The Research on the Benefit Evaluation Methodology of the Global Energy Internet and Case Analysis

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Abstract. This research focuses on the impact of Global Energy Internet(GEI) on the power system, energy environment, economy and society, and builds the comprehensive benefit assessment system of GEI. The benefit evaluation model system that realizes the quantitative assessment of the comprehensive benefits of GEI from the perspectives of economy, society, energy, and environment is constructed, which is based on global power planning and production simulation model, Global Trade Analysis project(GTAP) and Climate Change Assessment Model (MEGGIC). The results show that GEI is conducive to realize the complementary benefits of multiple energy sources across region, achieve a win-win between the main sending and receiving areas, promote the use of renewable energy resources, and help achieve the 2°C temperature control target.

1. Introduction
For the long time, fossil energy has supported the development of industrial civilization, but also brought about serious problems such as resource constraints, environmental pollution and climate change. Construct the GEI can provide new solutions to promote energy security, cleanliness, efficiency, and sustainable development. The GEI is the strong and smart grid with UHV power grids as the backbone network (channel), which will be led by clean energy transmission and global interconnection[1]. The construction and development of GEI will form a new energy development pattern for the interconnection of power grids in all countries and optimize the allocation of global power, which the renewable energy resources can be efficiently developed and utilized, fossil energy consumption and emissions of greenhouse gases can be reduced[2].

The construction of GEI will not only directly affect the development of the global power system in the future, but also have the profound impact on the economic and social development of all continents by reducing the cost of power supply and changing the infrastructure layout of power investment. As the import infrastructure, the investment of GEI is large, which has a long-term path-dependent effect.

For the benefit evaluation of GEI, the existing literature mainly focuses on strategic development directions, technical feasibility and economic analysis[3][4][5][6]. It is urgent to establish a comprehensive benefit assessment system of GEI from all kinds of perspectives, which can quantitatively analyze the benefits of developing the GEI, and provides a strategic evaluation tool for advancing the construction of the GEI.

2. The Benefit Identification and Evaluation Index System of GEI
From the perspective of the power system, the impact of GEI on the power system is mainly reflected in the two aspects of power transmission benefits and interconnection benefits. Among them, the power
transmission benefits mainly refer to the economic benefits brought by the reduction in the cost of power supply. The benefits of interconnection can be specifically divided into peak shift benefits, complementary benefits, and scale benefits. After the establishment of transcontinental and GEI, the capacity of renewable energy can be improved, which mutual backup of multiplicative energy can save the installation of fossil energy, increase equipment utilization, and improve the economics of the system, thereby bring benefits to the power system.

From the perspective of environmental benefits, the GEI has made greater use of Arctic wind resources and equatorial solar resources, increased the development and utilization of renewable energy, realized large-scale replacement of traditional fossil energy, increased the proportion of non-fossil energy power generation, and reduced consumption of water and land resources in the fossil energy mining, production and utilization. The use of large-scale renewable energy can greatly reduce the emissions of conventional pollutants such as SO2, NOx and fine particles, and reduce damage to human health; meanwhile, reduce greenhouse gas emissions, effectively slow global warming, and respond to climate change.

From the perspective of the economic and social system, the investment in the construction of transcontinental and GEI will drive the development of the industry, coupled with the increase of the system economy, it will bring down the cost of energy consumption, increase the return on investment, boost the productivity of the whole society, and further promote investment growth. , Thereby driving economic growth; at the same time, driving social employment and welfare growth.

Based on the above analysis of power system benefits, energy environmental benefits, and economic and social benefits brought about by the development of the GEI. Establish and complete a GEI benefit assessment index system.

3. Evaluation Model System Framework of GEI

The comprehensive benefit evaluation model system of GEI proposed in this study integrates the top-down Global trade analysis model, the bottom-up power planning and production simulation, the environmental climate change evaluation model and other tools, realizes the connection between the all kinds of models such as environment model, economy model, power planning model and so on, which expands the benefit evaluation of different models of power development Dimension and depth in the figure 1.
From the perspective of energy technology model, using the self-developed global power planning and production simulation model, aiming at the minimum total cost of system investment, considering the constraints of energy resources, policies and technical and economic characteristics of units in all continents, optimize the power supply construction and production plan; based on the scenario comparative analysis method, quantitatively study the power transmission benefits and networking brought by global energy interconnection benefits. It is worth noting that the global power planning and production simulation model provides boundary conditions such as investment cost, kilowatt hour cost and fossil energy consumption for the subsequent energy environment economic evaluation model. From the perspective of energy economic model, the traditional Global trade analysis model (GTAP) is improved, implicit cost parameters are introduced, the impact of intercontinental and global networking on power trade facilitation is depicted, and the impact of power investment and power supply cost changes on the economic and social development of each continent is simulated and analyzed, from regional economic growth, employment promotion, welfare index improvement and regional coordinated development and other aspects of the evaluation. At the same time, the dynamic global trade analysis model will also be a tool for global economic prediction. It will judge the boundary conditions such as power demand through economic prediction and feedback to energy technology models such as global power planning and production simulation.

From the perspective of the environmental climate assessment model, this paper uses the climate change assessment model to compare and analyze the impact of carbon dioxide emissions from the power sector on global temperature rise and sea level rise under the GEI and self-balancing scenarios, and analyze whether the 2 °C temperature rise target can be achieved. Based on the whole life cycle method, this paper compares and analyzes the consumption of various energy resources of different power generation technologies, establishes a GEI environment assessment model, and evaluates the impact of different development paths of global power on the environment from the perspectives of water resources, land resources and various pollutants.

4. Scenario design and quantitative analysis

4.1. Scenario design

Based on the independently developed global power planning model, optimize the power installation and structure, power flow scale and flow direction under the self-balancing scenario and the global networking scenario, and provide the analysis basis for quantitative evaluation of the GEI benefits.

4.1.1. Power installation and structure

Under the situation of self-balanced development, fossil energy power sources in all continents are gradually declining, and the power supply structure presents a diversified and balanced development trend. The installed capacity of fossil energy power sources in all continents is gradually decreasing and the growth rate is slowing down, especially coal-fired power units. In 2050, the power structure of each continent presents diversified characteristics, and the global power development scale will increase to 17.8 billion kilowatts. Among them, the total scale of fossil energy power generation such as coal power and gas power will be 4.6 billion kilowatts, accounting for 26% from 59% in 2015; the scale of conventional non-fossil energy power generation such as nuclear power and hydro-power will be increased from 1.5 billion to 3.5 billion kilowatts, accounting for 20%; the installed scale of new energy power generation such as wind and light will be increased from 680 million to 9.7 billion kilowatts, accounting for the 54% of the global installation [7].

In the context of global networking, the scale of global power development will increase to 22.3 billion kilowatts in 2050, among which the total scale of fossil energy power generation such as coal power and gas power will decrease to about 2.7 billion kilowatts, accounting for 12% from 59% in 2015; the scale of conventional non-fossil energy power generation such as nuclear power and hydro-power will increase from 1.5 billion to 4.7 billion kilowatts, accounting for 21%; the installed scale of new energy power generation such as wind and light will increase from 680 million to 14.7 billion kilowatts,
accounting for 66% from 12%, as shown in Figure 3. In order to meet the same power demand, the total installed scale in the global networking scenario is significantly higher than the self-balanced scenario. This is mainly due to the higher proportion of wind and solar installations in the global networking scenario, and its equivalent capacity is lower than that of conventional power sources.

4.1.2. Power generation and structure
Under the self-balancing scenario, in 2050, the global fossil energy power generation capacity such as coal power and gas power is about 20.9 trillion kWh, accounting for 37% of the total global power generation capacity; the conventional non-fossil energy power generation capacity such as nuclear power and hydro-power is about 16.9 trillion kWh, accounting for 30%; the new energy power generation capacity such as wind and light is about 19.3 trillion kWh, accounting for 34%. Compared with the self-balancing scenario, under the global networking scenario, coal and gas power generation decreased, wind and solar power generation increased, while hydro-power and nuclear power generation were mainly limited by resources and policy conditions. In 2050, the world's fossil energy power generation capacity, such as coal power and gas power, is about 5.8 trillion kWh, accounting for 10% of the world's total power generation capacity; the scale of conventional non-fossil energy power generation capacity, such as nuclear power and hydro-power, is about 22.6 trillion kWh, accounting for 39%; the new energy power generation capacity, such as wind and light, is about 23.8 trillion kWh, accounting for 41%, as shown in Figure 4.

4.1.3. Scale and direction of power flow
Under the global networking scenario, in 2050, the global channel capacity accounts for nearly 45% of the global power load, while the cross-continent exchange power accounts for 11% of the global power consumption[8]. In terms of the scale of cross continent interconnection and the scale of exchange electricity, the Arctic, as the region with the most abundant wind energy, has an obvious advantage in development and transmission. In 2050, the total electricity delivered by the Arctic to Europe, Asia and North America reached 3.0 trillion kWh, accounting for 6.5% of the electricity demand of the three continents[9]. Asia is rich in non-fossil energy resources. Although the scale of power consumption accounts for nearly 50% of the world's total, it has the potential to rely on itself to meet power demand; In addition to receiving a certain amount of wind power from the Arctic, Asia can achieve complementation of multiplicative energy between several regions by using time differences and seasonal differences with Africa, Europe and Oceania. Europe itself lacks power generation resources, so it needs to receive power from the Arctic, Africa and other places. South and North America are also rich in their own power generation energy resources. In addition to North America receiving a certain amount of wind power from the Arctic, South and North America will give priority to using local power generation energy resources to meet the power demand.

4.2. Quantitative Analysis
After the GEI is built, the joint operation of the intercontinental power grid can effectively utilize the complementarity between the load curve, power structure and the output characteristics of renewable energy, which are determined by natural attributes such as time difference, seasonal difference and energy structure difference, so as to optimize the global power resource allocation. The results show that the peak valley load difference of Europe, North America and Asia will be reduced from 40% to 23%, about 17 percentage points; the peak valley load difference of North America and South America will be reduced from 36% ~ 40% to 33% ~ 38%, about 3 percentage points. Through the optimal allocation of various types of power generation resources, the utilization hours of power generation increased by about 3% after global networking, and the utilization hours of wind power and solar power increased by about 10.8% and 5.7% respectively, which can reduce the installed capacity of conventional power sources such as coal power, gas power, hydro-power, nuclear power by about 3.2 billion kilowatts, which is about 37.44% lower than before networking.

The development of the GEI will achieve a win-win situation between the main sending end regions.
and receiving end regions, help to stimulate economic growth, increase employment opportunities in Africa and other sending end regions, reduce the cost of electricity consumption in Europe and other receiving end regions, promote the upgrading of industrial structure, and promote the coordinated development of intercontinental regions. The results show that the GEI is conducive to global economic growth, but different countries or regions benefit from different degrees. Compared with the self-balancing scenario, in 2050, the global network will promote the economic growth of Africa, Asia and Europe by an average of 0.26, 0.24 and 0.07 percentage points per year; increase the employment population by about 12 million, 6 million and 100000; increase the social welfare of Asia, Africa and other delivery areas by more than 6%; the impact of global network on the welfare of Europe and North America is less than that of other delivery areas. Driven by the adjustment of investment layout and technological progress, the Gini coefficient of global per capita GDP fell by about 0.04 in 2050.

The GEI will promote the transformation of the global power structure to the clean and low-carbon direction, promote the carbon emission of the power industry to reach the peak ahead of time, and contribute to the realization of the global 2 ℃ temperature control goal. The results show that the GEI can promote the global power industry carbon emissions to peak ahead of time. It is estimated that the carbon emission of the power industry in the self-balance scenario will peak in 2029, and the carbon emission of the power industry in the global networking scenario will peak in 2025, and the carbon emission peak in the global networking scenario is lower than that in the self-balance scenario. By the end of 2050, the global networking scenario has saved about 54 billion tons of greenhouse gas emissions compared with the self-balancing scenario. Through the climate change model simulation, it is found that the goal of 2 ℃ temperature control can be achieved under the global networking scenario, as shown in Table 2.

Table 1. The benefit assessment results (compared with the self-balancing scenario)*

| Index | 2050 |
|-------|------|
| **Power transmission benefit** |     |
| Total cost savings | Save the total cost of power generation (trillion yuan) | 6.94 |
| Energy conservation | Reduce the cost of electricity consumption (yuan / kWh) | 0.014 |
| Operation benefit | Increase coal power utilization hours (hours) | 99 |
| Capacity benefit | Saving installed capacity of thermal power (100 million KW) | 17.4 |
| Environmental benefit |     |
| Energy conservation | Reduce fossil energy consumption (100 million tons of standard coal) | 3015 |
| Emission reduction of conventional pollutants | Reduce water consumption (100 million tons) | 1623.6 |
| Energy conservation | Land value saving (US $100 million) | 775 |
| Emission reduction of conventional pollutants | Reduce sulfur dioxide emissions (10000 tons) | 1448 |
| Economic and social benefits | | |
| Economic performance | Reduce greenhouse gas emissions (100 million tons) | 0.18 |
| Social results | GDP growth (percentage points) | 0.0405 |
| | Reduce Gini coefficient | 2650 |
| | New jobs (10000) | 6 |

*The benefits of saving total cost, saving resources, reducing conventional pollutants and reducing greenhouse gas emissions are accumulated values, and the rest are current values.

5. Conclusions and suggestions
The construction of the GEI is conducive to the formation of a power flow pattern with multiple energy sources complementing each other across time zones, benefiting each other across seasons, and global
configuration. It can give full play to the peak load shifting benefit, improve the utilization efficiency of power generation equipment, and reduce the demand for power installation. The development of the GEI will achieve a win-win situation between the main sending end regions and receiving end regions, help to stimulate economic growth, increase employment opportunities in Africa and other sending end regions, reduce the cost of electricity consumption in Europe and other receiving end regions, promote the upgrading of industrial structure, and promote the coordinated development of intercontinental regions. Networking can promote the full utilization of renewable energy resources, save fossil energy, water resources and land resources consumption, reduce the emissions of sulfur dioxide, nitrogen oxides and fine particles, and realize the benefits of resource conservation and pollutant emission reduction. The GEI will promote the transformation of the global power structure to a clean and low-carbon direction, promote the carbon emission of the power industry to reach the peak ahead of time, and contribute to the realization of the global 2 ℃ temperature control goal.

The benefit compensation and sharing mechanism should be established to ensure that countries and regions through the network can obtain the corresponding power transmission benefits and network benefits, environmental benefits, etc. Strengthen the docking of investment and financing policies of various countries, optimize the investment environment of Commerce, law, supervision, taxation and other aspects, and eliminate the barriers of transnational investment and financing; for Africa and other regions with weak financial foundation, promote financial institutions such as the Asian infrastructure investment bank, the world bank, and policy banks of various countries to support key projects across continents. Strengthen investor protection mechanism host government provides risk protection for investors by providing government guarantee and various kinds of insurance.

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