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Spatial Quantitative Analysis of Urban Energy Consumption Based on POI and Night-Time Remote Sensing Data

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Abstract: Climate change has become a major global environmental issue that is widely concerned by countries around the world. It has been a very clear scientific consensus that the global carbon emission has to be cut urgently, facing the global warming and extreme climate. Currently, few studies on the urban energy consumption in total have been performed, especially the quantitative research on the scale of urban blocks, which is actually required by cities, in order to adopt precise control, optimize energy structure and reduce carbon emissions. It is time for joint action of the four sectors to accurately calculate synthesized energy consumption of each region, realize spatial energy consumption visualization, and formulate energy reduction targets and strategies more accurately. This paper has taken Jingmen, a resource-based city, as a case city. It quantitatively analyzed the spatial data affecting carbon emissions in transportation, industry, and construction sectors, respectively and discussed the impact of urbanization and industrialization on urban energy consumption. It is found that the continuous growth of energy consumption in the industrial sector has been the main driving factor for the city's total energy consumption growth. The energy consumption of Jingmen showed a trend of increase and concentration. The conclusions can fill up the problems that cannot be found in the energy consumption statistics of cities, and propose a more accurate way to reduce energy consumption in Jingmen City, which provide a reference for the green transformation of similar small and medium-sized resource-based cities.

Keywords: Climate Change, Energy Consumption, Night-Time Remote Sensing, Urbanization, Spatial Data, POI

1. Introduction

Climate change has become a major global environmental issue that is widely concerned by countries around the world. There has been a very clear scientific consensus that global carbon emission has to be cut urgently, towards global warming and extreme climate. Climate Change 2021: The Physical Science Basis published by IPCC confirms that "It is unequivocal that human influence has warmed the atmosphere, ocean and land." [1] The United States, China, and the European Union have set carbon neutrality targets. Special Report on Global Warming of 1.5°C (SR15) finds that limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities [2]. Around 2015, half of the world's population lives in cities, and this number continues to grow. It is estimated that 70% of the world's population will live in cities in 2050; cities occupy only 3% of the earth's land area, but energy consumption accounts for 60%~80%, carbon emissions account for 75% [3]. As a spatial combination space where human productive activity and daily life are highly concentrated, cities are also areas where energy consumption and pollution are highly concentrated. As the main body of energy consumption and carbon emission, cities should make appropriate adjustments and optimizations to the existing energy system and carbon emission system to face the above challenges.

The "Global Mining Development Report (2020-2021)" [4] shows that since the outbreak of the COVID-19 epidemic, global energy resource demand has generally shrunk. In 2020, global energy consumption dropped by 4.5%. The growth is mainly due to the companies rearranging their operations and recovering from the COVID-19 impact. But the market and global energy consumption is expected to revive soon. China has become the world's largest emitter of greenhouse gases in 2007, and its emissions account for approximately 20% of the world's total emissions [5]. Since Paris Agreement in 2016, China has realized its responsibilities and strengthened its environmental protection goals. In recent years, the total energy consumption of my country's 287 prefecture-level cities is 1.366 billion tce, and the carbon dioxide emissions are 2.916 billion tce, accounting for 55.48% and 54.84% of total. In 2020, the urbanization rate of my country's permanent population will reach 63.89%, and it is expected to reach more than 70% in 2035, which is close to the level of developed countries. With the acceleration of my country's urbanization process and the improvement of people's living standards, it will have two effects on energy consumption:(1) Further increase the energy consumption of residential buildings, and the scale of urban residents' demand for electricity, natural gas, coal (such as heating in winter) and other energy sources continues to expand;(2) Due to the acceleration of industrialization in some cities, energy has gradually become an important input factor, and energy consumption has accelerated [6].

At present, domestic and foreign research on urban energy consumption is mainly based on the macro-scale, and the research objects are the world, countries, provinces, cities, etc. Oda and Maksyutov [7] used point source databases and night light data to analyze the global 1 km×1 km high-resolution global fossil fuel carbon dioxide emission inventory from 1980 to 2007. Meng et al. [8] used DMSP/OLS to develop a top-down method for estimating city-scale CO_2 emissions, showing that the proportion of China's urban CO_2 emissions and per capita emissions is increasing. Ghosh et al. used night-time remote sensing data to create a global grid of fossil fuel carbon dioxide emissions [9]. Su Yongxian used DMSP/OLS night light data to conduct research on carbon emissions from energy consumption in China [10]. Liang Jing and Zhang Lixiao analyzed the spatial distribution characteristics of energy consumption in provincial capitals in my country [11]. Liu Zhu et al. calculated urban carbon emissions based on total energy consumption, energy balance and final energy consumption [12]. Wang Lei and Wei Houkai [6] analyzed the impact of China's urbanization on energy consumption by analyzing the relationship between urbanization rate and other indicators and energy consumption. But the research characteristics of these large-scale urban energy consumption fields:(1) Energy consumption research at the city level is mainly estimated based on per capita carbon emissions and statistical yearbook data. (2) Most energy and carbon emissions studies are concentrated on the city or urban scale, and there is a lack of smaller-scale research models. In addition, the existing urban energy planning lacks proper representation of the spatial distribution of energy consumption.

In addition, there are also many studies on urban energy consumption for a single energy consumption sector. Wu Di and Mao Jiansu analyzed the basic characteristics of industry and energy consumption in my country's key cities [13]. Shi Yuchun used the LEAP model to conduct an analysis and research on industrial energy consumption in Dalian [14]. Li et al. used a full life cycle dynamic simulation model to simulate the energy consumption of urban residential buildings [15]. At the same time, the author pointed out the problem of limited data sources. Huang Ying et al. simulated urban transportation energy consumption and low-carbon development paths based on the LEAP model [16]. Jia Tao et al. proposed a multi-source data fusion method for calculating carbon emissions with single buildings as the smallest unit, expanding the research scale of energy and carbon emissions from cities and urban areas to blocks and more detailed monomers building scale [17]. However, these studies on energy consumption sectors, such as transportation, construction, and industrial energy consumption studies, each have relatively complex models and are relatively independent. It is not convenient to compare the energy consumption of various sectors at the urban or finer scale, and also affects carbon emissions accounting. And quantitative research on energy consumption and air pollution.

Therefore, we consider how to use remote sensing and big data platforms to establish spatial models of industrial, construction, transportation, and comprehensive energy consumption to achieve block-scale urban energy consumption spatialization, and basically meet urban energy demand forecasts and refined governance and optimization of energy systems Adjustments are required for the purpose of energy saving and emission reduction. The aim of this paper is to (i) help to clear on quantitative analysis methods on precise scales of urban energy consumptions (ii) joint analysis of the four sectors to accurately calculate synthesized energy consumption (iii) spatial synthesized energy consumption.

2. Study Area

This paper selected Jingmen City as a case area, and its representative reasons are as follows: (1) Jingmen City is a microcosm of the development of small and medium-sized cities in China. In 2019, Jingmen City has a permanent population of 2,896,300, an urbanization rate of 57.91%, and a per capita GDP of 10,200 US dollars, which is equivalent to the national per capita GDP (10,300 US dollars) and urbanization rate (60.60%). High matching of features. (2) The energy consumption structure of Jingmen City is similar to that of China's traditional small and medium-sized cities. At the beginning of the 21st century, Jingmen City, as a city with heavy chemical industry as its background, has always been surrounded by petroleum, chemical industry, power plants, and cement. So far, coal is still the dominating energy resource in

Jingmen City, supplemented by petroleum. The production and utilization of clean energy has just started [18]. Energy consumption contributes 40% to the city's air pollution. (3) Jingmen City is in urgent need of green development and transformation to carry out comprehensive research on the urban energy system and carbon emissions. Its energy consumption model can be successfully transformed has important reference significance for the sustainable development of similar small and medium-sized cities.

Jingmen City is located in the central of Hubei Province, a regional central city in central Hubei with an area of about 12,000 km^2. Jingmen City currently has jurisdiction over Jingshan County, Shayang County, Zhongxiang City and Dongbao District, Diaodao District, Qujialing Management District, Zhanghe New District, Jingmen High-tech District, and 72 towns (blocks) (Figure 1) [19].

Figure 1. *Location map of Jingmen city (Sketch map).*

3. Research Methods and Data Sources

In 2015, the terminal energy consumption of Jingmen City was 6.2 million tce. Among the final energy consumption sectors, industry (industry and construction) was the main energy-consuming sector, consuming 3.87 million tce, accounting for 62.4%, followed by the construction sector (including commercial and public services, and residential life) consumes 1.3 million tce, and its energy consumption accounts for 21% of the total energy consumption. The transportation sector consumed a total of 750,000 tce, accounting for 12.1% of the total energy consumption. The rest is agriculture (including agriculture, forestry, animal husbandry, and fishery), which accounts for 4.5% of the energy consumption This article mainly analyzes the spatial distribution estimation methods of the three end-use energy sectors (accounting for 95.5% of the total energy use) industry, transportation, and building energy use [20].

Faced with the current ubiquitous research on urban energy consumption at the urban scale, on the one hand, it does not involve the consumption sector, while on the other hand, transportation, construction, and industrial energy consumption studies each have relatively independent and complex models, and the research results are not convenient for urban or fine-scale research. Comparing the energy consumption of various sectors, this study intends to use key related factors such as average traffic flow, building area, and major energy emission companies to conduct incomplete statistics on energy consumption of various sectors, and adopt big data methods such as night remote sensing and POI. Spatialize the energy consumption and comprehensive energy consumption of the block-scale energy terminal sector at the city level to more fully grasp the urban energy consumption path, as shown in Figure 2.

Total energy consumption of each town (block)=transportation energy consumption + industrial energy consumption + building energy consumption + others.

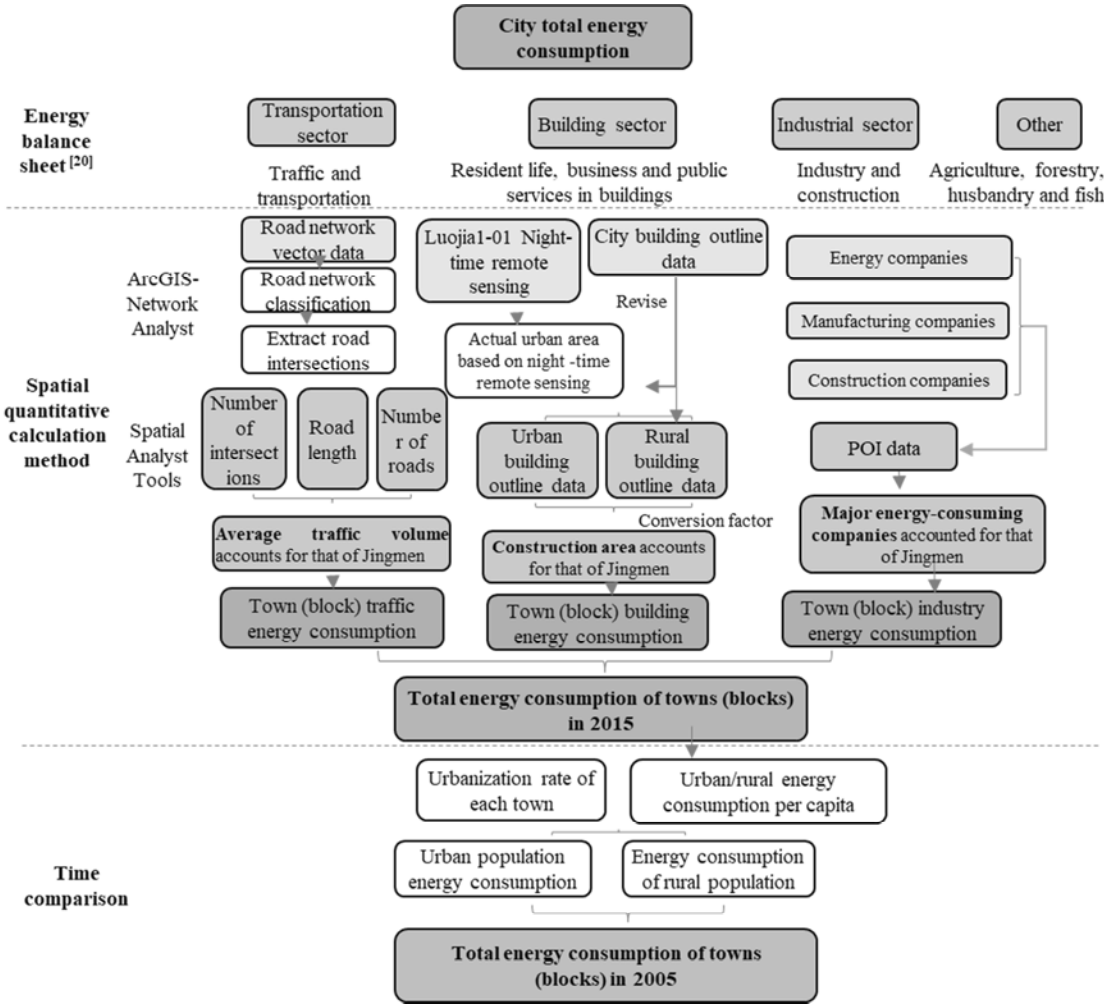


Figure 2. *Roadmap of urban energy consumption spatialization.*

Note: The energy consumption of the building sector in this article refers to the operating energy consumption of civil buildings (non-industrial buildings), including residential, commercial and public service energy. Excluding building material manufacturing energy consumption and building construction process energy consumption [19].

3.1. Transportation Sector Energy Consumption

The energy consumption of the transportation sector accounts for 12.3% of the total energy consumption of Jingmen City. Studies have shown that traffic volume is directly proportional to traffic carbon emissions. In areas with low traffic volume, traffic carbon emissions are small; and vice versa [21-22]. Refer to the Federal Highway Administration (FHWA) Road Monitoring System (HPMS) to multiply the annual average daily traffic volume of the sampled road section by the length of the road section to obtain the vehicle mileage traveled (VMT) which is the total mileage of all the motor vehicles traveled in the road network [23]. As a bottleneck restricting traffic flow [24], road intersections reflect the vitality of urban traffic and are an important factor reflecting the traffic volume and traffic energy consumption of road sections [25]. Studies have shown that night light images are suitable for the estimation of carbon emissions [26-27]. At the block level, the number of road intersections at the county level in Jingmen City is directly proportional to the DN value of the night light data, so this article uses the number of road intersections to represent the block-scale traffic volume. This is consistent with the fact that the number of road intersections above the county level in the rural areas of my country's small and medium-sized cities is small, and the number of road intersections above the county level in the center of towns and urban areas is large. Obtain the road network data of Jingmen City, and set the road grades of railways and expressways, first-class highways, second-class highways, third-class highways and urban roads to 5, 4, 3, 2, and 1 according to the current status of Jingmen's traffic road network. Network Analyst Tools in ArcGIS 10.2 was used to extract road intersections, and Spatial Analyst Tools was used to calculate the number of intersections in each town (block) (Zone field is selected as the road level). According to road length, road grades and road intersections at all levels, Calculate the total traffic flow of a town (block) in Jingmen City, and then calculate transportation energy consumption of the town (block) by calculating the town (block)'s total traffic flow proportion of the total traffic flow of Jingmen City.

3.2. Industrial Sector Energy Consumption

Industry is the main energy consumption sector in Jingmen City, accounting for 62.4% of the total energy consumption in Jingmen City. In 2018, the secondary industry accounted for 51.08%of the regional GDP of Jingmen City. In 2015, coal consumption accounted for 40.8% of final energy consumption, and its main consumption sector was the industrial sector. Diesel consumption accounts for 17.3%, and the main utilization sectors are industry and transportation. Electricity accounts for 16.7% of terminal energy consumption, mainly in the industrial and construction sectors. According on the characteristics of energy consumption in Jingmen City, the industrial energy consumption is calculated by numbers of various types of enterprises, including construction companies, energy companies, and manufacturing companies (including polluting chemical enterprises and waste gas emission enterprises) and the average energy consumption of each type (Table 1).

Table 1. *The status of polluting enterprises in Jingmen City.*

Chemical companies	Overview
Polluting chemical companies	6 wastewater discharge companies, 11 waste gas discharge companies, 5 sewage treatment plants, 15 heavy metal discharge companies, and 7 hazardous waste discharge companies
Exhaust gas companies	Eight nationally controlled emission gas source companies reported data. Compliance rate 87.5%
Energy utilization projects and companies	1) Coal-to-hydrogen project 2) 20,000 tons/year waste sulfuric acid regeneration unit construction project

3.3. Building Sector Energy Consumption

In 2015, the building sector was the second largest energy consumption sector in Jingmen City, accounting for 14.9% of the total energy consumption. At the end of 2019, the urban population of Jingmen City of 2,896,300 permanent residents was 1,741,400, an increase of 26,700 from 2018. The increase in urbanization rate will bring about an increase in energy consumption for buildings. In particular, after Jingmen City passed the "Interim Measures for the Management of Centralized Heating in the Central District of Jingmen" in 2019, it is expected that the energy consumption of urban residential buildings will further increase. Therefore, a reasonable assessment of the population and actual urban distribution of Jingmen City plays an important role in the spatialization of building energy use, and the assessment of the proportion of building energy use in the entire energy system. The light intensity of night time remote sensing data has a strong correlation with the block-scale residential population [29]. Regression analysis confirmed it by Luojia1-01 and NPP-VIIRS night remote sensing data and census data in Jingmen City. According to the clustering effect of urban population, this study intends to use night Light data to evaluate the actual city size [30]. In small and medium-sized urban areas, generally only building plan data can be obtained. The difference in height between urban buildings and rural buildings is important for evaluating the spatial distribution of building energy consumption. Therefore, a reasonable judgment of the actual urban area is very important for the results of the spatial distribution of building energy consumption calculation. According to field investigations, residential buildings in Jingmen City are mainly 4-6 storey residential buildings, and commercial buildings are mainly 4-6 storey buildings and 7-9 storey buildings, with an average of 6 floors. The rural buildings are mainly 1-3 storey buildings, with an average of 1.5 stories. Therefore, the conversion coefficient between the building outline area and the building area in Jingmen City is set to be 6 in the urban area, and 1.5 in the rural area. The building area of each town (block) is calculated as follows: the actual city size is judged by night-time remote sensing data, and building outline data is used as the fundamental basis, and the Identity function of ArcGIS Analysis Tools is used to distinguish urban areas. According to the ratio of the construction area of each town (block) to the total construction area of Jingmen City, the energy consumption of each town (block) is calculated.

3.4. Total Energy Consumption in 2005

Comparative analysis of changes in energy consumption is an important method to understand the impact of Jingmen's urbanization on changes in energy consumption. According to the Jingmen City Government Communiqué, the urbanization rate of Jingmen City was about 40% in 2005, and the urbanization rate was 55% in 2015. In 10 years, the urbanization rate increased by about 15%. According to the 2005 and 2015 statistical yearbooks of Jingmen City, the rural population and urban population of each town (block) in 2005 are estimated to calculate the energy consumption of each town (block) in 2005.

It is assumed that energy consumption increased year by year from 2005 to 2015; the growth rate of energy consumption is equivalent to the growth rate of urbanization. In 2005, the energy consumption of a rural person was about 1.5 tce. Based on this, the energy consumption of each town (block) in Jingmen City in 2005 was calculated.

4. Results

The area with the highest transportation energy consumption is Dadaoshi block, where the People's Government of Jingmen Municipality in the central district, with a prosperous economy and developed industry and trade with dense urban roads, and connecting national highways and expressways (Figure 3). This is in accordance with survey results that the highest population are concentrated in Nadaoshi Block; the number of household cars owned by every 100 urban residents is about twice the number of household cars owned by every 100 rural residents in Jingmen City [31]. Although transportation accounts for 12.3% of the total energy consumption, the exhaust emissions from urban traffic are one of the main culprits of severe haze weather [32]. It is recommended to build smart transportation systems to improve management levels [33] and improve the proportion of green travel, electric vehicles, etc., to slow down urban traffic energy consumption.

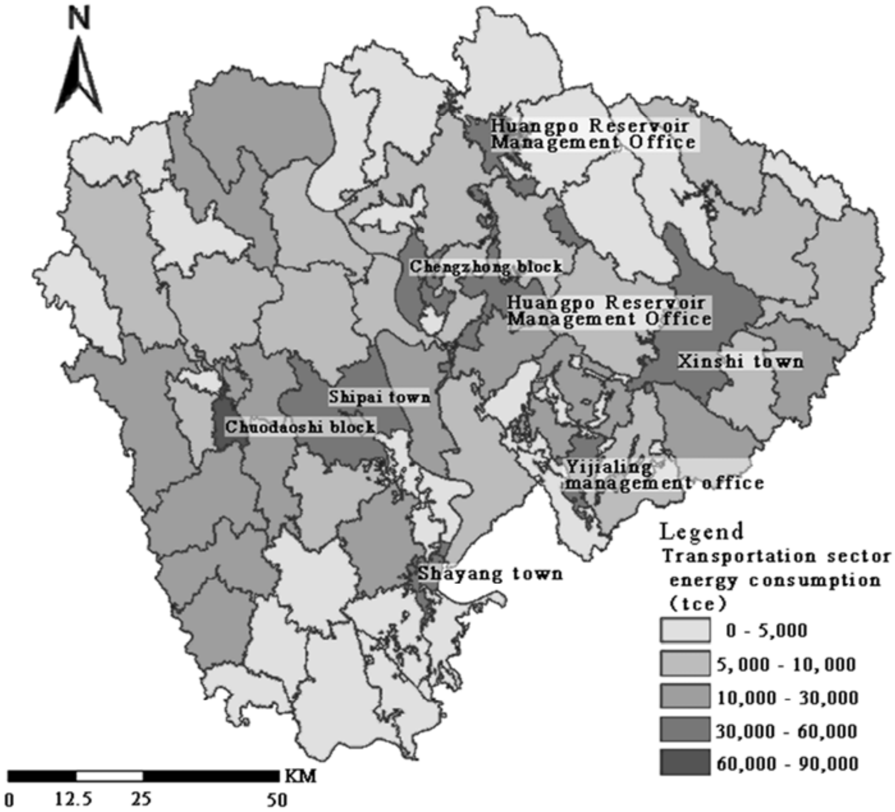


Figure 3. *Spatial distribution of energy consumption by transportation departments in Jingmen City.*

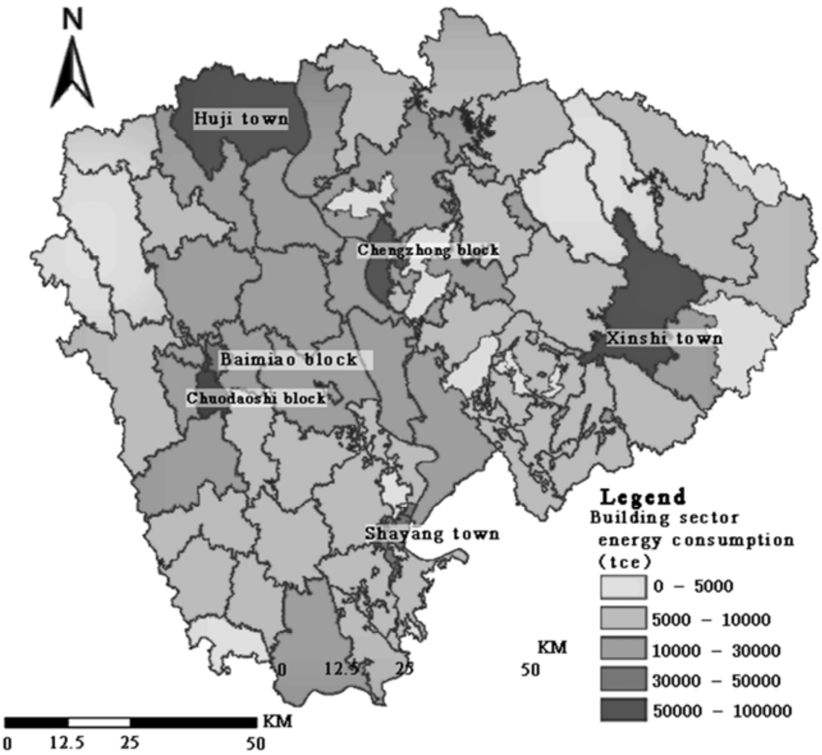


Figure 4. *Spatial distribution of energy consumption by building departments in Jingmen City.*

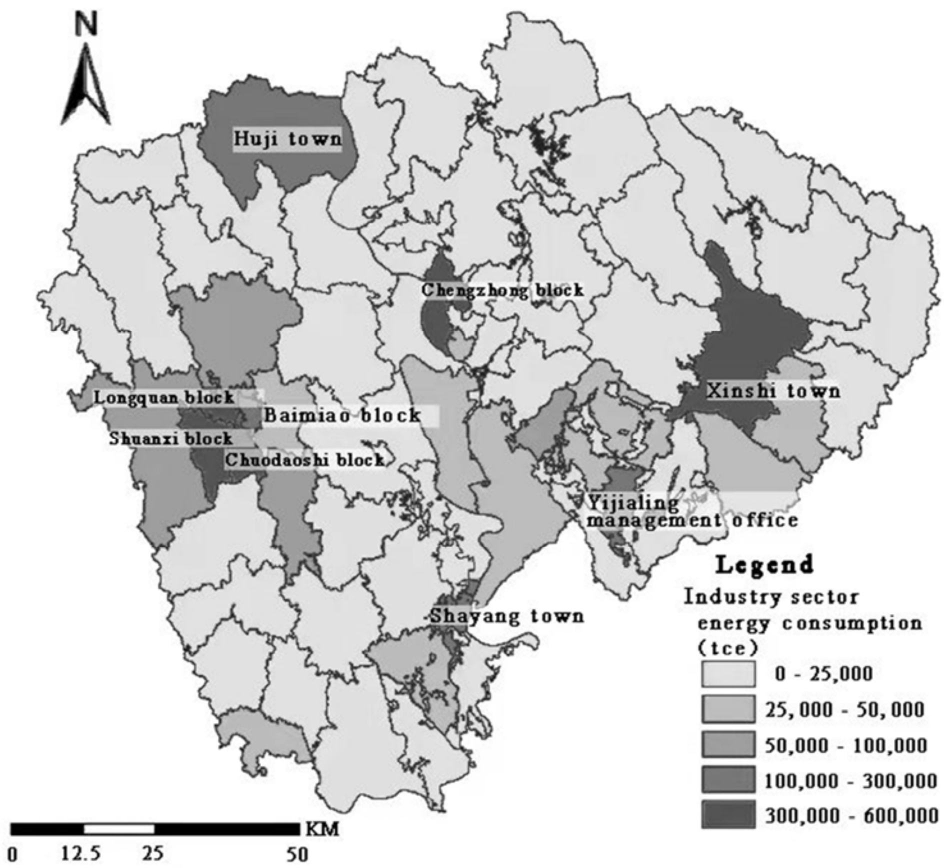
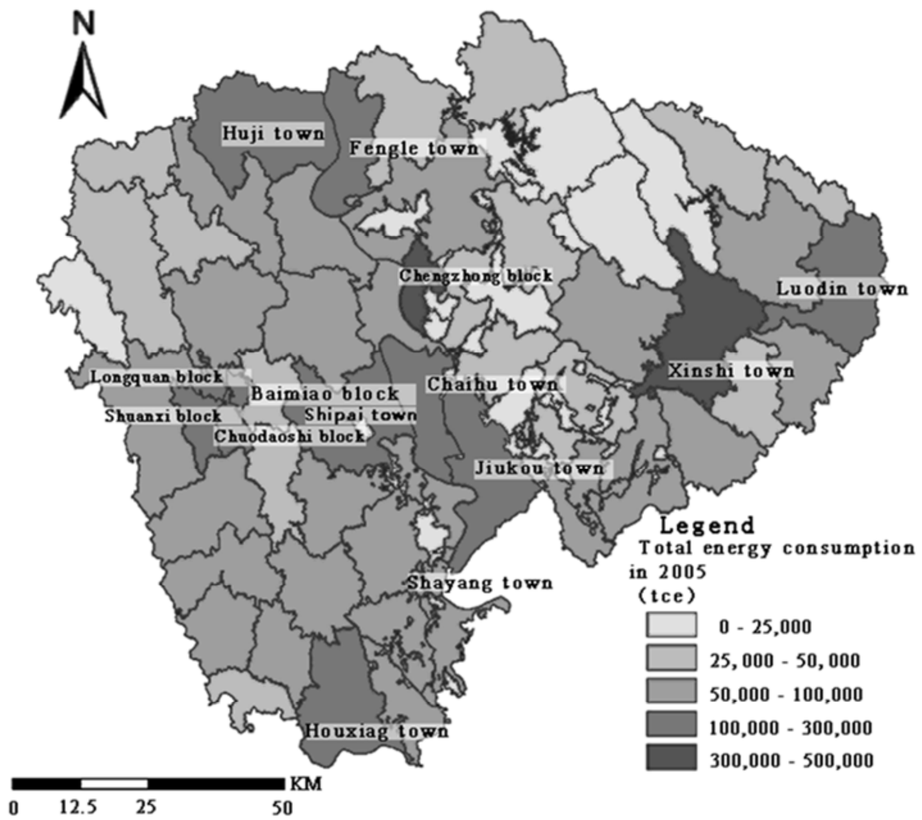


Figure 5. *Spatial distribution of energy consumption by industry departments in Jingmen City.*

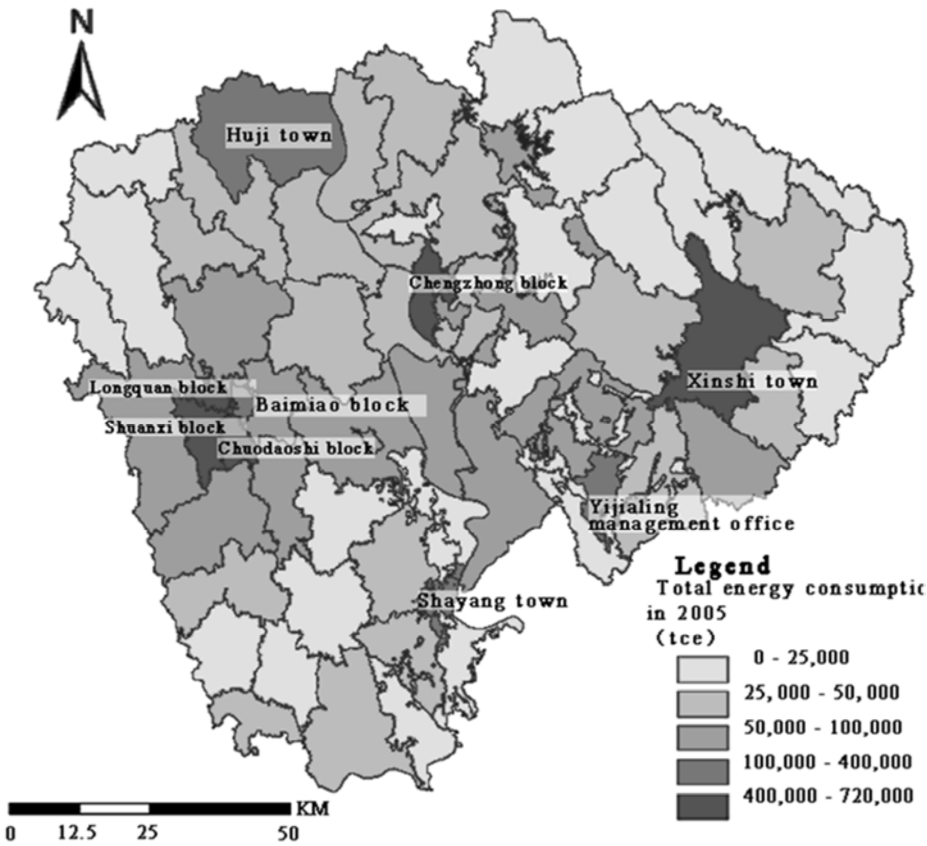
The areas with the highest energy consumption for buildings are Dadaoshi block, Yingzhong block, Xinshi town, and Huji town (Figure 4). Building energy consumption in most areas is less than 30,000 tce. With the urbanization and adjustment of industrial structure, as well as the rising living standards, the proportion of building energy consumption in Jingmen City may further increase in the future. It is suggested to promote the use of green buildings and renewable energy in buildings, combined with building energy-saving monitoring platform to improve energy efficiency.

Industrial energy is concentrated in Shuangxi Block, Dadaoshi Block, Longquan Block, Yingzhong Block and Xinshi Town (Figure 5). At the same time, the industrial energy consumption of the towns (blocks) with relatively advanced transportation systems such as expressways and national highways is also significantly higher than that of other regions. These areas are mostly concentrated heavy chemical companies such as phosphorous chemical, thermal power, petrochemical and refining chemicals. This is consistent with the research that the spatial distribution of secondary industries has the most significant impact on carbon emissions [34]. It is recommended to use towns (blocks) or enterprises that consume more industrial energy as the starting point to speed up the adjustment of industrial structure, improve energy efficiency, and reduce industrial energy use.

The results of the time-space analysis of the energy structure of Jingmen City from 2005 to 2015 show that in 2005, the total energy consumption of 58 out of 72 in total towns (blocks) was less than 10,000 tce (Figure 6). In 2015, the number slightly increased to a total of 62 towns (blocks). However, the total energy consumption of Jingmen City in 2005 was 5.3718 million tce, compared with 6.2 million tce in 2015, an increase of 828,200 tce. It shows that there is a trend of centralization in energy consumption in Jingmen City. The energy consumption of the main energy-consuming towns (blocks) has increased. Daodaoshi Block has increased from 249,793 tce to 454,099 tce. Centralization of energy use may bring about (1) centralized control of energy conservation and emission reduction is easier to achieve results; (2) if it is not controlled, it may cause local air pollution to worsen. Therefore, it is recommended that the Jingmen Municipal Government increase its efforts to control 10 energy consumption concentrated and industrial energy consumption dominant town or blocks, include Yijialing Office, Quankou Subdistrict, Huji Town, Shayang Town, Baimiaocheng District, Shuangxi Subdistrict, Jidaoshi Subdistrict, Longquan Subdistrict, Xinshi Town, Yingzhong Subdistrict.



(a) The spatial distribution of total energy consumption in 2005



(b) The spatial distribution of total energy consumption in 2015

Figure 6. *The spatio-temporal distribution of total energy consumption in Jingmen City.*

Figure 7. *Building footprint map (yellow) and satellite image (as basemap) for Jingmen.*

5. Conclusion

As the main body of energy consumption, cities have explored to adjust and optimize existing energy systems. Under the dual background of urbanization and industrialization, energy of traditional small and medium-sized cities in China still are dominated by coal and clean energy use has just started, how to clarify the key points of governance, and optimize the energy pattern is important for cities. However, using traditional methods to calculate energy consumption in urban fine scales often faces insufficient data problem, and thus it is difficult to study the problem of breakthroughs.

This paper uses a variety of big data sources including night-time remote sensing data, POI data, road network data, and building outline data to solve the problem of fine block scale data sources. The research analyzed energy consumption at the block scale and analyzes the time and special distribution of energy consumption to achieve more precise spatial resource allocation help to governance. The research conclusions can fill up the problems that cannot be found where city or urban area are used as the smallest energy consumption statistics unit. Results shows that as the urbanization rate of Jingmen City increases, energy consumption increases. In recent years, there has been a phenomenon that the distribution of energy consumption tends to be concentrated. Facing the increasingly severe pressure of carbon emission reduction, we suggest governments department can reduce the use of coal resources through industrial structure optimization and energy structure adjustment from the 10 towns (blocks) where industrial companies and energy consumption is concentrated in.

Meanwhile, the huge potential of rooftop photovoltaics is also a recommended way to reduce carbon emissions and increase the use of new energy (Figure 7). A total of 120 km^2 roof area was identified through outline data of different types of buildings with the correction coefficient Therefore, the potential area for installing photovoltaic modules on the roof is estimated to be about 42km^2 (assuming that the roof is a flat roof and 35% of the area on the roof can be used to install photovoltaic modules). Assuming that the photovoltaic efficiency is 180W/m^2, the total photovoltaic roof capacity of Jingmen is about 7560 MW. With the urbanization process and the continuous improvement of photovoltaic module efficiency, the potential of Jingmen's rooftop photovoltaic will be higher in the future. This study predicts that by 2030, the area of photovoltaic modules installed on the roof of Jingmen will increase by 30% (total 55 square kilometers). The total rooftop photovoltaic power generation capacity can reach 1.5-2 times of the current level.

At the same time, it should be noted that due to the complexity of traffic energy, building energy and industrial energy, this method is not a direct energy consumption accounting result. The absolute value of transportation, building and industrial energy consumption is not accurate in this paper. However, the significance of this paper is that it can spatialize the energy consumption of the city and enable the comparison of energy consumption in various towns (blocks) among the three main urban energy consumption departments, though it cannot fully reflect the actual energy consumption of each department. On the other hand, due to the complex factors involved, it is difficult to obtain block-scale energy consumption data within a city. It is suggested that follow-up research can deepen the energy consumption accounting methods of various consuming departments and improve the accuracy of the results. Although the spatial distribution of energy consumption is relatively in line with expectations, if the verification work can be carried out specifically for a certain area in the city, the reliability of the research results will be greatly improved.

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References

[1] IPCC AR6. Climate Change 2021: The Physical Science Basis. 2021-8-6. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.

[2] IPCC. Special Report on Global Warming of 1.5°C. 2018-10-8. https://www.ipcc.ch/sr15/.

[3] United Nations. Sustainable development Goal 11-Sustainable cities: Why they matter 2015. https://www.un.org/sustainabledevelopment.

[4] China Geological Survey of the Ministry of natural resources. The global mining development report 2020-2021. 2021-10-22.

[5] Lang Y H, Li H Q. International experience and China's actions in building a low-carbon energy system for cities. Energy of China, 2010, 07: 13-18.

[6] Wang L, Wei H K. The Impacts of Chinese Urbanization on Energy Consumption. Resources Science. 2014, 36 (6): 1235-1243.

[7] Oda T, Maksyutov S. A very high-resolution (1km×1 km) global fossil fuel CO_2 emission inventory derived using a point source database and satellite observations of nighttime lights. Atmospheric Chemistry and Physics, 2011, 11 (2): 543-556.

[8] Meng L, Graus W, Worrell E, Huang B. Estimating CO_2 (carbon dioxide) emissions at urban scales by DMSP/OLS (Defense Meteorological Satellite Program's Operational Linescan System) nighttime light imagery: Methodological challenges and a case study for China. Energy, 2014, 71: 468-478.

[9] Ghosh T, Elvidge C D, Sutton P C, Baugh K E, Ziskin D, Tuttle B T. Creating a Global Grid of Distributed Fossil Fuel CO_2 Emissions from Nighttime Satellite Imagery. Energies, 2010, 3, 1895-1913.

[10] Su Y X. Study on the carbon emissions from energy consumption in China using DMSP/OLS night light imageries. Guangzhou Institute of Geochemistry, Chinese Academy of Sciences. 2015.

[11] Liang J, Zhang L X. Analysis on Spatial Distribution Characteristics of Urban Energy Consumption among Capital Cities in China. Resources Science. 2009, 31 (12): 2086-2092.

[12] Liu Z, Geng Y, Xue B, et al. A Calculation Method of CO_2 Emission from Urban Energy Consumption. Resources Science. 2011, 33 (7): 1325-1330.

[13] Wu D, Mao J S. Comparative Study of Energy Consumption and Industrial Structure in China's Five Major Cities. Environmental Science & Technology. 2010, 33 (02): 184-191.

[14] Shi Y C. Analysis of industrial energy consumption in Dalian City based on LEAP model. Dalian Maritime University, 2014.

[15] Li G, Kou C, Wang H. Estimating city-level energy consumption of residential buildings: A life-cycle dynamic simulation model. Journal of Environmental Management. 2019, 240: 451-462.

[16] Huang Y, Guo H X, Liao C P, et al. Study on low-carbon development path of urban transportation sector based on LEAP model—take Guangzhou as an example. Climate Change Research, 2019, 15 (6): 670-683.

[17] Jia T, Yang S H, Li X, et al. Computation of carbon emissions of residential buildings in Wuhan and its spatiotemporal analysis. Journal of Geo-information Science, 2020, 22 (5): 1063-1072. DOI: 10.12082/dqxxkx.2020.190727.

[18] Municipal Government Office of Jingmen. The 13th Five-Year Plan for Energy development Hubei, Jingmen. 2016.

[19] Municipal Government Office of Jingmen. Jingmen new-type urbanization plan (2016-2020). Hubei, Jingmen. 2016.

[20] Gao N N, Zeng H, Li F. Spatial Quantitative Analysis of Urban Energy Consumption based on Night-Time Remote Sensing Data and POI. Journal of Geo-information Science, 2021, 23 (5): 891-902.

[21] Jiang Y. Current building energy consumption in China and effective energy efficiency measures. Journal of HV&AC, 2005, 35 (005): 30-40.

[22] Yan H, Wu Y, Zhang S J, et al. 2014. Emission characteristics and concentrations of vehicular black carbon in a typical freeway traffic environment of Beijing. Acta Scientiae Circumstantiae, 2014, 34 (8): 1891-1899.

[23] Xu S. Research on greenhouse gas emission inventory and its spatial distribution in Nanjing. Nanjing University, 2011.

[24] EPA. Development of Methodology for Estimating VMT Weighting by Facility Type 1999. Report EPA420-R-01-009, M6. SPD. 003.

[25] Zhang Y J. Research on Reverse Deduction of Traffic Flow at Road Network Intersections in Guiyang City. Dalian Maritime University. 2010.

[26] Li L Y, Cao D Z. The optimal prediction of road traffic flow and optimal control of intersection signal. Control theory and applications, 1993 (01): 67-72.

[27] Raupach M, Rayner P, Paget M. Regional variations in spatial structure of night lights, population density and fossil fuel CO_2 emissions. Energy Policy, 2009, 2: 61-65.

[28] SU Y X, CHEN X Z, YE Y Y, The characteristics and mechanisms of carbon emissions from energy consumption in China using DMSP/OLS night light imageries. Acta Geographica Sinica, 2013, 068 (011): 1513-1526.

[29] Zhao Y T. Model and algorithms for estimating fuel consumption and emissions on urban road network based on multi-source data. Beijing Jiaotong University, 2012.

[30] Gao N N, Li F, Zeng H, van Bilsen D, De Jong M. Can More Accurate Night-Time Remote Sensing Data Simulate a More Detailed Population Distribution? Sustainability, 2019, 11, 4488.

[31] Shu S, Yu B L, Wu J P, Liu H X. Methods for Deriving Urban Built-up Area Using Night-light Data: Assessment and Application. Remote sensing technology and application. 2011, 02: 44-51.

[32] Jingmen Bureau of Statistics. 2015 Jingzhou National Economic and Social Development Statistical Bulletin Hubei, Jingmen. 2015.

[33] Xie F F. Carbon Accounting and Space Distribution for the cities in China- A Case of Nanjing City. Nanjing University, 2013.

[34] Li X J. The Development of ITS in Europe and its Suggestions for China. Urban Transport of China, 2004, 2: 58-62.