Does the Energy Internet Improve the Efficiency of Resource Allocation? ---Theoretical Mechanism and Case Analysis

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Abstract. This paper analyzes the resource allocation effect of the Energy Internet through four theoretical analysis frameworks: Cournot model, time and space heterogeneity, information asymmetry, and structural upgrading. The study found that there are four path mechanisms for the Energy Internet to improve the effect of resource allocation: (1) Significantly increase the main body of energy supply and increase the level of market competition; (2) Distributed power and storage technology optimize the space-time allocation; (3) Information sharing, Reduce information asymmetry and improve the efficiency of resource allocation; (4) Advocate clean replacement and promote the upgrading of energy structure. Combining the case verification mechanism of Tianjin Sino-Singapore Eco-City, and presenting policy implications.

1. Preface

As the contradiction between human development and the unsustainable traditional energy structure will become increasingly acute, the worldwide demand and voice for energy supply and structural transformation continues to rise, thus catalyzing the reform and innovation of new energy structure and supply methods. In September 2015, Chinese General Secretary Xi Jinping proposed the "Building a Global Energy Internet" initiative at the United Nations Development Summit. By 2020, the initiative has been included in the UN High-level Conference Forum Policy Recommendation Report for three consecutive years. Judging from the current development trend, the emergence and development of the Energy Internet, which is characterized by the in-depth integration of renewable energy and Internet information technology, will be the key to achieving sustainable development of clean energy, low-carbon substitution, and efficient utilization, and is causing A new energy industry innovation and transformation.

After the 2008 financial crisis, in order to get rid of the unfavorable economic growth, countries stepped up technological research and innovation, hoping to use the technological revolution to achieve endogenous economic growth. Among these, the Energy Internet is the future development direction of the energy industry. Due to its nature, the Internet pursues deeper resource mobilization and more significant efficiency improvements, which can create greater economic benefits for the energy industry. The development of the integration of the Internet and energy is driven by many aspects such as environment, technology, economy, society and policy. It is not only the trend of the development and evolution of the energy system itself, but also the urgent requirements of the external environment and
conditions on the energy system. The construction of the global Internet can promote electric energy to meet global energy demand in a clean and green way, achieve historical transcendence and major innovations in traditional energy development concepts, and open a new pattern of world energy development.

Practice precedes academic research. From the literature point of view, in 2009, Long Weiding and others used the energy Internet as a key word to kick off the energy Internet research[1]. After 2015, the number of scholars' research in journals increased sharply, and the number of core journals reached a peak of 181 in 2017 (See Figure 1). Energy Internet has become a hot research topic. Ouyang Yi and Yang Jie (2017) Energy Internet uses energy microgrid, energy storage technology, and integrated energy system as the representative three technology realization paths[2]. Huo Molin, Guo Lei, and Zhang Shixiang (2020) conducted a systematic analysis of the current development status of China's multi-energy coupling regional energy Internet, and summarized the characteristics of the current development stage from four aspects: investment entities, technology applications, key markets, and related policies, and identified Key issues such as current technical issues, policy issues, and operational issues[3]. Miao Ankang (2016) analyzed that the energy Internet can be collected, stored, and used locally, effectively solving the energy crisis and security issues in the city, and supporting the development of smart cities[4]. Jiang Han, Gao Yi, etc. (2019) used the method of system dynamics to comprehensively evaluate the benefits and influencing factors of the regional energy Internet in economic, social, resource, and environmental aspects[5]. The research of Huo Molin, Guo Lei, Zhang Shixiang (2020) and Jiang Han, Gao Yi et al. (2019) expanded from the univariate problem of Internet energy development to the bivariate effect evaluation, and provided the preliminary ideas for this article. It is worth noting that the existing research literature mainly focuses on the realization of energy Internet technology and engineering optimization. The research on the economic effect of the energy Internet is quite scarce, and the research on the core aspect of the economy, namely its configuration effect, is rarely involved.

![Figure 1. Quantitative analysis of articles published in core journals with the theme of Energy Internet](image)

Data source: Bibliometric analysis of CNKI, data as of October 2020

The possible marginal contribution of this article is to clarify whether the energy Internet has improved the resource allocation and its resource allocation effect mechanism, using theoretical analysis and case-backed analysis methods, hoping to clarify the impact of the development and evolution of the energy Internet on the core economic development. Make up for the lack of current literature.
2. Theoretical mechanism analysis

Energy Internet is centered on electricity, based on electric energy and smart grids, and led by clean energy. It adopts a new generation of power electronic technology and information and communication technology to integrate the production, transmission, and transmission of power, heat, gas and other energy network systems. Storage, consumption, and other links are organically interconnected to achieve an integrated smart energy ecosystem that integrates energy allocation, multi-energy coupling, complementarity, economic convenience, cleanness and efficiency. This article focuses on the impact of the development of the Energy Internet on the allocation of energy resources, examines whether the development of the Energy Internet can improve resource allocation, and through which channels and mechanisms it will have an impact on the allocation of resources, and comprehensively examine this resource allocation effect of the Energy Internet.

Resource allocation involves not only the allocation of resources among different individuals, but also the allocation of resources in time and space. From the perspective of the nature of the allocation, it also includes the allocation of total and structure. The impact of the Energy Internet on resource allocation mainly includes the following aspects: its impact on time and space allocation, its impact on the main body of supply, its impact on energy structure, and the resulting network effects. as shown in figure 2.

![Figure 2](image_url)

**Figure 2.** Mechanism analysis diagram of energy Internet to improve configuration efficiency

**Source:** summarized by the author

2.1. Energy Internet brings resource allocation effects of increasing energy supply entities

Since the electricity market is a homogeneous commodity, the Cournot game model can be used to analyze the allocation of electricity resources by the number of suppliers in the electricity market. Comparing the Cournot equilibrium solution and its welfare in the electricity market of monopoly, duopoly and multiple electricity supply companies. We observe the impact of the number of power producers on the allocation of power resources. Among them, there is a demand function, as $q = a + bp + c$, $p$ is the market equilibrium price, $a$ and $b$ respectively represent the constant term and coefficient of the demand function, $c$ represent the variable cost of the electricity producer, $N$ is the number of power suppliers, $CS$ and $TS$ represent the consumer surplus and the total social surplus, respectively. Energy Internet optimizes resource allocation by linking more energy production enterprises.

In terms of market equilibrium prices, there are the following important relationships:
Market, the more benefits consumers will receive, decreases. This means needle energy is redistributed to improve the attention to the terminal energy utilization efficiency of electric energy, which can reach more than 90%, electric energy and realize electric energy substitution. Compared with other energy sources, the transmission is convenient, and the use process is clean and pollution-free. Electric energy can realize the mutual conversion of various forms of energy, and all primary energy can be converted into

\[
p_{i} = \frac{a + c}{2}, \quad p_{o}^{2} = \frac{a + 2c}{3}, \quad p_{e}^{N} = \frac{q = Nc}{N + 1}, N \leq 2
\]

It can be seen from formula (1) that when \( N \) increases, \( p \) decreases. This means that the number of power production companies increases in in the market, the equilibrium price of electricity in the market tends to continue to decline. Of course, electricity cannot fall indefinitely. There is a minimum limit. That is, when the number of power production companies is infinite, the equilibrium market price in the power market reaches the market price in perfect competition.

In terms of measuring consumer surplus, there are the following conclusions:

\[
CS_{1} = \frac{(a - c)^2}{8b} \quad CS_{2} = \frac{2(a - c)^2}{9b} \quad CS_{N} = \frac{(a - c)^2 N^2}{2b(N + 1)^2}, N \leq 2
\]

It can be seen from formula (2) that when \( N \) increases, \( CS \) also increases. This means that the number of power production companies increases in in the market, consumer welfare tends to increase. The more production companies that enter the power market, the more benefits consumers will receive, which is more beneficial to consumers.

In terms of measuring the total social surplus, there are the following conclusions:

\[
TS_{1} = \frac{3(a - c)}{8b} \quad TS_{2} = \frac{4(a - c)^2}{9b} \quad TS_{N} = \frac{(a - c)^2 N(N + 2)}{2b(N + 1)^2}, N \leq 2
\]

It can be seen from formula (3) that when \( N \) increases, \( TS \) also increases. This means that the number of power production companies increases in in the market, the total social surplus tends to increase. The more production companies that enter the power market, the more welfare the whole society will receive, and the more beneficial it will be to the whole society.

2.2. Energy Internet brings resource allocation effects of energy time and space transfer

The reverse distribution of energy resource enrichment areas and load centers requires attention to the spatial transfer of energy. The smart grid in the Energy Internet is a multi-energy coupling and complementary cross-regional energy transmission tool and channel. UHV flexible transmission technology is adopted, which can effectively improve the efficiency of long-distance and large-capacity energy transmission, and can achieve efficient cross-regional energy transmission and energy Coordinate and optimize the configuration. At the same time, the distributed energy storage system has flexible configuration and can be closely linked with distributed photovoltaic power generation, peak shaving and valley filling, and electricity bill management demand response. Energy Internet energy storage technology can realize the inter-period configuration of energy.

2.3. Energy Internet alleviates incomplete information and optimizes resource allocation

The Energy Internet adopts the technologies, concepts and methods of the Information Internet to realize open sharing and exchange sharing in the energy field. Idle energy is redistributed to improve the utilization rate of energy resources. The interaction of equipment information within the Energy Internet improves the information adequacy and transparency of the energy market, and greatly alleviates the problem of incomplete information in the energy market. Greatly improve the transaction efficiency of energy producers and energy consumption, make energy transactions close to the socially optimal social equilibrium point, thereby improving the efficiency of resource allocation in the energy market.

2.4. The substitution of electric energy brought about by the Energy Internet realizes a major change in the energy structure

The development of the energy Internet will give priority to the development of electric power and electric energy and realize electric energy substitution. Compared with other energy sources, the terminal energy utilization efficiency of electric energy is the highest, which can reach more than 90%, and the transmission is convenient, and the use process is clean and pollution-free. Electric energy can realize the mutual conversion of various forms of energy, and all primary energy can be converted into
electric energy. With the gradual development and utilization of clean energy in China, electricity and electricity will effectively replace fossil energy such as coal and petroleum, which can greatly improve energy conversion efficiency.

3. Cases
Tianjin Sino-Singapore Eco-City is a comprehensive demonstration project with the largest coverage area and the most complete construction functions in the world, covering the entire production process of power system production such as power generation, transmission, transformation, distribution, power consumption, and dispatching, as well as communication and information network platforms. Including 12 sub-projects such as distributed power access, micro-grid and energy storage system, smart community, smart park, electric vehicle, smart substation, power distribution automation, and smart business hall.

The project eased the tight supply and demand of petrochemical energy, the situation of single coal power generation, and the pressure of coping with climate change, and made the matching level of energy supply and demand higher. Form a new power supply and use relationship, change the past passive power use mode, realize real-time interaction with power grid companies, reduce the information asymmetry of energy suppliers and demanders, greatly reduce operating costs, reduce peak-to-valley differences, and reduce redundant construction investment for power grids. Improve the economic operation efficiency of power grid equipment and enhance the corporate image. The Tianjin Sino-Singapore Eco-City project can be replicated, promoted, and implemented, accumulating experience for the construction of the energy Internet, and exhibiting external economic characteristics. After the implementation of the Sino-Singapore Eco-City project, the power supply reliability of the Eco-City reached 99.999%, the voltage qualification rate was increased to 100%, and the average power outage time was shortened from 20.7 minutes to 5.26 minutes, and the reliability and quality of life of residents' electricity use were improved. Sino-Singapore Eco-City smart communities and power fiber to the home realize two-way interaction between users and the power grid, support the integration of three networks, realize automatic control of smart homes, make life more convenient and economical, and greatly improve the welfare of energy consumers and energy utilization effectiveness.

4. Summary and Enlightenment

4.1. Conclusion
Through theoretical analysis, this paper reveals the enormous effect of the Energy Internet on resource allocation. First, the increase of the main body of power supply enterprises will improve and optimize the allocation of resources. Since the energy Internet will greatly increase the main body of energy supply, it strongly proves that the energy Internet can significantly improve the allocation of resources and optimize the effect of resource allocation. Second, with the help of large energy grids and UHV flexible technology, the Energy Internet can realize the transfer of energy across regions and transfer energy from affluent areas to energy-scarce areas, which optimizes the allocation of energy resources in space; and the storage of energy Internet. The development of energy technology can realize the inter-period allocation of energy, thereby optimizing the allocation of energy resources in time, which also improves the use efficiency of energy resources. Third, the information advantages and trading platform of the Energy Internet, and the derived sharing economy also optimizes resource allocation, which optimizes resource allocation efficiency and maximizes the application of idle resources; Energy Internet also alleviates the problem of incomplete information in the energy market. Let energy buyers and sellers reach agreements more effectively, which also optimizes resource allocation. Fourth, the Energy Internet also has the resource allocation effect of energy structure transformation. The Energy Internet will realize the transformation from mainly relying on fossil energy to clean energy, and realize large-scale electric energy substitution.
4.2. Policy implications
Pay attention to the revolutionary significance of the supply and consumption of the Energy Internet, which has a positive impact on optimizing the efficiency of energy resource allocation. The advantages and urgency of the development of the Energy Internet require us to pay attention to the development of key core technologies of the Energy Internet, accelerate the process of energy marketization, and improve the energy Internet development mechanism to solve the energy resource problems that my country is currently facing.

References
[1] Weiding L, We Bi, Hao L, & Rui F. (2009). Energy systems in low-carbon cities. HVAC, 039(008), 79–84,127.
[2] Yi O, & Jie Y. (2017). Implementation path and practice of energy internet technology. CE, 39(002), 38–43.
[3] Molin H, Lei G, Zhe Z. Development status and policy recommendations of regional energy internet[J/OL].CEP:1-8[2020-10-24].http://kns.cnki.net/kcms/detail /11.3265.TM.20200706.1303.002.html.
[4] Shixiang Z, & Ankang M. (2016). Energy Internet supports the development of smart cities. CEP, 49(003), 12–17
[5] Han J, Yi G, Jun L, Yuan G, Pengfei X, & Yan Z et al. (2019). Comprehensive benefit analysis of regional energy Internet based on system dynamics. GEI, 2(01), 22–32.