# Research on Market Prospects of Intelligent Energy Efficiency Services Driven by Internet of Things Technology

Yucheng Ren [1], Jialei Ren [1], Ziyue Yang [1], Lingjuan Ma [1], Hengtian Wu [2*], Fang Tang [2], Rui Chen [2]

*wuhengtian@sgeri.sgcc.com.cn

[1] State Grid Jiangsu Electric Power Co., Ltd.
[2] State Grid Energy Research Institute Co.,Ltd.

**Abstract**. A DSTP (demand-supply-technology-policy) model to analyse the driving forces for the development of intelligent and energy efficient services is constructed. Further, focusing on the technology driven by the Internet of Things, a basic framework of intelligent energy efficiency service driven by the Internet of Things technology is constructed, including the physical layer and the business layer, and the corresponding driving mode is proposed. On this basis, an analysis model of intelligent energy efficiency service market prospect is proposed to analyse the investment scale and economy of intelligent energy efficiency service market. Finally, a numerical example of distributed photovoltaic as a key business direction of intelligent energy efficiency service is given.

**Key words:** Intelligent energy efficiency services; Internet of Things technology; Driving force; Market prospect

## 1. Introduction

Energy efficiency service is oriented to the terminal of energy system, through energy variety combination, technological progress, business model innovation, system integration and other ways, to improve users' energy efficiency and satisfaction with energy. As the accelerating integration of digital technologies such as the Internet of Things and big data with energy technologies, energy efficiency services have also ushered in a digital revolution. Digital technologies drive the continuous innovation of new technologies, new models and new business forms of energy efficiency services. Traditional energy efficiency services will gradually evolve and upgrade to smart energy efficiency services. The key technologies and overall architecture of the ubiquitous power IoT on the customer side is introduced in literature [1]. The typical application scenarios of intelligent energy efficiency services are analyzed based on the ubiquitous power IoT on the customer side, including energy efficiency monitoring, smart photovoltaic, etc. The application of big data technology in energy efficiency service is analyzesd in literature [2] and intelligent energy efficiency service strategy including data collection, user behavior analysis, energy consumption analysis, energy efficiency service design and other links is proposed. Literature [3] constructs an intelligent and energy efficient service platform including data layer, information layer,

MSEA 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2334211

knowledge layer and service layer, and designed the intelligent and energy efficient service process based on this platform. Based on the power big data, literature [4] proposes the intelligent energy efficiency service index and constructs the potential user screening model and service strategy model based on the index. Existing literatures have used PEST (political-economy-society-technology) model to analyze the development driving forces of energy Internet [5], clean energy [6] and power information physical system [7], but the above analysis results are not applicable to intelligent energy efficiency services.

## 2. Basic framework of intelligent energy efficiency service driven by Internet of Things

The development of intelligent and energy efficient services is driven by demand, supply, technology, policy and other factors. A DSTP (demand-supply-technology-policy) analysis model can be constructed, as shown in Figure 1.

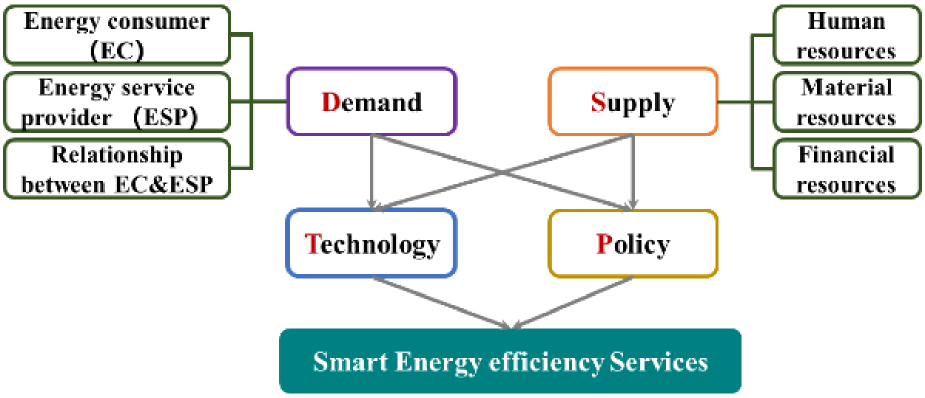


**Figure 1**. DSTP analysis model

### 2.1. Intelligent energy efficiency service driving force model

Demand factors mainly include demand subject, demand object and demand subject - object relationship.Demand main body is namely energy consumer. The lowest level demand is to meet the basic energy security and achieve energy security. The second level is that the demand subject is willing to pay higher energy cost for clean energy or change the original habit of energy use to achieve clean and low-carbon energy use. The highest level is to implement more flexible, even on-demand, energy services. The continuous evolution of the demand level will drive the upgrade of intelligent and energy efficient services to the direction of convenience, economy, clean, low-carbon and personalized.

Demand object is the energy service provider that provides energy goods and services for the demand subject. Energy service providers will be more committed to realizing the cleaning and electrification of energy products, multi-energy complementarity and synergy among multiple energy varieties, diversification of energy services, and promote the continuous enrichment of categories and brands of intelligent and energy efficient services, as well as the continuous improvement of quality and cost performance.The subject-object relationship of intelligent and energy efficiency service demand is shifting from object-centered to subject-centered. The intelligent energy efficiency service is developing from the traditional supply guarantee type to the demand-driven type. According to the demand orientation of energy consumers, the relationship between subject and object is constantly optimized, so that it presents new characteristics such as intelligent decision-making in energy use, sharing of energy use, and customization of energy goods and services.

The supply factors driving the development of intelligent and energy efficient services mainly include human resources, capital supply, resource endowment and other dimensions.

The level of human resources affects the innovation and development level of intelligent and energy efficient service industry. In areas with good labor quality and high education level, smart energy efficiency services tend to be specialized, difficult and have exemplary and leading value. In areas with abundant human resources and average education, smart energy efficiency services tend to be relatively mature and labor-intensive businesses. The scale of total capital supply, growth rate, adequacy degree and price level (interest rate) affect the development scale and speed of intelligent and energy efficient service industry. State-owned energy enterprises have relatively abundant capital and relatively low capital price, so they have obvious advantages in developing capital-intensive business. For small enterprises, capital shortage often becomes the bottleneck of development. It is a better strategy for small enterprises to develop asset-light business which is less dependent on capital and can recover funds as soon as possible. Resource endowment influences the specific form of smart energy efficiency services. Based on the principle of adapting to local conditions, intelligent and energy efficient services ensure the optimal allocation of resources by rationally developing local resources and optimizing the utilization of external resources.Human resources, capital supply and resource endowment are complementary to a certain extent. When a certain factor is lacking, energy service providers can use other factors to replace it, so as to promote the optimization and adjustment of smart and energy efficient service business types.

Technological innovation is an important driving force for the development of intelligent and energy efficient services. A strong driving force for expanding the market space and optimizing the industrial structure is provided. With the deep integration of digital technologies such as Internet of Things and big data with energy technologies, energy consumers can master their own energy consumption through intelligent terminals and actively adjust their energy consumption behaviors according to market signals and system operation. Thus consumer’s "personalized" demands are inspired. At the same time, technological innovation will drive business replacement and accelerate industrial upgrading. In the future, intelligent and energy efficient services will evolve to an integrated business model [8], providing comprehensive energy solutions for parks, buildings, homes and other scenarios.

Industrial policies will affect supply factors such as manpower and capital as well as demand factors such as quantity, type and quality of energy services[9]. Thus the development direction and speed of intelligent and energy efficient service industry are effected. At present, the implementation plan of carbon peaking in major energy use fields such as industry and construction has also been released one after another. These policies all take energy conservation, carbon reduction and efficiency improvement as the key point of promoting carbon peak work on the energy consumption side. It can be predicted that the policy environment for the development of intelligent and energy efficient services will be further improved.

### 2.2. Intelligent energy efficiency service model based on the Internet of Things

Demand as an internal factor originating from consumers is difficult to grasp. Supply is greatly limited by resource endowment. Research, formulation, introduction, implementation and effectiveness of policy require a process. In contrast, there are many technical research subjects with rapid upgrading and iteration, which is the most effective focus to promote the development of intelligent and energy efficient services.

The deep integration of digital technology and energy technology has triggered profound changes in energy systems. The digital technology has become a recognized core direction to drive the development of intelligent and energy efficient services. Among them, the Internet of Things technology provides a new technical basis for intelligent energy efficiency services at the physical layer and the business form layer, which is a typical technology-driven mode. Based on the DSTP model, this paper proposes the development mode of intelligent energy efficiency service driven by Internet of Things technology as shown in Figure 2.

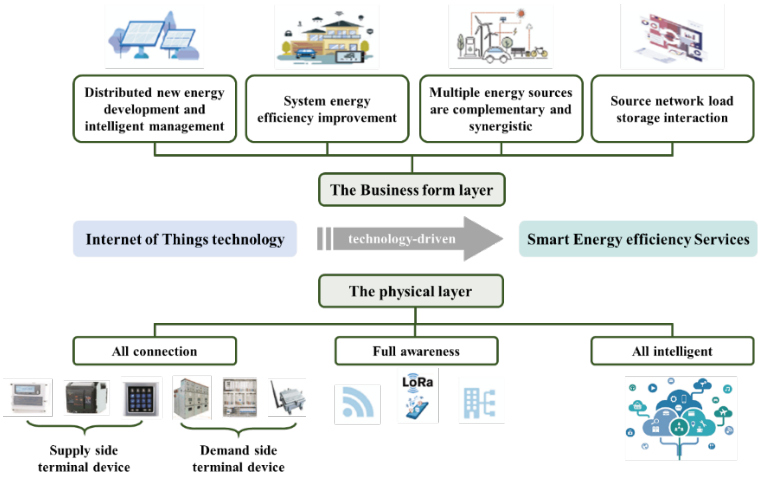


**Figure 2.** The Internet of Things technology drives the development model of integrated energy services

This mode includes physical layer and business layer. The physical layer is fully connected, aware and intelligent. Being fully connected means to realize the extensive access of terminal power related equipment and to promote the transformation of equipment from single to integrated, including vertical integration and horizontal integration. Vertical integration is to promote the coordinated development of "source, network, charge and storage" and the expansion of customized power business. Horizontal integration is to promote the integration of comprehensive energy systems with multi-energy complementarity and the upgrading of cross-category services. Being full sensing is the integration of data, information and applications related to intelligent and energy efficient clothing to realize the "mapping" between physical space and virtual space. Being full intelligence refers to the use of artificial intelligence technology to identify the user's energy consumption pattern, and then automatically generate customized solutions in various aspects such as energy type and quantity, supply time and intensity, operation and maintenance service frequency, so as to achieve "intelligent consumption" and "real-time management and control".

Based on the Internet of Things technology, the business model layer aims at the implementation pain points of smart energy efficiency services such as distributed photovoltaic development-utilization-management, system energy efficiency improvement, multi-energy complementarity, and interaction between source-network-charge-storage. With the goal of "more efficient, more comprehensive and more interactive", it creates a new business model and new business model. In view of the lack of distributed new energy monitoring methods, such as distributed photovoltaic and distributed wind power, and difficulties in online operation and maintenance, a digital monitoring platform is developed to provide photovoltaic operation monitoring and diagnosis, equipment operation and maintenance, settlement agent, green power trading and other operational services, so as to promote the improvement of new energy utilization efficiency and management ability. To solve low efficiency of commercial building and industrial enterprises, strengthen terminal equipment integration and control platform construction will promote monomer level to system level change of energy conservation. To solve the low independent supply efficiency, the comprehensive consideration of energy demand, energy efficiency requirements, cost, environmental standards is needed. With research and development of algorithm or complementary optimal operation model, it offers a variety of energy supply and arrangement service to achieve optimal allocation of energy efficiency, economic and environmental resources. To solve the problems as high power distribution network investment and low utilization rate by load surges and electric vehicles, the extensive connection of each link of interactive equipment is needed. Increase the controllable load resources and strengthening the group communication is adopted as well. Providing demand response and spot trading is also needed.

## 3. Analysis of intelligent energy efficiency Services market outlook

### 3.1. Measures

(1) Market investment scale analysis method

For distributed new energy business, its market investment scale can be characterized by the investment scale of installed capacity. At present, the widely used distributed new energy in China is mainly rooftop photovoltaic. The installed capacity of rooftop PV is related to the available roof area, annual utilization hours, PV module efficiency, etc. The calculation method is shown in Equation (1) :

$$\begin{cases} I_{\text{pv}} = \varepsilon \cdot E_{\text{PV}} \\ E_{\text{PV}} = \alpha \cdot \beta \cdot RCA \end{cases} \tag{1}$$

$I_{pv}$ is the scale of investment in distributed photovoltaic market (unit: yuan); ε is unit installed cost, unit is yuan/watt; $E_{pv}$ is the installed capacity of distributed PV (unit: watt); α is the coefficient of roof available area; β is the installed capacity per square meter, the unit is kW/square meter; RCA is the floor area of the roof, and the unit is square meters.

For other services, such as energy saving services and multi-energy complementarity, considering that these services are all aimed at improving energy efficiency, their market investment scale can be characterized by energy saving investment scale. The calculation method is shown in Equation (2) :

$$I_e = \lambda \cdot C_e \tag{2}$$

Ie is the market investment scale of energy saving services, multi-energy integrated supply and other services, the unit is yuan; λ for tons of standard coal price, unit is yuan/ton standard coal; $C_e$ is the estimated energy saving value generated during the business implementation period, and the unit is ton standard coal.

(2) Economic analysis method

In this paper, unit energy supply cost is used to measure the economy of smart energy efficiency service projects, and the calculation formula is shown in Equation (3) :

$$\begin{cases} LCOE = \dfrac{I + \sum_{y=1}^{T} \dfrac{P_y}{(1+j)^y}}{\sum_{y=1}^{T} \dfrac{K_y}{(1+j)^y}} \\ P_y = G_y + a_y \cdot I + b_y \cdot I \end{cases} \tag{3}$$

LCOE is unit energy supply cost; I is the initial investment; T is the project life cycle, y is the ordinal number of years, and $P_y$ is the operation and maintenance cost of the y year. J is the discount rate; $K_y$ is the total energy supply in year y, i.e., the total energy demand in year y; Gy is the cost of external energy purchased $B_y$ the user in year y, $A_y$ is the project maintenance cost rate in year y, and $B_y$ is the project principal and interest service rate in year y.

### 3.2. Example

(1) Market investment scale

The roof area of public buildings, industrial and commercial enterprises and residential buildings in China (excluding South China) is $1.39\times10^9$ square meters, $2.51\times10^9$ square meters and $13.36\times10^9$ square meters, respectively as shown in Table 1.

**Table 1.** Building roof area of China

| Region | Roof area (m$^2$) | | |
|---|---|---|---|
| | ***Public building*** | ***Industrial and Commercial Enterprise*** | ***Residents*** |
| North China | $0.17\times10^9$ | $0.27\times10^9$ | $1.47\times10^9$ |
| Central China | $0.31\times10^9$ | $0.36\times10^9$ | $2.9\times10^9$ |
| East China | $0.53\times10^9$ | $0.144\times10^9$ | $5.24\times10^9$ |
| Southwest China | $0.13\times10^9$ | $0.17\times10^9$ | $1.77\times10^9$ |
| Northeast | $0.08\times10^9$ | $0.13\times10^9$ | $0.8\times10^9$ |

| | | | |
|---|---|---|---|
| China | | | |
| Northwest China | $0.17\times10^9$ | $0.14\times10^9$ | $1.18\times10^9$ |
| **Total** | **$1.39\times10^9$** | **$2.51\times10^9$** | **$13.36\times10^9$** |

The available roof area coefficient α of public buildings, industrial and commercial enterprises and residential buildings should not be less than 40%, 30% and 20%. At present, the investment cost of distributed PV per unit capacity is 3-4 ¥ /W, and this paper takes 3.5 ¥ /W. If the installed capacity β per square meter is 0.1kW/m$^2$, the potential investment potential of China's rooftop distributed PV can be calculated by Equation (1), which is 139.3 billion yuan.

Through the Equation (2), the investment scale by region of distributed PV market in North China, Central China, East China, Southwest China, Northeast China, Northwest China and Southeast China is 154, 284, 592, 161, 81 and 12.3 billion Yuan respectively. The potential market investment scale of North China, Central China and East China accounts for 74% of the total scale, becoming the main gathering area of future distributed photovoltaic investment as shown in Figure 3.

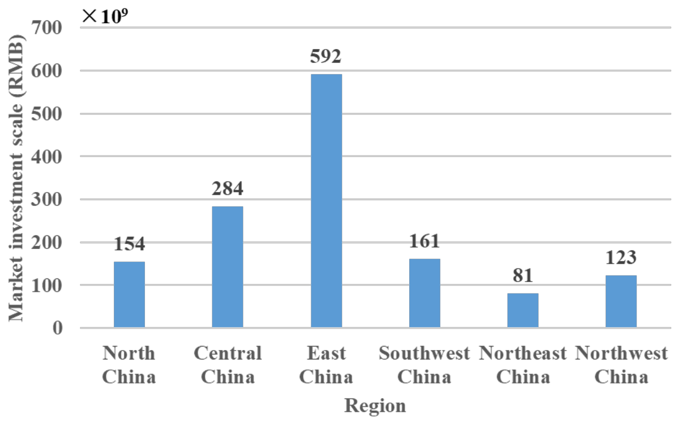


**Figure** 3. Investment scale of distributed PV market

(2) Economy

In this paper, three regions of North China, Central China and East China, as well as three types of rooftop PV, including industrial and commercial rooftop PV, public building rooftop PV and residential rooftop PV, are selected to construct typical scenarios for economic analysis. The basic data of each typical scenario is shown in Table 2. In addition, in the calculation process, the annual maintenance cost of distributed PV is 1%-2% of the initial investment (increasing year by year). The project cycle is 20 years; The proportion of project capital loan is 70%, the loan interest rate is 4.9%, the loan term is 15 years; The discount rate is 6 per cent.

**Table 2.** Economic analysis of basic data

| Region | User type | Electricity level ($kWh/m^2$) | Power load ($W/m^2$) | Electricity price （RMB/kW） | Total area （$m^2$） | Roof area （$m^2$） |
|---|---|---|---|---|---|---|
| North China | Office building | 50 | 10 | 0.6159 | 60000 | 10000 |
| | Commercial complex | 98 | 22 | | 80000 | 10000 |
| | Residential | 10 | 2 | | 20000 | 10000 |
| Central China | Office building | 50 | 10 | 0.6513 | 60000 | 10000 |
| | Commercial complex | 98 | 22 | | 80000 | 10000 |
| | Residential | 10 | 2 | | 20000 | 10000 |
| East China | Office building | 50 | 10 | 0.6674 | 60000 | 10000 |
| | Commercial complex | 98 | 22 | | 80000 | 10000 |
| | Residential | 10 | 2 | | 20000 | 10000 |

According to Equation (3), the distributed photovoltaic power supply cost and grid power supply cost in typical scenarios are shown in Table 3.

**Table 3**. Economic calculation results in typical scenarios

| Region | User type | Power supply cost （RMB/kW） | | Power supply cost reduction (%) |
|---|---|---|---|---|
| | | ***PV mode*** | ***Grid mode*** | |
| North China | Office building | 0.5620 | 0.6159 | 8.7% |
| | Commercial complex | 0.6004 | 0.6159 | 2.5% |
| | Residential | 0.3675 | 0.4777 | 23.1% |
| Central China | Office building | 0.5913 | 0.6513 | 9.2% |
| | Commercial complex | 0.6341 | 0.6513 | 2.6% |
| | Residential | 0.4408 | 0.5511 | 20.0% |
| East China | Office building | 0.6046 | 0.6674 | 9.4% |
| | Commercial complex | 0.6494 | 0.6674 | 2.7% |
| | Residential | 0.4301 | 0.5404 | 20.4% |

Although the construction of distributed PV increases the initial investment, the annual electricity cost is greatly reduced. According to the calculation results, the average power supply cost of distributed photovoltaic is 0.5422 ¥ /kW·h, and the average power supply cost of grid power supply mode is 0.6043 ¥ /kW·h. The distributed PV power supply cost is reduced by 10.28% compared with the grid power supply cost.

## 4. Conclusion

The intelligent energy efficiency service model its market prospects is analysed in this paper driven by IoT technology. Firstly, the DSTP model was constructed to analyse the development driving force of intelligent and energy efficient services. On this basis, the basic framework and service mode of intelligent energy efficiency service are constructed with the emphasis on the technology driven by the Internet of Things. Secondly, from the two dimensions of market investment potential and economic analysis, the market potential analysis method of intelligent energy efficiency service is proposed. The distributed photovoltaic (PV), a typical business of intelligent energy efficiency service, is taken as an example to conduct a numerical example analysis.

The main conclusions are as follows. (1) The IoT technology will greatly drive the physical foundation of "fully connected, fully aware and fully intelligent" for comprehensive energy services and will generate new business forms including distributed energy development and intelligent management, system energy efficiency improvement, multi-energy complementation and coordination, source- network-charge-storage interaction. (2) Utilization and intelligent management of distributed photovoltaic development is one of the representative businesses a good market prospect of intelligent energy efficiency services. The potential market investment scale reaches 139.3 billion yuan. The unit energy supply cost is 10.28% which is lower than that under the grid energy supply mode.

In the next step, further research will be carried out on business and process design and market outlook analysis of intelligent energy efficiency services driven by IoT.

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