Comprehensive theoretical and evaluation system of integrated energy system

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Abstract. In order to undertake and integrate into the global energy Internet, solve the city environmental pollution and energy security, based on the present situation and comparative analysis of city energy development, put forward the framework of city energy Internet system, and provide a theoretical basis for the construction of city energy Internet; first proposed the characteristics analysis of the target system of city energy Internet based on the energy of the Internet provides the quantitative basis for city development goals; taking Tianjin as an example, the city energy Internet development stage and target, promote the allocation of energy resources in larger scope, to promote all types of energy and electrical energy, improve the proportion of clean energy use in the power generation side and power consumption in the side, finally realize the city energy no carbon consumption.

1. Introduction

The global energy consumption pattern is divided into three stages: the first stage is the production oriented energy consumption. At the end of nineteenth Century to mid twentieth Century, the development of energy industry in the world, based on coal, the energy dispersive energy development, unreasonable structure of energy consumption, mainly rely on self-balance; the second stage is oriented by efficiency way of energy consumption. From the mid twentieth Century to the end of twentieth Century, the rapid development of world economy, the energy industry began to take the efficiency as the guidance, development and conservation of energy, a variety of common development, energy consumption in electricity and coal; the third stage is the sustainable development oriented energy consumption patterns. Since the beginning of twenty-first Century, the development and utilization of new energy is highly valued, and the proportion of energy in the final energy demand in higher power allocation of energy resources efficiency is more significant, worldwide network to interconnection direction, gradually formed to deliver clean energy as the leading global Internet, ubiquitous smart the grid - Global energy Internet [1-4]. This is an important transition period from fossil fuels to clean energy sources.

As the main body of global energy consumption, urban energy demand is huge, but urban resources are scarce. At the same time, the urban energy consumption structure is irrational, and the urban energy system has serious pollution problems. Therefore, in order to solve the city energy security, environmental pollution and energy consumption in the city cannot balance problems, the city area as the main form of global unit, construction of city energy Internet, realize the energy structure from high carbon to low-carbon, energy efficiency, to change the allocation of resources by the local balance to optimize the allocation of large range by the way, the energy service supply to the

intelligent interactive by extensive model use, effectively undertake the construction and development of global energy internet.

Some scholars have been on the global energy Internet related theories have made some research on the Internet, and for the city of energy related theory research literature: less [5] to establish the basic framework of energy Internet, discusses the basic structure and composition of the energy of the Internet literature; [6] established the energy Internet system model based on distributed generation; [7] given renewable the energy of high permeability, nonlinear stochastic, multi-source data and multi-scale dynamic 4 energy characteristics of the Internet literature; [8] established the basic model of energy router; literature [9] relying on the Beijing Yanqing smart grid innovation demonstration area construction project, analyzes the basic conditions and characteristics of the new energy Yanqing area, demonstration area was discussed from the energy supply and the form of consumption, main carriers, energy transportation management decision-making and public service etc. The contents of the building, build the application framework model of the energy of the Internet literature; [10] analysis and role positioning in the smart grid energy Internet system, put forward the "generalized energy Internet source - Net - charge - storage" coordination and optimization of operation mode. Most of the above literatures put forward a theoretical framework for energy Internet, and failed to put forward the development ideas and specific targets of energy Internet application in urban areas, which cannot guide the construction and development of integrated energy system.

Therefore, according to city regional energy Internet research: first a comprehensive analysis on the current situation of city energy development and comparison; on this basis, puts forward the theoretical framework of city energy Internet, and puts forward the target system to make quantitative analysis on city energy Internet development goals; finally, taking Tianjin as an example, put forward the development city planning of the energy of the Internet, to provide theoretical support and practical basis for future energy network construction.

2. Status and Challenges of Urban Energy Development

2.1. Raging Energy Demand in Urban Area

The city is the world's major economic activity and energy consumption place. In 2014, the global total GDP reached 77 trillion US dollars, of which only 300 of the world's largest cities GDP has reached more than 38% of the global total. The same year the world's total energy consumption reached 12 billion 928 million tons of oil equivalent, equivalent to 150276 TWh of the total electricity demand, of which 80% of the energy consumption is concentrated in the city. Table 1 presents the current situation and trend data of energy demand in four typical cities.

Table 1. Energy demand in Typical Cities

Cities	Energy needs /(TW·h)		
	2014	**2030**	**2050**
New York	1062	1300	1600
Beijing	556	750	900
Shanghai	902	1250	1600
Tianjin	663	950	1200
Total major cities in the world	120 221	166 000	190 000
Global total	150 276	210 000	240 000

At this stage, the city energy demand is huge, and with the expansion of urban scale and economic development, the energy demand of some cities will steadily increase in the future. Visibly, the city is the world's major contributor to GDP, but also the main energy consumption.

2.2. Energy Shortage in Urban Areas

Renewable energy which has been developed in city is not high, the future development of the total is very limited. Relatively speaking, the city has a huge demand for energy, in addition to renewable energy, other energy sources (especially fossil energy) basically rely on delivery, and the city presents

typical characteristics of energy consumption. Figure 1 shows the contrast between the amount of renewable energy, the amount of development, the amount of development and the total demand for energy in five typical cities.

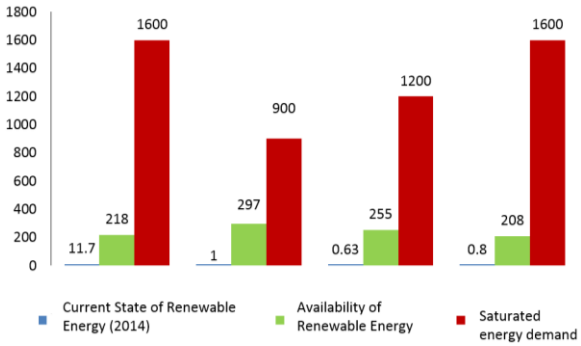

Figure 1. Renewable Energy and Energy Demand of Typical Cities (Twh/per year).

In the above figure, we can discover that there are some critical imbalances between supply and demand in these cities. There is a large shortage in local energy supply. The major part of energy needs be imported externally. Therefore, these cities are under severe energy resources deficiency.

2.3. Severe Pollution due to Urban Energy Consumption

So far, fossil fuel is still a major energy resource for urban energy consumption, and also the main source for urban pollution.

WHO global urban ambient air quality report shows that 89% of urban air quality fails to meet its health standard, where the air quality indexes of 57% of cities are 2.5 times higher beyond the standard value.

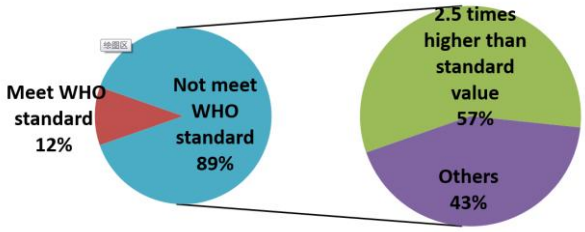

Figure 2. WHO Global Urban Air Quality Report.

The global urban pollution and CO_2 emission continue to increase year by year. A contradiction between urban development and environmental protection needs to be resolved as soon as possible.

3. Theoretical System of Integrated energy system

The integrated energy system is a connecting point for both global energy internet and Chinese energy internet. The essences of integrated energy system are electricity-oriented, cross-regional balance and low carbon.

City energy Internet is global energy Internet, Internet and China energy to undertake further extension on the load side of the subset, is the world's energy delivery to the end of the channel is an important support to protect thousands of households, with well ensure high voltage long distance transmission end, is an integral part in the city area of global energy Internet.

3.1. Core Concept

1) Electricity-oriented.

Considering power grid as a basic platform for energy allocation, it can support the integration of multiple energy resources (coal, oil, gas, wind, solar etc.) with electric power. Improve electric level has become to a basic measure to optimize energy structure and increase energy efficiency.

2) Cross-regional Balance

Gradually reducing the use of fossil energy and taking advantage of UHV long-distance transmission, it can increase the capability of receiving power externally and energy efficiency, solve the problems of large energy demand, deficient resources and environment protection, and promote optimal allocation of urban energy resources.

3) Low Carbon

By encouraging the large-scale integration of wind energy, solar energy and other external energy and promoting end-use alternative energy, it can boost market demand and benefit the development of low-carbon energy use.

3.2. System Architecture

Integrated energy system consists of physical layer, information layer, and service layer.

Service layer: Energy management platform of the city and service management center of integrated energy system.

Information layer: A communication and information system for all the regions and fields supplied by urban energy and the support of integrated energy system.

Physical layer: A strong, flexible, and sharing energy supply network and material basis of integrated energy system.

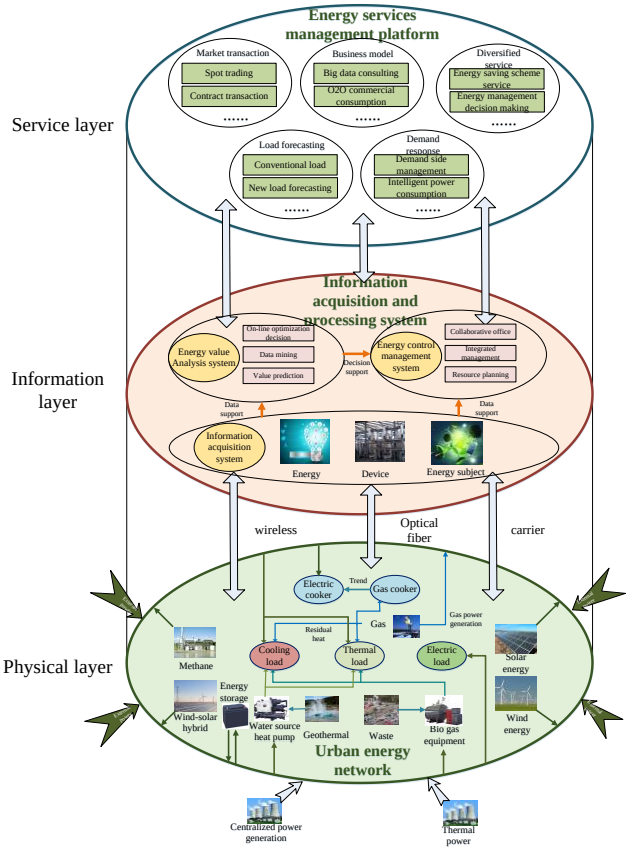

Figure 3. System Architecture of Integrated energy system.

3.3. Development Plan and Goal

Plan: By enhancing the construction of UHV external transmission and optimally coordinating different voltage level grids, large scale external electric power, wind and solar power can inject into the local network and be used properly. By encouraging smart grid construction and taking advantages of the internet properties of open, sharing, interaction, electricity, gas, heat and transportation networks can be connected and shared. By building energy service management platform, information collection and interactive business of the entities can be realized in the so called" source-grid-demand" structure. By exploring the value of each transaction of energy trade, it can stimulate the use of clean energy.
Development Goal: Constructing integrated energy system can overcome the issue of urban energy local imbalance, help to connect to global energy internet, realize large-scale energy allocation, drive the energy conversion between different types of energy resources and electric power, increase the ratio of using clean energy in the demand side, optimize urban energy pattern, increase energy efficiency, stimulate clean energy utilization, and achieve the carbon-free urban energy consumption.

4. Target System of Integrated energy system

The theoretical research on the integrated energy system has already taken shape, but there has been no research on the target system that reflects the level of integrated energy system development. Therefore, it is urgent to study a set of target system to quantitative analysis of city energy Internet development level, city guiding direction of energy development and utilization, promote clean and efficient use of energy, reduce the city carbon emissions, clean, electrification, information and network energy transformation.

4.1. Networked Target

Networking is the basic form of integrated energy system. Integrated energy system connection to external clean energy through UHV power transmission, the power is transmitted to the user through the internal implementation of strong smart grid, energy flow through the regulation of energy efficiency management platform and advanced communication technology, can realize the interconnection of various energy sources, and it is the efficient connection between energy and consumption.

Table 2. Networked Target

	Index	Unit
Networking	Energy form connectivity	%
	Sharing rate of energy service platform	%
	Energy information acquisition coverage	%

Energy form connectivity = the forms realizing energy connected with the energy management platform / total urban energy forms × 100%;
Sharing rate of energy service platform = the forms of energy sharing for service platform sharing / total urban energy forms × 100%;
Energy information acquisition coverage = energy information indicators that can be obtained / total information index × 100%.

4.2. Cleaning Target

Cleaning is the ultimate goal of integrated energy system. The construction of the Internet will be the implementation of the "energy city" development and utilization of clean energy and a high proportion of external power receiving wheel drive, to promote synergy, the eventual establishment of a clean energy lead new city energy supply system.

Table 3. Cleaning Target

	Index	Unit
Cleaning	Carbon emission per unit GDP	t/10000yuan
	Proportion of fossil energy to energy consumption	%
	Clean energy accounts for the total installed capacity	%

	External charge ratio	**%**

Carbon emissions per unit GDP = urban CO_2 emissions / GDP × 100%;
Fossil energy consumption ratio = fossil energy consumption / urban energy consumption × 100%;
Total clean energy to total installed capacity = total installed capacity of clean energy power generation / total installed capacity of urban power generation × 100%;
External power ratio = external battery / terminal energy consumption × 100%.

4.3. Electrification Target

Electrification is an important means of integrated energy system. With the continuous development and utilization of clean energy, the proportion of power consumption in the city's terminal consumption has been greatly improved. It has gradually realized the use of electricity instead of coal, electricity instead of gas, electricity with oil, greatly reducing fossil energy consumption.

Table 4. Electrification Target

	Index	**Unit**
Electrification	**The proportion of electric energy to terminal energy consumption**	**%**
	Electric vehicle ownership	**%**

Energy consumption in terminal energy consumption = power consumption / terminal energy consumption × 100%;
Electric vehicle ownership = electric car ownership / car ownership × 100%.

4.4. High Efficiency Target

High efficiency is the key support of integrated energy system. By improving the conversion efficiency of energy generation, realize the power supply side of multi energy complementary, improve energy efficiency; through advanced information communication, intelligent control technology, realize the city energy height of Internet communication and flexible control, realize the efficient allocation of resources among different areas.

Table 5. High efficiency Target

	Index	**Unit**
High efficiency	**GDP energy intensity**	**Ton standard coal / 10000 yuan**
	Primary energy input output ratio	**%**
	Maximum load utilization hours	**%**

GDP energy intensity = urban energy consumption / GDP × 100%;
Primary energy input output ratio = (coal, oil, natural gas, etc.) primary energy consumption / terminal energy consumption × 100%;
Maximum load utilization hours = annual sale / maximum load.

5. Case Study

During the "13th Five-Year" period, State Grid Tianjin Electric Power Company has become the city energy Internet construction, operation and management of the leader from the aspects of construction of all-round construction of city energy Internet.

5.1. Construction Prospective from 2030 to 2050

In 2020, Tianjin integrated energy system will be preliminarily constructed, incorporated to Chinese energy internet. The cross-national energy internet will be also realized. Green energy to primary energy rate is over 20%, electricity to end-use energy rate will reach 25%.
In 2030, Tianjin integrated energy system will be completed. Cross-continent grid connection will be preliminarily realized. It begins to integrate with global energy internet. Green energy to primary energy rate is over 40%, electricity to end-use energy rate will reach 35%.

In 2050, Tianjin integrated energy system will be well developed and extended. The close connection will be realized for cross-continent grid connection. It fully engage into the integration of global energy internet. Green energy to primary energy rate is over 80%, electricity to end-use energy rate will reach 60%.

5.2. Target system of Tianjin energy Internet

Based on the integrated energy system target system, Tianjin is used as a specific city target to quantify the phased development goals of the integrated energy system, specifically as shown in the table:

Table 6. Target System of Tianjin Energy Internet

Index		Unit	2015 year	2020 year	2030 year	2050 year
Networking	Energy form connectivity	%	80	90	100	100
	Sharing rate of energy service platform	%	50	80	100	100
	Energy information acquisition coverage	%	70	90	100	100
Cleaning	Carbon emission per unit GDP	t/10000yuan	1.87	1.35	0.52	0
	Proportion of fossil energy to energy consumption	%	83	70	45	0
	Clean energy accounts for the total installed capacity	%	3.11	12	40	100
	External charge ratio	%	23	35	45	60
Electrification	The proportion of electric energy to terminal energy consumption	%	17	25	30	60
	Electric vehicle ownership	%	1.23	15	40	100
High efficiency	GDP energy intensity	Ton standard coal / 10000 yuan	0.5	0.42	0.32	0.18
	Primary energy input output ratio	%	38	50	70	90
	Maximum load utilization hours	%	4998	5200	5800	6500

6. Summary

To deal with the city's scarce energy resources, environmental protection pressure situation, to offer clean energy for the mission, to undertake and integrate into the global energy Internet, the definition and concept of integrated energy system is proposed, the three layer architecture, integrated energy system development ideas and objectives are put forward.

Integrated energy system theoretical framework and target system are helpful to the allocation of energy resources to achieve greater range, to promote all kinds of energy and electrical energy, to improve the proportion of clean energy use in the power generation side and power consumption in the side of the city, to achieve clean energy, electrification and information and the transformation of the Internet, to provide the theory of support and practical basis for the construction of city energy internet.

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