

THE LOGICAL FRAMEWORK AND EVALUATION SYSTEM OF SUSTAINABLE URBAN ENERGY SYSTEM

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ABSTRACT

Sustainable urban energy system is an important support and driving force for the high-quality development of urban economy and society. In the context of addressing climate change and energy transformation, this paper summarizes the stylized facts of urban and energy system evolution. A sustainable urban energy system analysis framework is proposed to analyze the logical framework of the energy system from the physical, information, and value layers. Further, this paper proposes a comprehensive indicator system for quantitatively evaluating the degree of coordination between urban development and energy systems, and provides a method for assessing the comprehensive benefits of sustainable urban energy systems.

Keywords: urban energy system, logical framework, evaluation system, stylized facts.

1. INTRODUCTION

On the eve of Rio+20 summit, while still the UNSG, Ban Ki-moon said that the realization of global sustainable development depends on cities, which has become a broad consensus. A series of international negotiation documents has repeatedly reflected the same theme, that is, the realization of the sustainable development goals shall be based on local implementations^[1,2].

Energy, as the indispensable motive resources of human's city life, its sustainability is closely linked with urban sustainable development^[3,4]. The safe and efficient use of energy has a significant impact on economic growth, social stability and environmental

protection. Also, the sustainable use of energy is consistent with sustainable development goals, and even can be the key to sustainable development^[5].

Previous studies on urban energy consider cities and energy as two independent systems, adopting partial equilibrium method to energy allocation^[6]. Historical evidence had already indicated that some issues on urban energy use has triggered off socio-economic problems. Moreover, these problems have raised further concerns on whether the sustainable development can be realized or not and how to achieve it^[7-9].

It is widely acknowledged that the urban energy system is a complex system consisting of various multiple subsystems like energy, economy, society (including population), and the environment. With the increasing attention on sustainable development, an overall analysis on the development status, trends and capabilities between cities and energy from the perspective of historical evolution, exploration of the form and logical framework of the sustainable urban energy systems, and studies on the evaluation system of measuring the coordinated development of cities and energy systems are of great research values.

2. SUSTAINABLE URBAN ENERGY SYSTEM FOR THE FUTURE

2.1 The Stylized Facts of Urban Energy System evolution

As the correlation between urban development and energy supply pattern is interdependent and interacted, and the existence and development of cities rely on the support from energy system^[10]. Many factors including geographical location, historical tradition, and political system have an impact on the development of the city.

And optimization and adjustment of urban industrial structure, economic growth, and demographic changes directly affect the demand and utilization of various energy sources, which in turn affects the supply and demand pattern of energy. The improvement of the energy system plays a positive and important role on ensuring the orderly development of the urban economy and the healthy life of the local residents.

The evolution of urban development and energy systems has changed from single-track to interaction, from local coordination to comprehensive coordination, from energy supply security to comprehensive allocation, and also from the passive support of urban energy development to coordinated development of urban economy. The future coordinated development of the future energy supply systems and the cities are mainly reflected in three aspects namely the coordinated development of energy and urban economy and society, the coordinated development of energy and urban resource endowment, and the coordinated development of energy and urban ecological environment.

2.2 Stylized facts of urban and energy system evolution

To materialize urban sustainable development, numerous domestic and international cities have adopted different structural choices to improve energy efficiency and optimize urban energy systems. Especially in those metropolises with a large dense population, where service industry is relatively large in the local economy (service industry is relatively developed) and also is highly dependent on external sources. Therefore, in most cases, its energy consumption structure is more important than production structure.

First of all, urban development usually benefits from scale economy, but at the same time, the high-density development has brought new environmental problems. Consider the fact that the massive energy consumption is mainly brought by the increasing urban density, sustainable urban energy systems should be as clean and low-carbon as possible.

Secondly, there is no denying that the urban energy structure is more than likely to change rapidly. Long-term changes in energy structure are leech on the evolution of industrial structure. In those developed cities with industry structure dominated by service industry, prices and policies play critical parts while technology tends to be secondary.

Thirdly, transportation energy consumption accounts for a relatively large proportion of urban energy consumption. Reasonable planning on urban development and land use could improve the energy

efficiency of the transportation system, and meanwhile, it could reduce the emissions of pollutants.

Moreover, with the development of distributed, micro-grid and energy internet, the internalization of urban energy sources is expected to be improved, thus leading a further increase on the urban energy consumption efficiency.

Last but not least, thanks to the diversification and intelligent development of cities, building a well-developed urban energy system which is intelligent, low-carbon and sustainable, has become a common pursuit.

3. FRAMEWORK OF SUSTAINABLE URBAN ENERGY SYSTEM

3.1 Connotation of sustainable urban energy system

A sustainable urban energy system should be like this: while meeting the needs of the city's economic and social development, the energy system can achieve the goal of protecting the environment, adapting to climate change, reducing air pollution and natural resource depletion, and urban energy base. Facilities can have the ability to adapt to external shocks.

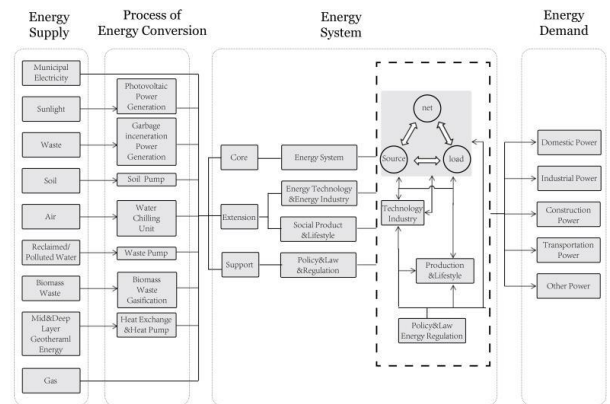


Fig 1 Sustainable Urban energy system framework

The sustainable urban energy system is a composite system composed of several complex systems and an important indicator of the harmonious development of cities and energy. It includes kernel, extension and support three aspects. From the perspective of the kernel, the sustainable development of the energy subsystem requires the coordinated development of power-grid-load and the rational allocation of resources inside and outside the region. In terms of extension, coordinated development of energy technology and related industries, will drive the transformation of social production and lifestyle, and promote the formation of low-carbon and eco-friendly producing and living mode. From the perspective of support, under the national legal

and policy framework, the innovation of urban energy management provides the driving force and institutional guarantee for the sustainable urban energy system.

3.2 Sustainable urban energy system logic framework

3.3.1 Physical layer

Considering the planning, design, construction, operation and other aspects of energy and power links, the physical layer is the basic framework of the urban energy system. A sustainable urban energy system is a comprehensive system that couples multiple energy sources. Focusing on the whole process of power generation, dispatching, transmission, power transformation, power distribution and power consumption, the collection, transmission, storage, processing and presentation of information in these links will realize the deep integration of data information and energy facilities to realize system operation. Linkage and efficient operation of data information and management services.

The sustainable urban energy system organically integrates the networks of different energy types such as heat, electricity and gas, thus forming a network of energy production, allocation and consumption coupled with multiple types of energy. Through the coupling of energy system and information technology, a smart energy operation system that matches the supply and demand linkage is constructed. From the perspective of supply, urban energy systems include smart grids, smart oil and gas networks, and intelligent thermal networks. In terms of demand, urban energy systems also include smart industries, intelligent transportation, intelligent buildings, and smart living. The future urban energy system integrates urban energy facilities from independent facilities and professional systems into a networked energy ecological group.

3.3.2 Information layer

The information layer is the interaction and integration of information, so as to achieve data integration across departments, cross-business, and cross-domain, and promote data sharing, and then provide data support for further analysis of key indicators to analyze energy-saving effects and energy efficiency of energy supply and consumption. The information layer provides high-speed and reliable network transmission capabilities and efficient data processing capabilities for urban energy management systems.

The collaboratively coupled management platform relies on the management level decision-making

platform of the urban energy system, and it has strong flexibility. Together, they effectively support the information data platform and resource allocation platform. They interact to support the smart energy service market and the energy trading market.

3.3.3 Value layer

The core goal of a sustainable urban energy system is to transform the urban energy system from a fossil energy source to a renewable, sustainable energy system. Internet-based technology will promote the balance of supply and demand, systematic management, and information exchange of energy systems, thereby improving the efficiency and wisdom of the entire system. The sustainable urban energy system not only realizes the interaction of energy flow and information flow, but also realizes the interaction of value flow, which has enormous economic and social benefits.

As a centralized reflection of business processing, data analysis and decision making in urban energy management systems, the value layer is the value realization of the energy management platform. It can achieve efficient and rational distribution of energy system internal and external, achieve clean and low carbon development of the city, and realize multiple values of economy and environment.

4. SUSTAINABLE URBAN AND ENERGY SYSTEM COLLABORATIVE DEVELOPMENT EVALUATION

4.1 Evaluation principles

The comprehensive benefit indicator system for energy and power planning is a statistical indicator group that reflects the relationship between sustainable cities and energy systems as depicted in 3.1. The principles for constructing the evaluation index system for the coordinated development of cities and energy systems are as follows:

4.1.1 Hierarchical principle

The indicator system consists of three levels. The first level includes the four first-level indicators of economic industry, urban function, energy system, and environmental protection level, which are used to evaluate the impact of energy systems on urban economic, social, energy consumption and the environment. The second level is the specific identified benefit aspect and is a further classification of the first level indicator. The third level is a specific indicator that can be used to calculate or evaluate specific benefits.

4.1.2 Scientific principle

The scientific principle means that when setting up the indicator system, it must reflect the requirements of rationality, accuracy and system. Rationality means that the indicator must be able to properly reflect the objective situation of the evaluation plan. Accuracy refers to the fact that the form and content of the indicator can reflect the object being evaluated unambiguously. Systematic means that indicators can reflect the relationships and benefits between systems in different ways.

4.1.3 Measurable principle

The design of indicators should be measurable in terms of time, space, price, and method. However, this refers to the unit of measure for all indicators. If the units of calculation results of each indicator are different, a comprehensive measurement of different dimension indicators can be achieved through subsequent comprehensive evaluation methods.

4.2 Comprehensive evaluation system for coordinated development of cities and energy systems

Urban energy sustainability is a key indicator for measuring the sustainable development of urban energy. To analyze the multi-dimensional coupling relationship between urban development and energy supply and demand, it is necessary to consider various factors such as economy, society, resources, environment, energy and technology. This paper constructs a coordinated evaluation system of urban and energy systems from four dimensions of economic industry, urban function, energy system and environmental protection level, which is used to

evaluate the comprehensive benefits of cities and energy systems, as shown in Figure 2.

This evaluation index system can be used to quantitatively evaluate the degree of coordination between different cities and energy systems, and can be used to analyze the supporting role and comprehensive benefits of the energy system for the city's economy, society, and environment.

5. CONCLUSIONS

Through studying the evolution of domestic and foreign urban energy, we find that the city's energy supply system is in line with the development trend of economic and population growth, and consolidate the general stylized facts of sustainable urban energy system development. With the expansion of the city scale, industrial restructuring and quality of life, the energy supply system is increasingly diversified, intensive and clean.

The main contribution of this paper is to propose a sustainable urban energy analysis framework, including its connotation, logical framework and evaluation system. Sustainable urban energy systems coexist with economic and environmental benefits through measures such as energy supply structure transformation, technological innovation, and management informationization. The urban smart energy system consists of four core systems: production system, energy consumption system, integrated service system and energy storage system, which are composed of various forms of energy networks, information networks and commercial networks. To comprehensively measure the degree of coordination between energy systems and urban development, this paper provides a measurable, multi-dimensional evaluation indicator system to provide a scientific reference for sustainable urban energy management and decision-making.

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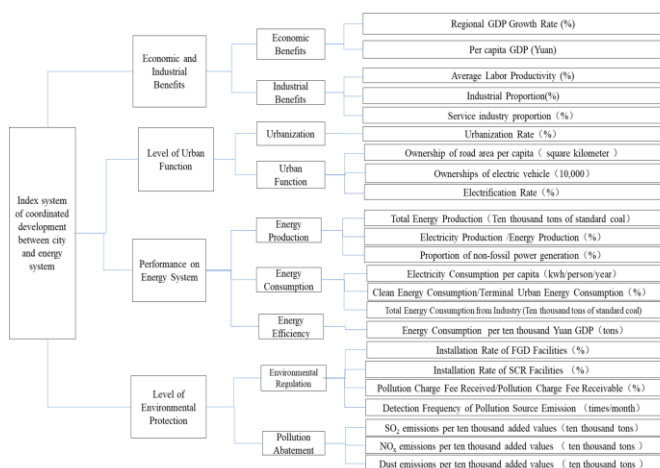


Fig 2 Urban and energy system comprehensive benefit evaluation index system

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