Research on evaluation method of economic and social benefits of China’s power planning

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Abstract. The evaluation of economic and social benefits is the core content during the power planning. The study firstly analysis the characteristics of energy and power planning system, and describes in detail the impact path of large-scale development of new energy and adjustment of power distribution on economy and society. Secondly, we construct the hybrid model through coupling energy technology model and energy economy model, which embodies the characteristics of China's economic transition and energy transformation. At last, based on scenario analysis method, we carry out quantitative comparative analysis of different planning schemes. The results show that large-scale development of renewable energy can promote economic growth, optimize the industrial structure in receiving regions, promote the advantage of resource in sending region into economic advantage, create new jobs and raise the level of the local per capita income.

1. Introduction

With the transformation of economy and energy development, the main purpose of energy planning is now different from traditional planning in China. Therefore, the content and dimensions of the evaluation power planning have also changed accordingly. To implement the energy strategy and promote the green transformation of energy structure, the new feature of China's power planning in the 13th Five-Year Plan is to accelerate the large-scale development and utilization of renewable energy sources. The development of renewable energy has the complex influence on energy, environment, economy and society, and it is difficult to evaluate the benefits in a single field. It is an urgent problem to be solved on how to focus on the development of large-scale renewable energy and evaluation the economic and social benefits of power planning.

Power planning involves energy systems, economy-social systems and ecological environment systems, the evaluation of which belongs to the category of energy-economy-environment (3E) comprehensive evaluation [1,2,3]. At present, the approach of 3E models mainly include bottom-up, top-down and hybrid models. The top-down model is mainly based on economic models, including computable general equilibrium model, input-output analysis model and macroscopic econometric model, etc. The bottom-up model is mainly energy system analysis model [4,5]. Hybrid model incorporates both bottom-up and top-down modelling approaches, which links energy system and macro-economic systems and broadens the scope of research [6,7].

Based on the theory of system engineering, this research integrates energy-technology model and energy-economy model, and constructs the benefit evaluation model for power planning. Based on
scenario analysis method, the benefits of power planning scenarios in the 13th Five-Year Plan are compared.

2. Analysis of energy and power planning in China
Energy and power planning in different periods in China has its own characteristics. The 11th Five-Year Plan aims to optimize development of energy industry, and build a stable, economical, clean and safe energy supply system. The 12th Five-Year plan aims to promote the transformation of energy production and utilization, and build a safe, stable, economical and clean modern energy industry system. The key issue for energy planning in this period is to ensure a secure, stable and economical energy supply. Unlike the previous plans, the main contradiction in China is no longer to guarantee energy supply, but to find the balance point among the clean, safe and efficient development. The focus of the 13th Five-Year Plan for Energy shift from ensuring supply to increasing efficiency [8,9]. The low-carbon transformation of energy supply should become the new major goal.

The 13th Five-Year Plan for energy covers production, consumption, technology and energy system mechanisms. It covers all types of power sources and transmission and distribution networks, including hydropower, nuclear power, coal power, gas power, wind power and solar power. With the changes of international and domestic environment, the 13th Five-Year Plan for Energy is paying more attention to the quality of development, structural adjustment, system optimization, market laws, and mechanism innovation.

3. Benefit evaluation methods for power planning

3.1 Framework
Considering the complementary relationship between the energy model and the macro-economic model, the study connects two models and analyzes the influence of different energy development path on regional economy, industrial sector and energy system. Based on the system engineering, the research constructs a comprehensive evaluation model system for energy and power planning, taking TIMES model, which is a multi-region energy system optimization model, and multi-region energy-economy-environment computable general equilibrium (CGE) model as the core.

![Figure 1. Benefits evaluation model framework for power planning](image)

3.2 Mechanism and function
The system of economic and social benefit evaluation for power planning is as follow. The macro-economic benchmark scenario is derived from the multi-region dynamic energy-economy-environment computable general equilibrium (CGE) model, and the demand of energy service are derived by inputting the parameters such as population, GDP and industrial structure into the forecast model, which is an exogenous driving variable for the multi-regional energy system optimization...
(TIMES) model. As the result of the energy system optimization model, the final energy demand, the total amount, the structure and the layout of the primary energy supply are obtained, and the CO2 and SO2 emissions from production and utilization of energy are derived by the coupled environment module. The research considers the influence of energy supply-side structural reforms and energy revolution, sets up different energy development scenarios, applies CGE model to analyze the influence of different energy development schemes on regional economy, and makes recommendations based on the comprehensive comparison between the energy systems and the economic systems.

Figure 2. Basic application steps of the benefit evaluation model for power planning

3.3 Characteristics
(1) In terms of hypothetical conditions, account division and macroscopic closure, the CGE model in the study has taken into account the transformation measures of economy and energy.

In recent years, China has faced with the shortage of labor and it has been a consensus that the population dividend will soon disappear. Therefore, the macroscopic closure principle of Keynes is adopted in the study [10, 11]. With the assumption of factor market clearing, the model also sets the total supply of labor and capital as exogenous, and that both can flow freely between sectors. The model sets infrastructure investment as exogenous variables and simulates the shock of grid construction and clean energy investment.

At present, the upgrading of industrial structure, the increase of labor compensation ratio and the improvement of resource utilization efficiency are the important indexes to measure the development mode of economy transformation. The sectors of renewable energy generation, thermal Power and other energy generation are set as the separate accounts in order to observe resource utilization indicators.

(2) The study integrates environmental factors and energy resource factors into production function and utility function of the benefit evaluation model, which can be used to simulate the pollution rights trading, total energy consumption control and other related policy effects.

In this research, environmental pollution and energy consumption are taken as the independent factors, which are combined to production function and utility function, and we establish the quality equation of economic and environmental factors. Then Hamilton function is constructed to find the first order condition of each control variable [12, 13]. Euler equation of the stage variable is solved to find the growth rate of each variable under the steady growth condition, and finally the optimal growth rate of each element is obtained.

(3) The price module of evaluation model constructed in this study reflects the policy control economy of non-competitive commodities such as electricity.
This study mainly links different economic entities and industrial sectors by relationships of the various prices, which include sales prices, cost prices and tax rates of various products. Unit costs of sectoral products are expressed by intermediate input costs which are the sum of input costs of production factors, as shown in Equation (1).

\[ PA_c = \sum (a_i \cdot PQ_c + (P_{EKc} + W \cdot L_c) / QA_c) \]  

(1)

Adding the production tax to the unit cost of a sector product is the basic price of the sector product, as shown in equation (2).

\[ PA_c = (1 + t^P_c) \cdot PA_c \]  

(2)

Assuming that CIF and FOB remain unchanged and import duties are taken into account without export duties, import prices and export prices may be expressed by equation (3) and (4) respectively.

\[ PM_c = PWM_c \cdot (1 + tm_c) \cdot \Phi \]  

(3)

\[ PE_c = PWE_c \cdot \Phi \]  

(4)

The price of goods in the electricity sector may be expressed in equation (5) and the final consumer price of electricity in equation (6).

\[ PX_c = (PDA_c \cdot QDA_c + PE_c \cdot QE_c) / QX_c \]  

(5)

\[ PQ_a = (PDC_a \cdot QDC_a + PM_a \cdot QM_a) / QQ_a \]  

(6)

\[ PA_c \] is the unit cost in the electricity sector, \( PA_c \) is the basic price of the electricity sector, \( t^P_c \) is the tax rate of production, \( PM_a \) is the price of imports, \( PWM_a \) is the international prices for imports, \( \Phi \) is the exchange rate, \( PE_c \) is the price of exports, \( PWE_c \) is the international prices for exports, \( PX_c \) is the production price of electricity sector, \( PQ_a \) is the final consumer price of the goods.

4. Quantitative analysis of power planning benefits

4.1 Scenarios design

Applying power system planning optimization model, the study mainly designs benchmark scenarios and policy scenario. The main differences between two scenarios are the development speed of renewable energy, the adjustment of the power layout and the scale of trans-regional transmission in the future.

In the benchmark scenario, the scale of wind power and photovoltaic power will reach 400 and 350 million kW by 2030. The layout of coal power is still dominated by regional balance. The potential of renewable energy in the east and central region is fully exploited, and the renewable energy distribution in the east and west is about 1:1. The national trans-regional power flow will be 400 million kW in 2030 and the flow from the northwest, northeast, north China, Sichuan-Chongqing-Tibet to East central region will reach 310 million kW. In the policy scenario, the scale of wind power and photovoltaic power will reach 470 and 420 million kW in 2030. The distribution of coal power will be gradually tilted from the east to the northwest and northeast. The renewable energy in the east and central China will be moderately developed to about 80 percent of the resource potential, which will be mainly distributed in the north and west region. The domestic trans-regional power flow will reach 460 million kW, and the flow from the northwest, northeast, north China, Sichuan-Chongqing-Tibet region to the east central region will reach 360 kW.
4.2 Results

4.2.1 Economical benefits

The simulation shows that the power investment will lead to annual GDP growth of about 0.4% during the 13th Five-Year Plan period. By region, due to the impact of fixed asset investment and a low base of total economic output, power investment will drive annual GDP growth of about 1.7 percentage points in North China and Northwest China. As the receiving area, the average annual GDP growth in the east central region is about 0.3% due to the large economic volume.

Figure 3. The effect of power investment on the annual GDP of different Regions from 2020 to 2015

In view of renewable energy, in the two scenarios the total investment of wind power and solar power during 2015-2030 will be about 5.0 and 6.1 trillion Yuan. The utilization of renewable energy will lead to an annual increase the output of 1.2 and 1.8 trillion Yuan, which is will contribute 0.15% to 0.21% of GDP.

The development of renewable energy will help to promote industrial upgrading and the optimization of the economic structure in China. It will have a significant pulling effect on upstream industries, especially the growth of industries in high technology and high value-added sectors, such as the electronic equipment manufacturing, precision instruments, research and development, and productive services, to achieve rapid development.

4.2.2 Social benefits

Considering the reform of power system, technology development and application, and the large-scale development of renewable energy, the price of electricity will gradually decline. The simulation shows that with development of policy and technology, if electricity price decreases by 5% in 2020, the consumer price index in 2020 will drop by 0.68%, welfare will increase by 0.19%. The consumer price index will fall by 1.6% in 2030 and the welfare will increase by 0.55%, when electricity price decreases by 10% in 2030.

Renewable energy investments in two scenarios in 2015-2030 can create direct and indirect employment for about 600 thousand per year. The impact of the large-scale renewable energy on the real per capita income is similar to that of GDP per capita, but varies in magnitude. The simulation shows that in the policy scenario, the actual per capita income of northwest area which is the sending region will increase by 4.9% compared to the benchmark scenario in the 2030. It is mainly because power investments promote local industries and labors shift from agriculture to industries. The real per capita income in east and central region will drop by 2.3% compared to benchmark scenario in 2030, because the development focus on tertiary industries after the adjustment of power layout. In other regions, as the sending region, real per capital income will increase, but the benefit will be much lower than the sending region.

5. Conclusions

Based on the theory of green accounting, the study expands the traditional concept of production factors, integrates environmental pollution and energy resources consumption into production function and utility function, which depicts the impact of environment and energy resources on economic
growth and residents' welfare. We adopt Keynesian macro closure principle to depict the gradual disappearance of China's population dividend and the inflection point of Lewis.

From the economic and social perspective, the adjustment of power layout and the development of renewable energy can promote the economic growth, optimize the industrial structure of the affected area, promote the resource advantage of the sending region into economic advantage, create new opportune of jobs and raise the level of the local per capita income. The large-scale development of renewable energy has great economic and social benefits. The main fields and development directions of China's energy and power planning in the future lie in strengthening the consumption of renewable energy, increasing the ability of cross-district consumption, and promoting the development of electrification.

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