Research on the Influencing Mechanism and Modeling Method of Supply Side Reform on Power Supply

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Abstract. Electric power industry is an important pillar of national economic development, so it is of great significance to study and explore the sustainable development of electric power industry. Firstly, this paper analyses the influence mechanism of capacity removal, leverage removal, shortage compensation and cost reduction on power supply in supply-side reform. Secondly, from the perspective of policy, cost and environment, this paper establishes the model of power supply prediction included in supply-side reform. Finally, the problem is solved by LEAP software, and deeply analysed the influence of supply-side reform on power supply. The results show that the installed capacity of China's total power generation will grow at a low speed in the future, the proportion of clean energy generation will continue to increase, and the growth rate of power generation is higher than that of fossil energy, which is conducive to reducing carbon dioxide emissions, improving environmental quality and achieving the goal of green and sustainable energy development.

1. Introduction
The electric power industry is the lifeblood of the national economy and plays a fundamental role in the economic and social development. It has the important characteristics of long industrial chain, wide coverage, capital-intensive and technology-intensive, and is an important support for the realization of national energy transformation and upgrading [1]. The structural reform of supply side in power industry is an industry operation mechanism with clean and efficient development of power supply, optimization and upgrading of power grid, market-oriented trading and flexible and reasonable price by means of eliminating production capacity, optimizing stock, reducing cost and making up for shortcomings under the general idea of promoting structural reform of supply side in China [2]. Deeply promoting the structural reform of the supply side of the power industry is an urgent requirement for serving the overall situation of the structural reform of the supply side in China, and an important way to realize the healthy and sustainable development of the power industry [3].

The main ideas of pushing forward the structural reform of power supply side include: Resolving and preventing overcapacity and reducing ineffective low-end supply. Implementing major strategic projects to promote the structural adjustment of power supply. Striving to make up for the shortcomings of supply and improving the ability of coordinated development. Innovating production and consumption modes and fostering the momentum of innovation and development [4]. Based on these, the key tasks of promoting the structural reform of power supply side are as follows:
(1) Resolving the excess capacity of coal industry;
(2) Resolving the excess capacity of coal and electricity;
(3) Focusing on solving the problems of water abandonment, wind abandonment and solar energy abandonment;
(4) Accelerating the transformation of electricity to the ground, strengthening the poverty alleviation of electricity, and improving the overall operation efficiency of power system.

The structural reform of power supply side has a far-reaching impact on China’s medium and long-term power supply situation. Firstly, this paper studies the influence mechanism of the structural reform of power supply side on power supply. Secondly studies the method and model improvement strategy of incorporating power supply side reform into power supply forecasting. Finally, based on the above analysis, a power supply forecasting model is established, and the forecasting results of installed capacity, generation capacity and carbon emissions in China in the medium and long term are obtained.

2. Influencing Mechanism of Power Supply Side Structural Reform on Power Supply

In the reform of power supply side, there is no de-inventory problem because the characteristics of power production are immediate use and no inventory; even if there is energy storage, it is stored for use and there is no backlog of products. The other four tasks of capacity removal, leverage removal, cost reduction and shortcomings compensation should be properly handled according to the characteristics of the power industry.

![The influence mechanism of power supply side reform on power supply and power grid](Figure1)

In the reform of power supply side, the capacity removal is mainly aimed at coal-fired power units. Relevant measures include: eliminating backward coal-fired power units, cleaning up and rectifying illegal construction projects, issuing and implementing annual risk warning, strictly controlling new coal-fired power production capacity, advancing emergency work of coal-fired power as needed, coordinating energy-saving and environmental protection renovation, and further improving coordination mechanism. The measures mentioned above include reducing new coal-fired generating units, increasing decommissioned coal-fired generating units, making full use of existing generating units, improving equipment utilization ratio, and steadily increasing utilization hours of power generation equipment.
The core task of deleveraging in the reform of power supply side is to reduce the ratio of assets to liabilities. To promote deleveraging, on the one hand, reducing investment in power grid (which accounts for more than 90% of investment in power grid enterprises) can reduce liabilities by reducing investment in power grid, which will lead to a decline in the growth rate of new installed machines and a slowdown in the pace of power grid construction; on the other hand, enterprises can tap profit growth points by exploiting new business to improve risk resistance.

The cost reduction in the reform of power supply side is to reduce electricity price, and to develop new energy sources. With the vigorous promotion of the national tax reduction and fee reduction policy, the electricity price of general industry and commerce has been lowered for two consecutive years to reduce the cost of electricity consumption of enterprises. This measure will stimulate the demand for electricity of general industry and commerce, and then promote the growth of electricity generation. In addition, the new energy maintains a relatively rapid development trend, with the continuous progress of related technologies, the construction cost of new energy and the cost of power generation are declining, which will be conducive to the rapid growth of new energy installations and power generation, and restrict the growth of coal-fired installations and power generation.

In the reform of power supply side, the compensating board mainly includes three aspects: ultra-low emission and energy-saving transformation of coal-fired power units, technological progress of new energy sources, and compensating board of power grid infrastructure. In the aspect of ultra-low emission and energy-saving renovation of coal-fired power units, environmental protection supervision has become increasingly stringent in recent years, and coal-fired boilers will implement higher emission standards, and coal-fired power plants with large pollution will be shut down one after another, and ultra-low emission and energy-saving renovation of coal-fired units will be accelerated, which will restrain the growth of coal-fired power loaders and power generation, and increase the utilization hours of coal-fired power equipment. In the field of new energy technology, the capacity of wind turbines continues to increase, and the technology of low-speed wind turbines, crystalline silicon batteries and thin film batteries develop rapidly, which will improve the efficiency of new energy generation, reduce the cost of new energy construction and operation, and significantly improve the competitive advantage of new energy. In terms of grid infrastructure, cross-provincial and cross-regional transmission is accelerating, the main grid structure of provincial power grids is continuously optimized and improved, a number of extra-high voltage (EHV) transmission projects are promoted, and a new round of rural power grid renovation and upgrading projects are speeded up. This will expand investment in power grids, and speed up the construction of lines, substation capacity and supporting power sources.

3. Method and Model Improvement Strategy of Incorporating Power Supply Side Reform into Power Supply Forecasting

In the previous paper, the influence mechanism of de-productivity, de-leverage, make-up board and cost reduction on power supply in supply-side reform is introduced. The final forecasting results of the power supply model include various indicators such as installed capacity, generation capacity and utilization hours. How supply-side reform affects these indicators needs to be further clarified. For this reason, this section studies the specific impact of supply-side reform from three aspects of policy, cost and environmental constraints, and studies the methods and model improvement strategies for incorporating power supply forecasting.

![Figure 2](image-url)
Firstly, from the policy point of view, affected by a series of policies, such as strict control of the scale of coal-fired power plants, resolving the backward capacity of coal-fired power plants and reducing emissions, new coal-fired power plants will be controlled, and high-emission coal-fired power plants will be quickly cleaned out. Because the government of China adheres to the policy of safe and efficient development of nuclear power, nuclear power plants will also be greatly affected by the policy, but with the low cost of nuclear power generation and high utilization hours of power generation equipment, it is conducive to cost reduction promotion, so it has advantages in various types of power generation installed. In the near future, the energy and nuclear power policy has been gradually improved, and the Nuclear Safety Law of the People's Republic of China has been speeded up. It is expected that nuclear power will also usher in a new stage of development. In the model, combined with recent policy constraints, the installed capacity of coal-fired power can be given exogenously. For example, the installed capacity of coal-fired power can be controlled within 11 billion kilowatt in 2020, no new coal-fired power will be built in the central and eastern regions after 2022.

Secondly, from the cost point of view, with the rapid development of new energy power generation technology in recent years, the corresponding construction and power generation costs are also significantly reduced; however, influenced by policy, coal price and other factors, the cost of construction and power generation has increased; other types of power generation installed costs have little change. Taking new energy as an example, in recent years, the price and investment cost of wind turbines have been declining, and the cost of photovoltaic power generation projects and electricity consumption have been significantly reduced. It is expected that the price of follow-up wind turbines will decrease in a limited space and remain stable basically. The cost of photovoltaic investment will continue to decline rapidly, and will be reduced to about ¥5.2 per kilowatt by 2020. In summary, by setting up the current situation and future development trend of various varieties' cost in the model, and taking the minimum construction cost and operation cost as the optimization objective, the forecast results of the installed capacity scale of different varieties can be obtained.

Finally, from the perspective of environmental constraints, thermal power development will be affected by carbon emission limits. In recent years, the gradual establishment of domestic carbon emission trading market, especially the carbon emission trading market construction plan issued by the National Development and Reform Commission of China, which will promote the carbon emission constraints of power generation enterprises, and power generation enterprises will become the major greenhouse gas emitters in China. The fierce competition in the electricity market brings new opportunities and challenges for coal-fired enterprises to improve their profitability under the constraint of carbon emissions. In the future, the cost of carbon emissions will increase rapidly, from ¥20 per ton in 2020 to ¥200 per ton in 2050. Carbon emissions should be fully considered in the model, and the cost of carbon emissions should be taken into account in the whole society. The installed capacity and power generation of different types should be optimized together with the construction and operation costs.

4. Construction of Power Supply Forecasting Model for Supply-side Reform

The frame diagram of power supply forecasting model is shown in the figure 3. The objective function is to minimize the cost of the whole society, which includes construction cost, operation cost and environmental cost; the constraints of forecasting include the constraints related to coal-fired power installation (such as coal-fired power installation planning value), the constraints of new energy output (fully considering the randomness and volatility of wind power and photovoltaic output), and the constraints of electricity balance/system backup; The exogenous variable is the whole society's electricity consumption, that is, the forecast result of Chapter 5. In this paper, LEAP software is used to solve the problem. Finally, the forecasting results of various types of installed units, power generation, utilization hours and so on can be obtained [5,6].
In order to simulate and analyse the power supply situation under the supply side structural reform and benchmark situation, this paper uses LEAP software to model. The model is divided into three modules: primary energy module, processing conversion module and terminal demand module. Among them, primary energy module includes wind power, solar energy, hydropower, nuclear power, biomass, coal, crude oil, natural gas. The energy processing and conversion module includes power generation, coking, oil refining, heating and power transmission loss. The terminal demand module is electricity demand, which is exogenously given according to the forecasting results.

Considering the energy policy orientation, climate and environment constraints, environmental protection technology development, power generation technology progress, new energy development, energy supply structure optimization and other factors, combined with the results of power demand forecasting, the following boundary conditions are set for power supply forecasting: China accelerates the elimination of backward coal and electricity production capacity, vigorously supports the development of renewable energy, and promotes the energy structure to be clean and low carbon. With the transformation, the development of new energy is faster than the benchmark scenario, and the cost of new energy generation is lower than the benchmark scenario. Before 2035, major breakthroughs will be made in energy development technologies such as wind power, solar power, renewable energy generation technology, clean coal power generation technology and so on. In 2050, the installed cost of wind power and photovoltaic power will drop to ¥3000 per kilowatt and ¥1900 per kilowatt. The accelerated progress of energy storage technology and the significant reduction of cost provide strong support for peak shaving of power system and new energy absorption. In 2020, the cost of renewable energy power generation is comparable to that of fossil fuel power generation. In 2025, the cost of renewable energy power generation is lower than that of fossil fuel power generation.

5. Power supply forecasting results adapted to supply-side reform
The installed capacity of power generation is growing at a low speed, and the proportion of installed clean energy power generation continues to increase. From 2018 to 2050, the installed power generation of china increased by 2.1 times from 1.9 billion kW to 5.95 billion kW, with an average annual growth rate of 3.6%. Among them, the installed capacity of fossil energy (coal and gas) power generation decreased from 1.09 billion kilowatts to 920 million kilowatts, with an average annual decline of 0.5%. The installed capacity of clean energy power generation increased from 810 million kilowatts to 5.03 billion kilowatts, with an average annual growth rate of 5.9%. In 2020, 2035 and 2050, the proportion of installed clean energy power generation capacity to total installed capacity was 53.9%, 73.8% and 84.5%, respectively.

The growth rate of clean energy power generation is higher than that of fossil energy, and its proportion in total power generation has steadily increased. From 2018 to 2050, the electricity generation of China increased by 2.4 times from 700 million kWh to 14.8 trillion kWh, with an average annual
growth rate of 2.4%. Among them, fossil energy (coal and gas) power generation decreased from 4.7 trillion kWh to 2.5 trillion kWh, with an average annual decline of 2.0%. The clean energy power generation increased from 2.3 trillion kWh to 12.3 trillion kWh, with an average annual growth rate of 5.4%. In 2020, 2035 and 2050, the proportion of clean energy power generation to total power generation was 53.2%, 72.6% and 83.2%, respectively.

Carbon dioxide emissions from energy combustion will decline rapidly after peaking, which will help to achieve the goal of self-emission reduction of China. Carbon dioxide emissions from energy combustion will peak at about 10.76 billion tons in 2027 in China, an increase of 1.27 billion tons over 2016. After peaking, carbon dioxide emissions declined rapidly. It is estimated that emissions in 2035 and 2050 will be 102.6 and 8.15 billion tons respectively, which are 50 million tons and 2.61 billion tons less than in 2027. It is estimated that the carbon dioxide emissions per unit GDP of China will be 12 tons in 2020, 46.8% lower than in 2005; the carbon dioxide emissions per unit GDP will be 0.7 tons in 2030, 67.8% lower than in 2005; and 0.27 tons in 2050, 88.4% lower than in 2005.

6. Conclusion
This paper mainly analyses the influence mechanism of de-productivity, de-leverage, shortening board, and cost reduction of supply-side on power supply and establishes a supply-side model incorporating into power supply forecasting, and sets scenario prediction parameters, such as installed capacity, power generation and carbon emissions. Through the analysis of the prediction results, the following main conclusions can be drawn:

- On the capacity of electric power installation. By 2050, the total installed capacity of China of power generation will grow at a low speed, with an average annual growth rate of 3.64%. Among them, the installed capacity of clean energy power generation increased significantly, with an average annual growth rate of 5.9%, while the installed capacity of fossil energy power generation decreased, with an average annual decline of 0.5%.

- In terms of electricity generation. The proportion of clean energy power generation increased steadily, with an average annual growth rate of 5.4%, while fossil energy power generation decreased significantly, with an average annual decline of 2.0%. It is expected that by 2050, clean energy will account for 83.2% of the total electricity generation in China.

- In terms of carbon emissions. Carbon dioxide emissions of China from energy combustion are expected to peak in 2023, at about 9.87 billion tons. In 2020, 2030 and 2050, China's carbon dioxide emissions per unit GDP will be 12, 0.7 and 0.2 tons, respectively. China's carbon dioxide emission peak time and intensity can achieve the goal of self-emission reduction, which will effectively improve the environmental quality.

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