Research on Electricity Supply Forecasting Model and Application of China Adapting to Supply-Side Structural Reform

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Abstract. Since 2012, China's economy has entered a new normal of declining potential growth rate, mainly due to insufficient effective supply, structural imbalance and mismatch between supply and demand. In order to solve the structural problems of China's economic development, since 2015, the government has made major theoretical innovations and decision-making arrangements for supply-side structural reform. Electric power industry is the key area and important support of supply-side structural reform. In order to simulate and forecast the electric power supply situation under the structural reform of supply side, this paper uses Long-range Energy Alternatives Planning (LEAP) model to construct the energy processing conversion module, and optimizes the power generation module based on the principle of minimum cost. In this model, power generation capacity, electricity generation and carbon emission is calculated under both basic and active supply side structural reform scenarios. Under the active supply side structural reform scenario, the results show that China's power generation capacity and electricity generation will reach 5949 GW and 16.1 billion MWh in 2050 respectively, and the proportion of clean energy for both power generation capacity and electricity generation increased significantly. China's carbon dioxide emissions from energy combustion will peak in 2023, with a peak of about 9.87 billion tons.

1. Introduction
Since 2012, China's economy has entered a new normal of declining potential growth rate [1]. On the surface, the deceleration of economic growth is due to insufficient effective demand, but it actually reflects the insufficiency of motive force of China's economic growth [2]. At present, there are periodic problems in China's economic development, but structural problems are the most prominent [3]. The main aspect of contradiction is on the supply side. That is to say, the deep crux of China's economic downturn lies in insufficient effective supply and unbalanced structure [4, 5]. Therefore, we should pay attention to the quality of economic growth, and achieve a high level of supply and demand balance as the main direction. Since 2015, the central government has estimated the new normal of China's economy, comprehensively judged the current world economic situation, and made decision-making arrangements for supply-side structural reform [6].

The macro-level structural reform of supply side, mainly focuses on the optimal allocation of supply factors such as natural resources, labour force, capital and technology [7]. As an important basic industrial product and means of production, electricity power development is the key area and important support of supply-side structural reform [8]. For one thing, power resources development, processing, transformation, distribution and terminal sales need the support of resources, funds, manpower,
technology and other elements, which is an important part of the economic supply system itself. For another thing, Electric power is not only an indispensable factor of production and intermediate input for the development of various industries, but an irreplaceable daily consumption of urban and rural residents.

However, the power supply has not kept pace with the demand. The prominent contradiction is the coexistence of "structural excess" and "structural insufficiency", which are mainly manifested in supply capacity, industry management, service products and so on. The structural reform of power supply side is to realize the leap from low-level supply-demand to high-level supply-demand, from the perspective of improving the quality and efficiency of power supply [9].

In order to simulate and analyse the electric power supply under the structural reform of supply side, this paper uses Long-range Energy Alternatives Planning (LEAP) model to construct energy processing conversion module, including power generation, coking, oil refining and heating [10,11]. Power generation capacity, electricity generation and carbon dioxide emission are optimized under the means of cost optimization in both basic and active supply side structural reform scenarios.

2. Main influence factors
This section introduces main factors such as electricity demand and power system cost, which influence electricity supply.

2.1. Electricity demand
At present, China's electricity demand growth has changed a lot. Firstly, the growth rate has slowed down, and will maintain stable growth at medium speed in the future. Secondly, the proportion of the secondary industry in the total social electricity consumption will accelerate to decline, and the proportion of the tertiary industry and residential electricity consumption will continue to increase. Thirdly, traditional high-energy-consuming industries have weakened the pulling role of electricity consumption growth, while equipment manufacturing industry has increased the pulling role of electricity consumption growth. Fourthly, the demand of traditional electricity load areas in the central and eastern regions has maintained rapid growth, while the western region has maintained high-speed growth. Fifthly, the users' personalized and flexible demands for power quality and service have been constantly improved.

In the future, the total electricity demand will continue to grow, and the growth rate will gradually slow down. Around 2035, the electricity demand will enter the growth saturation stage. With the large-scale development of clean power and the progress of electricity technology, the competitiveness of electric energy in terminal energy consumption has increased significantly, which promotes the sustained growth of power demand. The total demand of electric power in 2050 is expected to reach 14.1 billion to 15.3 billion MWh.

2.2. Power system cost
In the future, the cost of power system in China will rise first and then decrease. Before 2030, electricity demand has maintained a relatively rapid growth. As new energy generation technology is still in the development stage, energy transformation needs to pay a certain economic cost, and the cost of power system continues to rise. From 2030 to 2050, the growth of electricity demand has gradually become saturated, the installed cost of new energy generation has dropped to a lower level, and its marginal cost of operation has tended to zero. With the gradual increase of the proportion of new energy in the system, the system construction and operation costs will enter a downward period. At this stage, the low-carbon objectives of energy development and economic objectives will gradually coincide, and the energy transformation will be based on market self-selection. If the external cost of carbon emissions is internalized, the cost of power system in 2050 will be approximately equal to the current level. However, if the cost of carbon emissions is not considered, the cost of power system in 2050 will be slightly lower than the current level.
3. Model and scenarios
This section introduces the LEAP model as the method to forecast electricity supply in China. The results are calculated in both basic and active supply side structural reform scenarios.

3.1. Model
LEAP model is an econometric model developed by Stockholm Institute of Environment in Sweden and Tellus Institute in Boston. LEAP is specially designed for mid-long term energy planning, and has been applied in energy, transportation, and environment. The structure of the model is the bottom-up. Through the three processes named "resources", "transformation" and "demand", the complete process of energy development to meet demand is realized. Among them, "resources" include the development of primary and secondary energy. "Conversion" includes the processing, utilization, transportation, storage and other intermediate links of primary and secondary energy. "Demand" is the demand of all sectors of society for total energy.

In order to predict the mid-long term electric power supply in China, this paper uses LEAP model to build energy processing conversion module, including power generation, coking, oil refining, heating and other links. The main input variables in the energy processing conversion module include dispatch rule, process efficiency, capacity, maximum availability, capital cost, fixed operation and maintenance (OM) cost, variable OM cost and system energy load shape.

3.2. Scenarios
The next 30 years will be a critical period for China to promote the energy production and consumption revolution. It can be predicted that new energy and smart grid will develop rapidly, which will lead to significant changes in China's energy production and utilization mode. Considering energy policy, environment constraints, power generation technology progress, energy supply structure optimization and other factors, combined with both basic and active supply side structural reform scenarios, the following power supply boundary conditions are set up.

Basic supply side structural reform scenario (Basic-SSR): In order to achieve the goal of reducing carbon dioxide emission intensity by 60%-65% in 2030 compared with 2005, it is necessary to optimize the power supply structure and reduce coal-fired power installation. With the development of technology, the cost of installing new energy power generation is decreasing. China's electricity demand will reach 14.1 billion MWh in 2050, and the average growth rate will be 2.3% in 2016-2050. In 2025, the cost of renewable energy power generation is comparable to that of fossil fuel power generation. In 2035, the cost of renewable energy power generation is lower than that of fossil fuel power generation. In 2050, the cost of wind and solar power generation dropped to 3600 yuan/kW and 2300 yuan/kW respectively.
Active supply side structural reform scenario (Active-SSR): Compared with basic supply side structural reform scenario, the development of new energy is faster, and the cost of new energy generation is lower. China will accelerate the elimination of backward coal-fired power generation capacity. Renewable energy generation technology will make important breakthroughs, and the progress of energy storage technology will be accelerated. China's electricity demand will reach 15.3 billion MWh in 2050, and the average growth rate will be 2.6% in 2018-2050. In 2020, the cost of renewable energy power generation is equivalent 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. In 2050, the cost of wind power and solar power generation is reduced to 3000 and 1900 yuan per kilowatt respectively.

4. Electricity supply forecast
This section forecasts China's power generation capacity, electricity generation and carbon emission in the above two scenarios.

4.1. Power generation capacity
China's power generation capacity will grow steadily and the growth rate will gradually slow down. In the basic supply side structural reform scenario, China's power generation capacity will reach 5240 GW in 2050, and the average growth rate will be 3.0% in 2016-2050. During this period, the power generation capacity in 2020 and 2035 will be 2403 GW and 4120 GW. In the active supply side structural reform scenario, China's power generation capacity will reach 5949 GW in 2050, 709 GW higher than the basic scenario, and the average growth rate will be 3.4% in 2016-2050, 0.4 percentage points higher than the basic scenario. During this period, the electricity demand will be 2534 GW and 4678 GW respectively in 2020 and 2035.

![Power generation capacity of China, 2016-2050](image)

Figure 2. Power generation capacity of China, 2016-2050.

The proportion of power generation capacity with fossil energy will keep declining, but power generation capacity with clean energy will grow rapidly.

In the basic supply side structural reform scenario, China's power generation capacity with fossil energy drops to 915 GW in 2050, and the average growth rate is -0.5% during 2016-2050. In 2020, 2035 and 2050, the proportion of power generation capacity with fossil energy will be 48.1%, 29.9% and 17.5%, respectively. However, the clean energy installations are growing rapidly. The power generation capacity of clean energy increases to 4325 GW in 2050, and the average growth rate is 12.4% during 2016-2050. In 2020, 2035 and 2050, the proportion of power generation capacity with clean energy will be 51.9%, 70.1% and 82.5%, respectively.

In the active supply-side structural reform scenario, the power generation capacity of fossil energy will be 919 GW in 2050, and the average growth rate is -0.5% during 2016-2050. In 2020, 2035 and 2050, the proportion of power generation capacity with fossil energy will be 46.1%, 26.2% and 15.5% respectively, which is lower than the basic scenario. The power generation capacity of clean energy increases to 5030 GW in 2050, and the average growth rate is 12.9% during 2016-2050. In 2020, 2035
and 2050, the proportion of power generation capacity with clean energy will be 53.9%, 73.8% and 84.5%, which is higher than the basic scenario.

**Table 1.** The structure of power generation capacity in Basic-SSR, 2016~2050.

| Year | Coal | Nature gas | Nuclear | Hydropower | Wind | Solar | Biomass and the others |
|------|------|------------|---------|------------|------|-------|------------------------|
| 2016 | 1006 | 83         | 45      | 352        | 184  | 175   | 55                     |
| 2020 | 1052 | 103        | 75      | 397        | 332  | 344   | 110                    |
| 2035 | 1054 | 177        | 188     | 565        | 886  | 933   | 318                    |
| 2050 | 754  | 161        | 247     | 618        | 1261 | 1767  | 433                    |
| Growth rate (2016-2050) | -0.8% | 2.0% | 5.2% | 1.7% | 5.8% | 7.0% | 6.3% |

**Table 2.** The structure of power generation capacity in Active-SSR, 2016~2050.

| Year | Coal | Nature gas | Nuclear | Hydropower | Wind | Solar | Biomass and the others |
|------|------|------------|---------|------------|------|-------|------------------------|
| 2016 | 1006 | 83         | 45      | 352        | 184  | 175   | 55                     |
| 2020 | 1056 | 111        | 84      | 413        | 372  | 376   | 122                    |
| 2035 | 1009 | 215        | 233     | 642        | 1076 | 1129  | 375                    |
| 2050 | 737  | 182        | 281     | 702        | 1491 | 2066  | 491                    |
| Growth rate (2016-2050) | -0.9% | 2.3% | 5.6% | 2.0% | 6.3% | 7.5% | 6.7% |

4.2. **Electricity generation**

China's electricity generation will grow steadily and the growth rate will gradually slow down. In the basic supply side structural reform scenario, China's electricity generation will reach 14.8 billion MWh in 2050, and the average growth rate will be 2.6% in 2016-2050. In the active supply side structural reform scenario, China's electricity generation will reach 16.1 billion MWh in 2050, 1.3 billion MWh higher than the basic scenario, and the average growth rate will be 2.5% in 2016-2050, 0.2 percentage points higher than the basic scenario.

The proportion of fossil energy power generation declined, while the proportion of clean energy power generation increased. Under the basic supply side structural reform scenario, in 2020, 2035 and 2050, fossil energy generation accounted for 50.5%, 33.9% and 21.1% of total power generation, while clean energy generation accounted for 49.5%, 66.1% and 78.9%, respectively. In the active supply side structural reform scenario, the proportion of clean energy power generation increased faster, 53.9%, 73.8% and 84.5% respectively in 2020, 2035 and 2050.

**Figure 3.** Proportion of electricity generation, 2050.

4.3. **Carbon emission**
The peak time of carbon dioxide emission from energy combustion in China can achieve the goal of self-emission reduction ahead of time. China proposes that carbon dioxide emissions would peak around 2030. In the basic supply side structural reform scenario, China's carbon dioxide emissions from energy combustion will peak in 2027, with a peak of about 10.76 billion tons. After peaking, emissions in 2035 and 2050 were 10.26 and 8.15 billion tons respectively. In the active supply side structural reform scenario, China's carbon dioxide emissions from energy combustion will peak in 2023, four years ahead of the basic scenario, with a peak of about 9.87 billion tons, down 0.89 billion tons from the basic scenario. After peaking, carbon dioxide emissions declined rapidly, with emissions of 8.67 billion tons in 2035 and 6.35 billion tons in 2050, respectively.

The reduction of carbon emission intensity is expected to achieve the goal of self-emission reduction. China proposes that the intensity of carbon dioxide emissions in 2030 will decrease by 60%-65% compared with 2005. In the basic supply side structural reform scenario, China's carbon dioxide emissions per unit GDP in 2020, 2030 and 2050 were 122, 74 and 27 tons per million yuan, respectively, 46.8%, 67.8% and 88.4% lower than that in 2005. In the active supply side structural reform scenario, China's carbon dioxide emissions per unit GDP in 2020, 2030 and 2050 were 119, 68 and 25 tons per million yuan, respectively, 48.3%, 70.2% and 89.3% lower than that in 2005.

5. Conclusion
Supply-side structural reform, as an important main line of China's future economic transformation, will have profound impacts on economic growth rate and industrial structure, thus driving steady growth in power demand. It is estimated that China's power generation capacity and electricity generation will reach 5949 GW and 16.1 billion MWh in 2050 respectively, and the proportion of clean energy for both power generation capacity and electricity generation increased significantly. The peak time of carbon dioxide emission from energy combustion in China can achieve the goal of self-emission reduction ahead of time. China's carbon dioxide emissions from energy combustion will peak in 2023, with a peak of about 9.87 billion tons.

Acknowledgments
This work is supported by the Science and Technology Project of State Grid Corporation of China (Research on the method, model and application of economy and electricity demand forecasting based on supply-side reform).

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