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Planning community energy system in the industry 4.0 era: Achievements, challenges and a potential solution

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ABSTRACT

Many industries have undergone a transformation in today's highly developed information technology era. In this study, we descript a future community energy system perspective based on the principle of industry 4.0 and a literature review of current research achievements on community energy system planning (CESP) After a review, we indicate that information sharing, consumer's participation, and cross-business cooperation are the noteworthy features of CESP in the industry 4.0 era. We also indicate that future CESP is based on stakeholders' deep participation and that decentralised independent decision-making is the main planning pattern. The lack of hierarchical and parallel information interaction between different stakeholders at the planning stage makes CESP inefficient and an investment waste. Furthermore, the basic data utilised by CESP have the potential to be supplemented.

After discussing about the future community energy system, we recognise that CESP is not a final blueprint of community energy system, and should offer an interest-coordination mechanism and information exchange platform for community energy stakeholders. Moreover, CESP does not provide an overall solution for economic and technical problems related to the community energy system but provides a communication platform and regulations for stakeholders. In this work, we propose an information interactive platform structure based on a multi-agent system model for CESP process, which is a modularised and open system to improve the systematisms of multitudinous energy systems planned by different proprietors.

1. Introduction

With rapid economic development and the accelerated urbanisation process, energy consumption increased quickly in developing countries. High energy consumption and construction activity induced environmental degradation of urban human settlement and energy-supply problems. Many researchers recognised that building an ecological, less fossil energy resource-dependent and livable city is the affectual approach to addressing the challenges of environmental and resource limitations [1–4]. To achieve ecological urbanisation, urban energy systems should overcome the challenges from both demand and supply sides. On the supply side, the eternal puzzle is how to acquire enough renewable and sustainable energy in a cost-effective manner. On the demand side, energy efficiency improvement and energy demand management is tending to be an unending task.

The comparisons of demand- and supply-side energy planning can be illustrated in Fig. 1. Supply-side energy planning focuses on urban energy resilience with enough energy sources, while the demand-side energy planning pays attention to the energy utilisation process of end users. To a great extent, urban supply-side energy planning is limited by the national/international energy market circumstances and resource endowment. On the other hand, the urban energy system (urban demand-side) is a complex dynamic network system which involves energy exploitation, processing, conversion, transmission, and consumption.

From Fig. 2, we can find that it is an extremely challenging and significant task to lead and regulate energy utilisation in urban areas. Specifically, a community (including several blocks) is an important spatial carrier of demand-side energy planning. In addition, CESP works as a linkage in urban energy system researches, which involves both specific technology and systematic integration of the energy system. Just as Klein stated, ‘Building a sustainable energy future, one community at a time’ [5].

The morphology of energy utilisation has evolved following the development of society. Wood, coal, oil and electricity became the energy symbols of the previous industrial revolution. Fittingly, the form

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Nomenclature

CESP	community energy system planning
CSEM	community secondary energy trading markets
TPEM	traditional primary energy markets
MAS	multi-agent system

of energy utilisation on the demand side changes over time. For example, following the increase of distributed generators and limited renewable energy power generation on the demand side, urban electrical power systems have become one of the most complex systems. In order to ensure that the urban energy infrastructure runs efficiently, strengthening the coordination control of demand-side prosumers and power plants is quite necessary.

The spread of Internet and Mobile Internet has made information interaction between consumers and producers more convenient and timely. Along with information explosion, data is changing the production, working, and lifestyle modes of the human society. To some extent, information similar to coal, oil, and electricity, tends to be the basic force driving a new industrial revolution called industry 4.0.

Industry 4.0 was presented by the German federal government in 2011 to describe its future high-tech industrial development strategy. Drath [6] believed that the proposition of industry 4.0 is very important because it is for the first time that an industrial revolution is predicted a priori but not observed ex-post by people. Companies and research institutes have opportunities to discuss and shape the future. Kagermann thinks industry 4.0 will profoundly change social production and shape our life. The vision of industry 4.0 described by Kagermann [7], Wang [8] and Bürger [9] is as follows: 1) All the production, transportation and consumption systems and related machinery are integrated in Cyber-Physical Systems; 2) Smart factories are distributed in different places and every factory can response as required based on global optimisation; 3) The smart product system, enterprise management system, business process, and consumption system are deeply integrated, and the full life cycle record of a product (from raw materials to consumption and disposal process) is used to improve its design and production; 4) Smart machines in the assembly line are completely digitised and each of them can autonomously exchange information, triggering actions and controlling each other

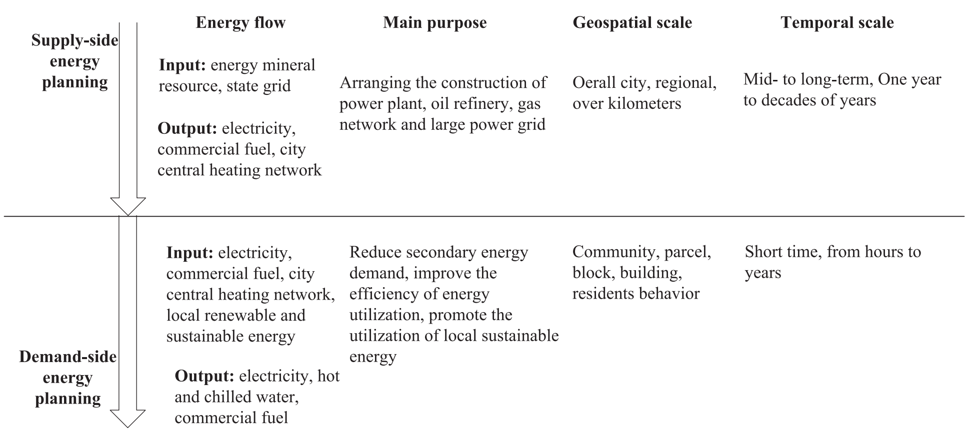

Fig. 1. The relationship between demand-side and supply-side energy planning.

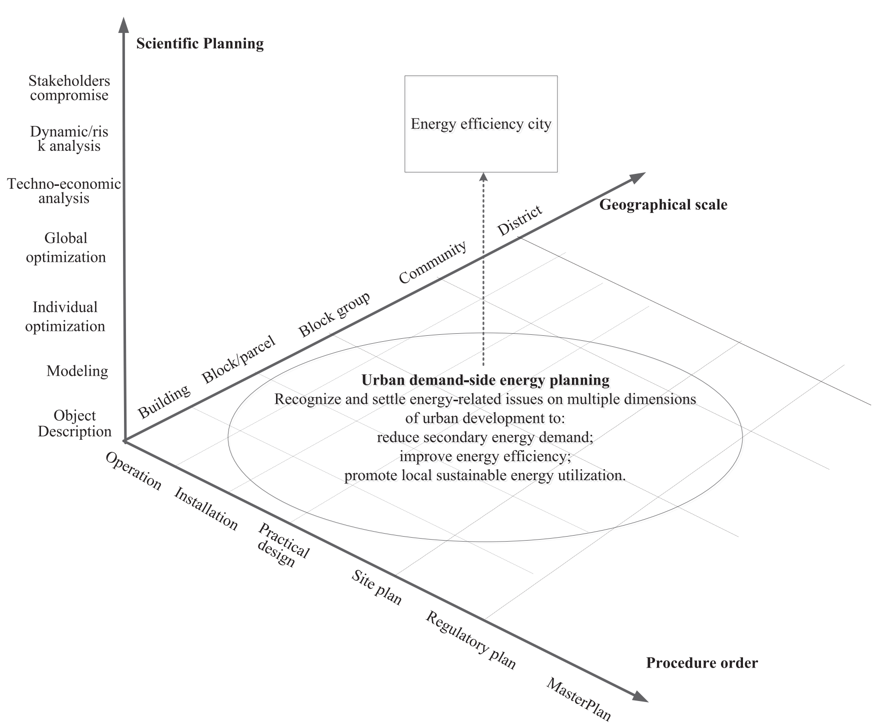

Fig. 2. Urban demand-side energy planning.