The Framework of Urban Energy Map and Case Study

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Abstract. Urban energy map is an energy solution that combines map elements and energy elements, including information of energy exploration and production, processing and transformation, transmission and distribution, consumption and other links, and is an important part of the construction of energy Internet. This paper proposes the overall framework and basic functions of urban energy map, which include three parts: data layer, technology layer and interaction layer. Taking geographic information system (GIS) as the spatial support technology, and based on the industrial enterprise energy data collected by Spatiotemporal database of China energy flow and carbon emission (SDCEC) and other relevant data from Suzhou Smart Energy Management Platform, the energy map of Suzhou New District is drawn and its characteristics are analysed. The research shows that the urban energy map can effectively reflect the spatial concentration, pattern change, and ranking of urban energy consumption.

1. Introduction
The energy map is built upon energy spatial data (mainly for enterprises), integrating relevant data such as environment, economy, population, society, natural ecology, etc. With geographic location as the core, it realizes the correlation of multi-dimensional spatio-temporal dynamic information through location information and effectively links various locations information, including energy exploration and production, processing and transformation, transmission and distribution, consumption, etc. And then energy element layers with intuitive scene, accurate location and clear trajectory are formed, and a highly operable energy solution is produced.

The current studies related to urban energy maps have mainly focused on the integration of maps and the exploration and utilization of single energy variety, such as the integration of maps and power grids [1], the visualization of park power data [2], three-dimensional geographic information systems and building energy conservation [3], coal consumption maps [4], information management of natural gas gathering and transmission [5], and spatio-temporal maps of carbon emissions [6]. The above researches particle size is mainly macro and there is a lack of energy map research with enterprises as the smallest energy consumption unit. This paper is based on the principles and methods of urban energy map construction, takes GIS as the spatial support technology, and uses SDCEC database as the main initial data source. The main frame of the energy map is built, and Suzhou New District is taken as an example to draw a regional energy map, and finally the spatial characteristics of its energy consumption are analysed. The content structure of the article is as follows: in the second part, the
framework structure and main functions of the urban energy map are introduced. The third part introduces the characteristics of energy data and data sources for constructing the prototype of the Suzhou New District energy map. In the fourth part, the results of the Suzhou New District energy map are given and the characteristics are analysed. The fifth part gives the main conclusions of this paper.

2. Overall framework and basic functions

2.1. Overall framework
The overall framework of the urban energy map is mainly composed of three parts: the data layer, the technology layer, and the interaction layer. The basic structure is shown below:

2.2. Basic functions
According to figure 1, the urban energy map is equipped with basic functions such as multi-source access, panoramic display, online analysis, scene simulation and human-computer interaction.

2.2.1 Data layer. The basic functions of the data layer is to access energy data from multiple sources, including public data sources (statistical data of energy, economy and population, non-statistical data, etc.), professional databases (SDCEC, etc.), secondary processing data (processed data based on big data technology), etc.

2.2.2 Technology layer. The technology layer is a series of technologies that support the construction of urban energy maps, including energy flow maps, geographic information systems, database technologies, etc., and supports functions such as panoramic display of energy consumption and utilization, online analysis, and scene simulation, etc.

2.2.3 Interaction layer. The main function of the interactive layer is to form a friendly interface for human-computer interaction, including a public interface and a dedicated interface. The public interface mainly displays public data and spatio-temporal information, energy supply and demand information, etc. The dedicated interface mainly displays data correction and inspection results, energy system problem diagnosis, energy clean index ranking and other contents.
3. Data characteristics and classification

3.1. Data characteristics
The basic characteristics of urban energy data are: (1) huge data volume; (2) high data generation rate, high timeliness requirements; (3) diversified data types. Energy big data is usually structured, semi-structured and unstructured data. In addition, there are some inter-industry data (such as electric vehicle related data) and external industry data (such as weather data). (4) The energy big data is of low potential value density, but of high value in fact. The value of energy big data needs to be explored and tapped to make sense to support business decisions or customer service.

3.2. Data classification
The data required by the urban energy map are mainly thematic data with spatial attributes such as city full-caliber enterprise data, key energy consumption enterprise data, power plant and coal-fired unit data, coal-fired boiler data, etc.

3.2.1 Full-caliber enterprise data. The data of industrial and commercial registered enterprises is mainly grabbed from public websites and statistical literature using big data technology and tools. The data entry content includes the province (region, municipality), prefecture, district / county, street / township, industry, detailed address, main products and other information.

3.2.2 Key energy consumption enterprises data. The data of key energy-consuming enterprises is mainly selected and collected from professional databases, such as "China Industrial Enterprise Environmental Database", "China Industrial Enterprise Database", "China Small Business Investigation Database", etc.

3.2.3 Power plant coal-fired unit data. The data entry content of power plant data includes the capacity of power generation equipment at the end of the period, power generation, on-grid electricity, average utilization hours of power generation equipment, standard coal consumption for power generation (tce), standard coal consumption rate for power generation, standard coal consumption rate for power supply, raw coal consumed for power generation, natural gas consumed for power generation, heat supply, heating standard coal consumption, heating standard coal consumption rate, and heating fuel consumption (raw coal and natural gas), etc. The data entry content of the coal-fired unit data entry includes the name of the company to which each coal-fired unit belongs, the company's unified social credit code, the company's industry code, unit number, rated capacity, unit nature, power supply coal consumption (g / kWh), soot / sulfur dioxide / Nitrogen oxide emission concentration, whether it is connected to the grid, the year of operation, the annual power generation, the average annual utilization hours, etc.

3.2.4 Coal-fired boiler data. The coal-fired boiler data includes the name of the unit to which the coal-fired boiler belongs, detailed address, certificate number, boiler model, corresponding boiler steam tonnage, user unit, user unit address, boiler purpose, boiler scale, remediation measures, completion time, SO2 emission reduction (ton), NOx emission reduction (ton), soot emission reduction (ton) and other basic information.

4. Construction and Analysis of Suzhou New District Energy Map

4.1. Construction steps
Step 1: Extract and summarize the full-caliber enterprise data of Suzhou New District from relevant databases and collected data.
Step 2: Deeply clean and verify the extracted data, and obtain the total number of enterprises (4345 in 2014, 4716 in 2015, 5119 in 2016) and above-scale industrial enterprises (679 in 2014, 687 in 2015, 690 in 2016) with the same amount as the "Statistical Yearbook of Suzhou New District".

Step 3: Merge all enterprises into 20 major industries, including textile industry and so on.

Step 4: Collect and certify the energy consumption by variety of each industry, which mainly includes comprehensive energy consumption, raw coal, cleaned coal, coke, other coking products, coke oven gas, blast furnace gas, natural gas, gasoline, diesel, heat, electricity, etc. The total energy consumption of studied enterprises accounts for about 90% of the total energy consumption of the Suzhou New District.

Step 5: Collect and calculate the output value of various industries, employees and other information.

Step 6: Based on the GIS-Suzhou platform, locate and update all energy consumption points of above-scale industrial enterprises in the Suzhou New District.

Step 7: Import energy data, output value data, and employee data of each consumption point into the GIS-Suzhou database and associate them.

Step 8: Update and form the energy map system of Suzhou New District by industry sector.

4.2. Results analysis

4.2.1 Basic information of Suzhou New District.
Suzhou New District has a good energy data base with rich industry types. There are old and new industries intertwined, with large-scale textile, steel and other traditional high energy-consuming industries, and also a large number of high-tech industries with low energy intensity. Thence it’s very representative for the energy map research.

4.2.2 Energy spatial pattern and ranking characteristics.

Industry classification and its abbreviations are as follows:

| Industry classification                        | Abbreviations |
|-----------------------------------------------|---------------|
| Smelting and Pressing of Ferrous Metals       | SPFM          |

Figure 2. Changes in the top 10 industries in Suzhou New District by spatial location and their comprehensive energy consumption from 2014 to 2016.
Raw Chemical Materials and Chemical Products  RCMCP
Computer, Communications and other Electronic Equipment Manufacturing  CCoEEM
Production and Supply of Electricity & Heat Industry  PSE&HI
Electric Equipment and Machinery  EEM
Nonmetal Mineral Products  NMP
Automotive Industry  AI
General Equipment Manufacturing  GEM
Rubber and Plastic Products Industry  RPPI

It can be seen from figure 2 that there is relatively high energy consumption concentration in Suzhou New District, and the top five industries account for nearly 80%, showing a trend of agglomeration. From vertical comparisons in different years, the map can visually show the industry rankings and changes in energy consumption and the changes in energy companies involved. Taking the 2016 results as an example, the top five industries in overall energy consumption remain unchanged from 2014-2015. The raw chemical materials and chemical products ranks first, with consumption of 432,114 tons of standard coal, accounting for 27% of total consumption, an increase of 41,593 tons of standard coal over the previous year, and the number of industry-affiliated enterprises increased to 54. The smelting and pressing of ferrous metals industry ranks second, with a consumption of 315,887 tons of standard coal, accounting for 20% of the total consumption, a decrease of 20,636 tons of standard coal over the previous year, and still 9 companies affiliated with the industry. In 2016, the total energy consumption of the top five industries totalled 12,745,512 tons of standard coal, accounting for 78% of the total energy consumption of industrial enterprises above designated size in the year, and a cumulative increase of 25,295 tons of standard coal over the previous year. While the total energy consumption of above-scale industrial enterprises decreased by 9183 tons of standard coal, the consumption of the top five industries rose against the trend, showing a trend of energy consumption gathering in a few major energy-consuming industries.

4.2.3 Coal spatial pattern and ranking characteristics.
The energy map can also show the characteristics of different energy varieties. Here gives the results of coal spatial pattern and ranking characteristics. Coal consumption for power generation occupies most, and the difficulty of coal reduction changes from easy to difficult in the near future. The consumption of raw coal of above-scale industrial enterprises in Suzhou New District decreased from 767,500 tons in 2014 to 696,800 tons in 2016. In 2016, the total consumption of raw coal in the top five industries totaled 689,952 tons, accounting for 99% of the total coal consumption of above-scale industrial enterprises in the year. The proportion of coal used for power generation ranking in the first place increased rapidly by 4 percentage points to 81%, further expanding the gap compared with the second-ranked industry in the consumption of raw coal.

4.2.4 Natural gas spatial pattern and ranking characteristics.
The analysis of natural gas follows the same principle. The spatial pattern and ranking characteristics of natural gas in Suzhou New District are: stable growth and time to release potential. From 2014 to 2016, the consumption of natural gas of above-scale industrial enterprises in the Suzhou New District was stable, with annual consumption slightly higher than 110 million cubic meters. Taking 2016 as an example, the top five industries remained unchanged. The non-metal mineral products industry ranked first, with consumption of 32.59 million cubic meters, accounting for 28% of total consumption, an increase of 5.61 million cubic meters over the previous year, and a decrease of 2 companies. The computer, communications and other electronic equipment manufacturing industry ranked second, with consumption of 21.92 million cubic meters, accounting for 19% of the total consumption, a
decrease of 2.04 million cubic meters over the previous year, an increase of 6 companies over the previous year, and the total number of companies increased to 121.

5. Conclusions
Based on the concept of coordinated development of cities and energy system, this paper puts forward the overall framework and basic functions of urban energy map construction, accomplishes the energy map of Suzhou New District and the characteristics are analysed.

The main conclusions are that: (1) there is relatively high energy consumption concentration in Suzhou New District, and the top five industries account for nearly 80%, showing a trend of agglomeration. (2) Coal consumption for power generation occupies most, and the difficulty of coal reduction changes from easy to difficult in the near future. (3) The consumption of natural gas has stable growth and needs time to release potential.

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