

Study on feasible technical potential of coal to electricity in china

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Abstract. The control of bulk coal is one of the important work of air pollution control in China's future. Existing research mainly focuses on the adaptability, economy, construction and renovation plan, and operation optimization of specific energy substitution utilization, and lacks the strategy research of long-term layout of energy substitution utilization in large area. This paper puts forward a technical potential prediction method of coal to electricity based on the thermal equivalent method, which is based on the characteristics of regional coal consumption, and combined with the trend of adaptability and economy of energy substitution utilization. Also, the paper calculates the comprehensive benefit of coal to electricity according to the varieties of energy consumption and pollutant emission level of unit energy consumption in China's future. The research result shows that the development technical potential of coal to electricity in China is huge, about 1.8 trillion kWh, including distributed electric heating, heat pump and electric heating boiler, mainly located in North China, East China, and Northeast China. The implementation of coal to electricity has remarkable comprehensive benefits in energy conservation and emission reduction, and improvement of energy consumption safety level. Case study shows the rationality of the proposed method.

1. Introduction

Large-scale exploitation and utilization of fossil energy results in many global problems such as shortage of resources and energy security. Development of human society is facing increasingly serious fossil energy predicament. Greenhouse gas emissions and air pollution problems that result from fossil energy production and consumption are increasingly arousing people's concern. According to scholars study, one of the main sources of air pollution problem is burning bulk coal. Coal to electricity directly consumes electricity instead of coal in the energy consumption, which can increase the proportion of electricity in terminal energy consumption, and fundamentally solves the problems that restrict sustainable development of human society such as energy environment and climate change. In paper [1], the author establishes an equivalent substitution model between different energy based on the analysis of the equivalent conversion relationship of a variety of energy in the process of energy conversion and utilization. The author also considers the influence of price factor on energy utilization type, and establishes a multi-objective optimization model with the goal of maximum energy efficiency and minimum system operation cost, and verifies the rationality and superiority of the proposed model through the comparative analysis with the traditional energy utilization way. In paper [2], the author studies the difference of pollution emission rate between power industry and other industries by exploring the internal relation between energy, economy and environment. The author also uses system dynamics theory to build benefit simulation system of coal to electricity, and



establishes a benefit analysis model of coal to electricity emission reduction, and verifies the implementation effect of coal to electricity using Beijing as an example. Paper [3] studies the market equilibrium problem of multi-energy systems with electric-gas equipment, and models the multi-energy systems with electric-gas equipment based on the energy center modeling method, and describes the market equilibrium problem of multi-energy systems as a game problem that all energy centers simultaneously participate in. The optimal response equations of the Nikaido-Isoda function are used to solve the iteration problem in the multi-energy market. In paper[4], a cost model and operation constraint are established for ground source heat pump system with the heating and cooling function, and for heating supply system which supplies cool with cooling water generation unit in summer, and heat with heat storage electric boiler in winter. An optimization model with direct solution of the boundary conditions is established, taking the minimum system cost deviation of the above two types as objective, which is used to determine the applicable areas of the two systems. In paper [5], several typical scenarios of energy substitution in rural areas of developing countries are studied. In paper [6], the ground source heat pump system with both heating and cooling functions is modeled, and the artificial neural network (ANN) is used to predict the EER of the system. In paper [7], the electric boiler and ground source heat pump technology are integrated. The author analyzes the operation strategy of the electric boiler and the heat pump in the joint use of different performance curves based on the energy consumption and economic cost. The integrated solution of using ground source heat pump as the main heating facility and electric boiler as auxiliary heating facility is put forward. Based on the consumption situation of coal, natural gas and electricity, the author in paper [8] analyzes the situation and potentiality of energy substitution in Tianjin, and estimates the economic efficiency of several energy substitution utilization. The existing researches mainly focus on the adaptability, economy, construction and operation optimization of specific energy substitution technologies, and lack strategic research on long-term planning of energy substitution in large area.

In view of the next 5-10 years, one of the focus of China's air pollution control is to control bulk coal, this paper puts forward a coal to electricity technical potential prediction method based on thermal equivalent method, which is according to the characteristics of coal consumption in various regions, and combined with development trends of energy substitution utilization adaptability and economy. Then the paper calculates the comprehensive benefits of coal to electricity. Case studies show that the proposed method is reasonable.

2. Analysis Model of Technical Potential for Coal to Electricity

Calculation method: The national and local air pollution control action plans and implementation plans, energy consumption and coal consumption control objectives, as well as the city, industry and other development planning of the corresponding energy substitution areas are all considered. China's energy substitution utilization technology level, its application status and development trend, energy consumption of different species, the economy and comparability trends of energy substitution, the manufacturing capacity of main kinds of electricity substitution equipment and other factors are also taken into account to make a comprehensive speculation. Taking the energy efficiency into consideration, the fossil energy consumption which has feasible energy substitution technology is converted to the technical potential of coal to electricity according to the thermal equivalent method, which is called electricity substitution potential of coal to electricity.

Formula: Technical potential of coal to electricity

$$p = \sum_{i=1}^N \frac{c_i \times u_i}{e_i} \quad (1)$$

p represents the technical potential of coal to electricity.

c_i represents coal consumption of the i -th industry which has feasible coal to electricity technology.

u_i represents coal utilization efficiency of the i -th industry which has feasible coal to electricity technology.

e_i represents electricity utilization efficiency of the i -th industry which has feasible coal to electricity technology.

N represents the quantity of industry.

There are more than 50 kinds of coal to electricity technologies, such as distributed electric heating, heat pump, electric boiler heating, building material kilns, electric cookers and medium frequency induction furnaces. The costs of migrating from coal to these technologies include their construction cost, fuel cost, electricity consumption cost and other operation cost. As for a consumer, the total cost of electricity utilization technology should be comparable to that of coal utilization technology.

Calculation range: First, bulk coal is all replaced, and the coal used for centralized heat supply in the area that is not suitable for combined heat and power cogeneration is also been replaced, steam coal (excluding thermal coal and industrial furnace coke) is partially replaced according to the characteristics of coal consumption. Second, the substitute power generation of the captive power plant's thermal coal is the incremental power generation by increasing the power generation efficiency through the high-efficiency generating unit considering generation rights transactions. Third, other coal consumption shall be considered as bulk coal, centralized heating coal, steam coal and chemical raw coal according to the proportion of all kinds of coal consumption, and the corresponding substitute electric energy shall be calculated.

Main calculation approach: First, coal consumption in different industry is counted with its utilization technology. Second, whether there is a feasible coal to electricity technology is checked for each main industry. Third, whether the total cost of electricity utilization technology is comparable to that of coal utilization technology is checked for each main coal consumer. Fourth, if the above two steps are yes, the technical potential of the main coal consumer is calculated according to formula (1). Fifth, coal consumption in the i -th industry is added up according to step fourth. Sixth, if various national and local planning has more coal consumption control target than that to be replaced in the i -th industry, and there is sufficient manufacturing capacity of corresponding coal to electricity equipment, and the technical potential in the i -th industry is modified according to formula (1). Seventh, technical potential of coal to electricity in each industry is added up. Eighth, according to the coal consumption to be replaced and its original pollutant emissions per unit of coal consumption, the comprehensive benefits of coal to electricity are estimated.

3. Case Study

According to the data of China coal consumption survey directed by the research group, and that from National Bureau of Statistics of the PRC and National Energy Administration, the national primary energy consumption in 2015 is 4.40 billion tons of standard coal equivalent, the total coal consumption reaches 3.965 billion tons, 3.7% down as compared to the previous year, but still accounts for half of the world's coal consumption. Among them, the power industry consumes 1.839 billion tons of coal, while 627 million tons of coal is consumed in iron and steel industry, 525 million tons in building materials industry, and 253 million tons in chemical industry. The proportion of coal in China's primary energy consumption structure is about 64%, far higher than the average world coal consumption ratio level [9], which is 30%. Much input data can be referred to in report [9].

Considering the development of major types of coal to electricity technologies and their application scale in past 10 years, such as electric boilers, electric kilns [9], using the above forecast method to estimate the technical potential of China's future coal to electricity, coal to electricity technical development potential is huge, which is about 1.8 trillion kWh, equivalent to reduction of 700 million tons of bulk coal. The types of technology for coal to electricity mainly include distributed electric heating, electric boiler heating, heat pumps, industrial boilers, industrial kilns and other coal to electricity areas. Among them, distributed electric heating, heat pump and electric boiler heating technical potentials are 500 billions, 500 billions and 300 billions kWh respectively, accounting for 28%, 28% and 17% of the technical potential for coal to electricity, which is more than 70% in total. The technical potential for coal to electricity of building material kilns, electric cookers and medium frequency induction furnaces are 190 billions, 150 billions and 85 billions kWh respectively,

accounting for 11%, 8% and 5% of the technical potential of coal to electricity. Other coal to electricity technology has less potential, only 3% of the total, as shown in Figure 1.

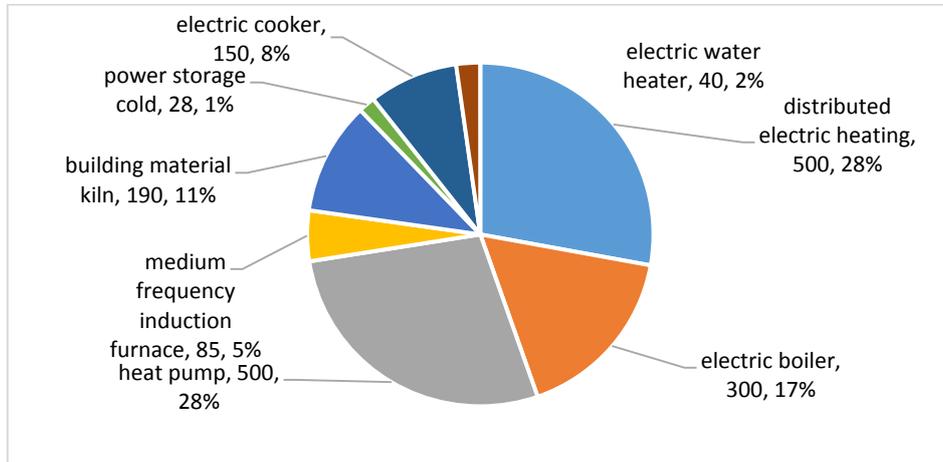


Figure 1. Distribution of technical potential for different types of coal to electricity (billion kWh, ratio)

The technical development potential of coal to electricity is mainly distributed in North China, East China, Northeast China, which is 655.6 billions, 319.7 billions, 221.8 billions kWh respectively, accounting for 37%, 18%, 12% of the technical potential for coal to electricity, which is about two-thirds in total. The technical potential for coal to electricity in the Central China, South China and Northwest China is 186.6 billions, 135 billions and 133.8 billions kWh respectively, accounting for 10%, 8% and 7% of the total. Other areas have less technical potential for coal to electricity. The technical potential for coal to electricity in the West Inner Mongolia and Southwest China is 111.4 and 29.4 billion kWh, less than 10% of the total, as shown in Figure 2.

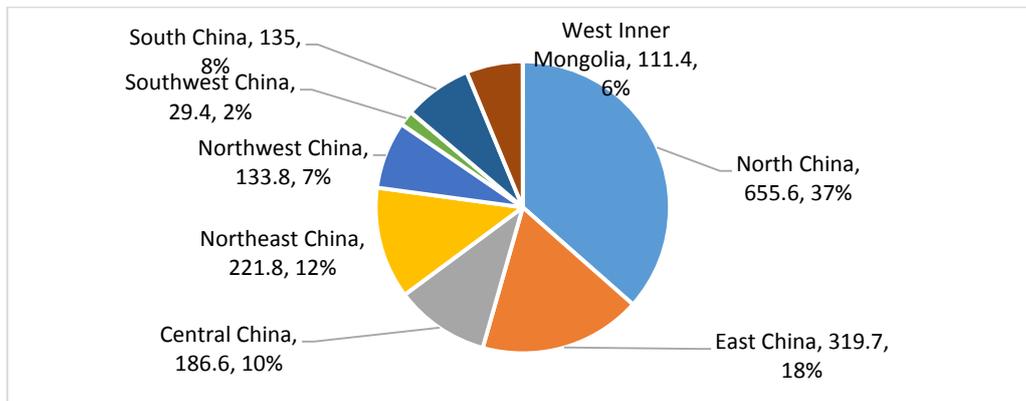


Figure 2. Area distribution of technical potential of coal to electricity (billion kWh, ratio).

The implementation of coal to electricity has significant comprehensive benefits, such as energy-saving, emission reduction, improving the level of energy utilization safety and others.

First, it can improve energy utilization efficiency, reduce energy waste. China's waste of energy due to inefficient utilization of bulk coal is more than 114 million tons of standard coal equivalent, accounting for about 4% of the total terminal energy consumption. Most of the industrial coal-fired boiler's actual operating efficiency is between 60-65%, and some are between 30-40%, 10-20% lower than the average level of advanced countries. Electric boiler's operating efficiency is about 85- 90%. Industrial kiln efficiency is about 40%, while electric kiln efficiency is up to 70-80%. Energy utilization efficiency of resident's bulk coal burning is generally lower than 20%, while the efficiency

of electric cookers is up to 50-80%. Implementation of coal to electricity can effectively reduce the waste of distributed inefficient coal consumption and improve the overall energy efficiency level.

Second, it can significantly reduce air pollution and greenhouse gas emissions. According to China's future energy consumption of different kinds and their pollutant emissions per unit of energy consumption, if the total technical potential of coal to electricity is implemented, the annual emissions reduction of sulfur dioxide, nitrogen oxides and PM2.5 are about 8.4 million tons, 2.8 million tons, 0.3 million tons respectively. If the increment electric energy from coal to electricity is supplied by the clean energy, it can reduce 1.4 billion tons of carbon dioxide emission.

Third, it can improve the health and safety level of residents. Through the promotion of distributed electric heating, cooking, bathing, etc., gas poisoning incidents can be avoided, and the safety level of energy consumption is improved.

4. Conclusion

The control of bulk coal is one of the key work of air pollution control in China in the future. Based on the characteristics of coal consumption in different regions, considering the adaptability and economy development trend of energy substitution technology, this paper puts forward a technical potential forecast method of coal to electricity based on thermal equivalent method and estimates the comprehensive benefits of coal to electricity. The results show that China's coal-to-electricity technical development potential is huge, about 1.8 trillion kilowatt-hours, which is equivalent to utilization reduction of 700 million tons of bulk coal. Distributed electric heating, heat pump and electric boiler heating technical potential accounts for 73% of coal to electricity technical potential. North China, East China, Northeast China's coal to electricity technical potential is about 2/3 of the total. The implementation of coal to electricity has significant comprehensive benefits, such as energy saving, improving energy utilization safety levels and other. The case study shows the rationality of the proposed approach.

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