOKE. Thirdly, the input that meets the requirements is obtained, which the meteorological background field and the emission source file are then processed by CAMx. At last, pollutants contribution to regional and industry is simulated by using technology of particle source tracer and sensitivity analysis.

This study divided the emission source into four categories which are respectively thermal power, industry, transportation and civil source. Based on the regional source partitioning scheme, it is possible to judge the distribution of regional pollutants sources in various industries and provide theoretical support for selecting the measures of industrial emission reduction.

**Scenario Design**

Comprehensive consideration of renewable energy technology and economy, the policies of electricity replacement and so on, this study constructed ultra-low emissions of the thermal power scenario, renewable energy scenario and electricity replacement scenarios, which provide the reference for design the path of power industrial emissions reduction.

**Scenario 1: Ultra-low emission**

During the period of the 13th Five-year, the transformation goal of China's thermal power electricity is to achieve ultra-low emissions standards [6], ultra-low emission standards in China has been far beyond the foreign emissions standards, which will be the most tightly standards in our country. According to ultra-low emissions requirement, the emission standard of dust in electricity industry is 10mg/m³, the sulfur dioxide emission standard is 35mg/m³, and the nitrogen oxide emission standard is 50mg/m³ in 2020. In this scenario, clean replacement and electricity replacement are progressing steadily. The development of renewable energy is carried out in accordance with
established planning objectives, and all of coal power construction will achieve ultra-low emissions in 2020.

Scenario 2: Clean energy replacement

Combined with the national non-fossil energy strategic target, the hydropower/nuclear development process, and the renewable energy planning target [7-8], the requirements for the total amount of renewable energy development are measured. In order to realize China's energy development strategy, non-fossil energy supply demand will reach 1.1 billion tce which occupied 25% proportion of energy consumption, when the total of energy demand is expected to reach around 5.5 billion tce in 2030. The amount of non-fossil energy demand which is used to power generation is about 970 million tce, which occupied 88% of the total non-fossil energy. In order to achieve carbon reduction targets in 2030, the total installed scale of China's renewable energy power generation is at least 880 Gw, which include around 400 Gw wind power, 350 Gw solar power, 30 Gw biomass power generation. In the scenario, thermal power fully realizes ultra-low emissions standards in 2020, and the scale of the renewable energy are larger than ultra-low emissions scenario. On the demand side, energy substitution and energy conservation are the same as those of ultra-low emissions scenario.

Scenario 3: Electricity replacement

The implementation of electricity replacement can improve the overall energy efficiency by reducing inefficient coal burning [9]. According to the whole process of power production, the pollutant discharged from thermal power generation can be centrally dealt with. At present, the desulfurization rate of thermal power plant can reach more than 90%, the denigration rate can reach above 80%, and the dust removal rate can reach over 99%. With the development of renewable power, the environmental advantages of electricity replacement will be further revealed. In this scenario, we increase the scale of electricity replacement, Which the electricity demand in 2020 and 2030 will increase 300 billion kWh and 400 billion kWh respectively, compared with ultra-low emissions scenario and clean energy replacement scenario.

The Result

The Impact on Environment of the Whole Country

In the ultra-low emissions scenario, because the contribution of the power industry to the national pollutants concentration is small, its own emissions reduction potential is limited. Although almost near-zero emissions of the electric power industry is achieved, it is relatively limited to reduce the ash haze. The concentration of PM2.5 is decreased by 3.5 percent and 5.3 percent in 2020 and 2030 by the full implementation of ultra-low emissions.

In clean energy replacement scenario, although we speed up the development of wind power, solar power and other clean energy, the proportion of clean energy power in total generating capacity is relatively low and the capacity of coal power is only less slightly than one in thermal power ultra-low emissions scenario. The total emission of air pollutants for thermal power industry and the concentration was not much lower than thermal power ultra-low emissions scenario. As clean energy becomes the main body of energy supply after 2030 and a large number of coal capacities become the main of balance adjustment power, which coal power replaced by large-scale clean energy power generation, the haze governance effect will be even more significant in the country.

In the case of electricity replacement, the power industry not only realizes net zero emission, but also promotes other industries to reduce the emission of coal pollution by replacing other energy with electricity. Compared with 2015, the concentrations of pollutants such as SO2, NOX and PM2.5 in China are respectively decreased by 40.7%, 28.2% and 23.5% in 2020, and were reduced by 55.4%, 38.6% and 34.2% respectively in 2030. According to the simulation results, it is more important to increase the power substitution to the national grey haze governance than the power industry itself to develop clean energy and implement ultra-low emission.
The Impact on Environment of Some Areas

In thermal power ultra-low emissions scenario, because the capacity of thermal power is less and the local thermal power emission standard is more stringent in the Beijing-Tianjin-Hebei region, the effect of ultra-low emission is less to improve regional environment. Compared with 2015, the concentrations of pollutants such as SO2, NOx and PM2.5 in the elderly triangulation region were reduced by 3.3 percent, 3.8 percent and 4.7 percent respectively. The concentrations of SO2, NOx and PM2.5 in the region are decreased by 4.9%, 5.1% and 6.1% respectively in 2030. The simulation results show that compared with the Beijing-Tianjin-Hebei region, the thermal power generating capacity of the Yangtze River delta region is large, and the effect of ultra-low emission on the emission reduction of atmospheric pollutants in the region is obvious.

In clean energy replacement scenario, the Beijing-Tianjin-Hebei region receives more clean electricity from outside of the region. Compared with 2015, the concentration of pollutants such as SO2, NOx and PM2.5 in the beijing-tianjin-hebei region decreased by 7.4%, 5.2% and 4.7% respectively in 2020 and decreased by 7.9%, 5.8% and 5.5% respectively in 2030. Simulation results show that the concentration of pollutants such as SO2, NOx and PM2.5 in the region are decreased by 4.9%, 5.1% and 6.1% respectively in 2030, compared with 2015.

In electricity replacement scenarios, beijing-tianjin-hebei region continuously increase the scale of the electricity replacement, and the level of electrification will be higher than the national average in 2030. In this context, the reduction effect of electricity replacement is most obvious. Compared with 2015, the concentration of SO2 decreased by more than 50%, the concentration of NOx decreased by more than 40%, and the emission concentration of PM2.5 decreased by more than 25% in 2020. In 2030, the concentration of SO2 decreased by more than 50%, the concentration of NOx decreased by more than 40%, and the concentration of PM2.5 decreased by more than 25%. The environmental improvement in the Yangtze River delta region is greater than that in the Beijing-Tianjin-Hebei region. Compared with 2015, the concentration of SO2 will be respectively reduced by more than 60% and 70%, the concentration of NOx will be reduced by more than 40% and 50%, and the concentration of PM2.5 will be reduced by more than 30% and 40% in 2020 and 2030 in the Yangtze River delta region. Compared with 2015, the emission concentration of SO2 in the Pearl River delta region decreased by 28% and 36% respectively the concentration of NOx emission decreased by 15% and 19% respectively, and the concentration of PM2.5 emission decreased by 18% and 25% in 2020 and 2030.

Table 1. The environmental effect of different measures in Scenarios.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Pollutions</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2020</td>
</tr>
<tr>
<td>CHINA</td>
<td>SO2</td>
<td>-8.4%</td>
<td>-9.8%</td>
<td>-10.1%</td>
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<td></td>
<td>NOx</td>
<td>-5.2%</td>
<td>-6.4%</td>
<td>-6.7%</td>
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<tr>
<td></td>
<td>PM2.5</td>
<td>-3.5%</td>
<td>-5.3%</td>
<td>-5.5%</td>
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<tr>
<td>Beijing-Tianjin-Hebei</td>
<td>SO2</td>
<td>-5.7%</td>
<td>-6.1%</td>
<td>-7.4%</td>
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<tr>
<td></td>
<td>NOx</td>
<td>-3.8%</td>
<td>-5.1%</td>
<td>-5.2%</td>
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<tr>
<td></td>
<td>PM2.5</td>
<td>-3.1%</td>
<td>-3.7%</td>
<td>-4.7%</td>
</tr>
<tr>
<td>The Yangtze River Delta region</td>
<td>SO2</td>
<td>-3.3%</td>
<td>-4.9%</td>
<td>-5.1%</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>-3.8%</td>
<td>-5.1%</td>
<td>-5.4%</td>
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<tr>
<td></td>
<td>PM2.5</td>
<td>-4.7%</td>
<td>-6.1%</td>
<td>-5.1%</td>
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<tr>
<td>Pearl River Delta region</td>
<td>SO2</td>
<td>-11.4%</td>
<td>-12.3%</td>
<td>-11.4%</td>
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<tr>
<td></td>
<td>NOx</td>
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<td>-7.0%</td>
<td>-6.2%</td>
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<tr>
<td></td>
<td>PM2.5</td>
<td>-5.2%</td>
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To sum up, due to the characteristics of industrial structure, the effect of pollutants concentration reduction in Yangtze river delta region is superior to the Beijing-Tianjin-Hebei region and the Pearl River delta region, because the burning coal of Yangtze river delta region outweigh the above two areas. The simulation shows that the effect of implementing ultra-low emissions and clean energy replacement in Yangtze river delta region is superior to the above two areas, because coal plants of Yangtze river delta is greater.

**Summary**

Due to the limited space and potential of emission reduction in the power industry, the environmental impact of ultra-low emission and clean energy replacement in the power industry is far less than the emission reduction effect under the electricity replacement scenario. In the context of China's vigorous advocacy of ecological civilization and the construction of beautiful China, the improvement of electrification level is not only the standard for improving the economy, but also the key element of environmental improvement. In the future, it is an effective way for China to solve the haze problem by optimizing the energy system with electric power, increasing the proportion of coal in power generation and reducing the coal burning.

The implementation of the power replacement strategy should be accelerated, reduce the scattered coal consumption, raise the level of electrification, and optimize the terminal energy consumption structure. Carry out the investigation of burning coal and its pollution emissions, and make the fiscal and taxation policies policy of accelerating electricity substitute, which encourage enterprises to replace the coal-fired boiler and fuel furnace with the electric boiler. We will speed up the development of key equipment, improve the efficiency of power conversion, speed up the construction of grid facilities, and create conditions for the large-scale electricity replacement.

The ultra-low emission of coal power is should be continue to evaluate and study, and improve the environmental and economic benefits of ultra-low emissions from coal-fired power plants. And strengthen the application of ultra-low emission technology in other industries such as steel. Widely draw lessons from the advanced technology and management experience of the ultra-low emission in the power industry to realize pollutant emissions in a wide range of industries.

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**References**


