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Research on Low-carbon Layout and Planning of Urban Space Driven by Sustainable Development

Youxiang Huan[1]

[1] Professor, Department of Architectural Engineering,
School of Civil Engineering, Yangzhou Polytechnic College,
Yangzhou, China
E-mail: **18012134611@163.com**

Abstract. Carbon dioxide emissions, leading to global warming, have threatened human development. It is urgent to control and slow down greenhouse gas emissions to maintain ecologically sustainable development. The energy demand and pollutant emissions generated in the process of urban development are the main reasons leading to climate and environmental change. Scientific planning for cities and construction of low-carbon urban development models are the first work to deal with climate and environmental issues. In view of these problems, the article takes Guangyuan City as an example of low-carbon city construction, through transforming the city's industrial structure, strengthening the energy and science and technology innovation, establishing and improving the low-carbon system and other methods to implement the specific construction of low-carbon city, to build a clean, low-carbon new urban life mode, Make Guangyuan City from 2015 to reach the exploitable hydropower installed capacity of 65% to 80% in 2020. In this paper, we propose a series of specific low-carbon urban spatial layout and planning strategies, which not only in-depth analysis of the key problems in China's urbanization process, such as energy consumption, carbon emissions, etc., but also propose targeted solutions. By implementing these strategies, we can effectively meet the challenges brought about by urbanization and promote the development of Chinese cities in a more low-carbon and sustainable direction.

Key words. Low-carbon City, Sustainable Development, Dioxide Emissions, Environmental Issues.

1. Introduction

To solve the contradiction of resource and environmental constraints, it is necessary to establish a resource-saving and environmentally friendly national economic system that is suitable for economic development, and take the path of new industrialization. The proposal of an environmentally friendly society is timely and in line with China's current national conditions. Currently, China is still a developing country with uneven regional development and much lower urbanization compared to developed countries. The population is mainly agricultural, on backward agricultural production and tens of millions of impoverished people. At present, China's high energy and high material consumption industries are developing intensively, and the problem of high pollution cannot be avoided. The vast majority of China's per capita resource share is lower than the world average, but its consumption is among the top in the world. All of these determine that our country must take the path of leapfrog development, that is, we must choose to build a resource-saving and environmentally friendly society [1]. At present, China is still a developing country, with unbalanced regional development and much lower urbanization than developed countries. China's agricultural population is mainly based on backward agricultural production and tens of millions of people living in poverty. At present, China's high energy consumption, high material consumption industry concentrated development, and high pollution problems cannot be avoided. China's per capita resources are mostly lower than the world average, but its consumption is at the forefront of the world [2], [3].

The primary breakthrough to solve the problem of resources and environment lies in cities. In order to balance the relationship between economic development and energy conservation and emission reduction, all countries in the world have carried out theoretical research and action practices on low-carbon cities [4], [5]. China's urbanization development is fast, but also needs to actively respond to the international trend, the urban construction of low carbon reform [6], [7].

Urban development has been injected with vitality because of the advancement of industrialization, but urban resources are tightening, environmental pollution is becoming increasingly serious, traffic congestion is too heavy, more and more unsuitable for living and other "urban syndrome" gradually prominent, the development of low-carbon cities is undoubtedly the way out of urban sustainable development [8]. Through comparative analysis, we can obtain valuable experience from it, and broaden our thinking by combining the experience of various aspects at home and abroad. To seek a more effective implementation plan for the sustainable development [9]. This paper studies that urban low-carbon development is an inevitable model of sustainable development.

2. Low Carbon Economy

A. Basic Concepts of Low-carbon Economy

In the study of this paper, we used a variety of data sources, including official statistics, field research data, and literature review. For the calculation of carbon emissions, we have adopted the internationally widely recognized IPCC (United Nations Intergovernmental Panel on Climate Change) method, and made appropriate adjustments based on the specific situation of China. Choosing Guangyuan City as a case study is mainly based on its representativeness in geographical location, economic development level and city scale, as well as its active exploration and practice in low-carbon city construction. The emergence of a low-carbon economy is important for global cooperation to fight against global warming and solve global climate problems. If we find out the corresponding theory from the economic theory then the market externalities should be more consistent with the low-carbon economy. In the process of production, enterprises will emit CO2, which will affect the global climate and increase the possibility of extreme weather around the world, which will affect the production of other industries. Therefore, the current carbon tax is to solve this externality [10], [11].

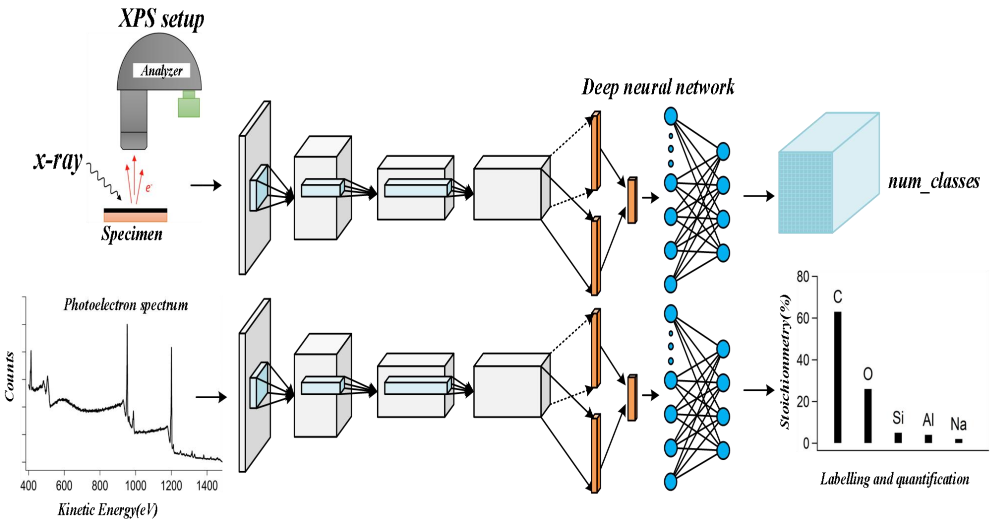

Figure 1. Sustainable Development and Urban Space and Low-carbon Layout

Figure 1 shows sustainable development and urban space and low-carbon layout. Firstly, based on industry types, a carbon emission model for energy consumption is established to correspond to its types and consumption situation. Quantitative analysis is conducted according to regional differences based on different types, and specific strategies are proposed to optimize spatial layout for emission reduction. When calculating carbon emissions from energy consumption, the consumption data from the energy balance sheets of each province in the China Energy Statistical Yearbook is used. Currently, there are mainly the following types of energy: fossil energy, electricity, wind energy, biomass energy, etc., which belong to the first category of energy; There are also secondary energy sources such as electricity and heat. In 2006, fossil fuels accounted for 86.9% of all energy consumption. As the most representative type of energy, fossil fuels are the main cause of carbon emissions. So, this article mainly focuses on fossil fuels or biomass energy, which belong to traditional high-carbon emission energy sources. Fossil energy is a necessary form of energy that includes coal, oil, and natural gas. This study is based on national statistical data and sorts out basic data according to different types of industries, consumption situations, etc. The formula of low carbonization target is shown in (1):

$$Q_{e1} = A_1\dot{x} + \frac{V_{e1} + A_1 x}{\beta_e}\dot{p}_{e1} \quad (1)$$

Where Q represents total carbon emissions, and P_{el} represents energy consumption. Energy-saving benefit is shown in Equation (2):

$$p_2 = 1 + A \cdot \exp(-\tau \cdot t) \quad (2)$$

Low carbon index is shown in Equation (3):

$$w_t = a \cdot \frac{\mathcal{F}^{-1}[z_t]}{\max|\mathcal{F}^{-1}[z_t]|} \quad (3)$$

Where w_t represents the carbon emission factor, and a represents the number of energy types.

B. Constraints of Urban Sustainable Development

The concept of carbon footprint, originally derived from the concept of ecological footprint, is used to measure the level of carbon emissions in a region. At present, different studies in different fields have different understandings of the concept of carbon footprint. To sum up, there are two levels of understanding: one is the surface understanding, which simply refers to the carbon dioxide directly caused by the burning of fossil fuels; The other is a deeper and broader understanding, which refers to the direct or indirect carbon dioxides generated by a product in its whole life cycle. This indirect emission also includes the indirect emission in its production or service process. This paper is based on the latter, the deeper and broader concept of carbon footprint. The industrial carbon footprint includes the carbon footprint of productive activities and the carbon footprint of non-productive activities [12].

Our goal is to calculate the carbon emissions of different types of industrial spaces and analyze their situation. Based on energy balance, we will construct a basic framework for energy consumption projects and land use, and make arrangements, mergers, and adjustments to establish corresponding relationships between different industrial spaces and carbon emission projects. The formula of the building energy efficiency benefit is in (4):

$$z_i = n \cdot \frac{1}{i \cdot \sigma\sqrt{2\pi}} \cdot \exp\left(-\frac{(\ln i - \mu)^2}{2\sigma^2}\right) \quad (4)$$

Where z_i represents the total carbon emissions of the transport system, And n indicates the number of vehicles.

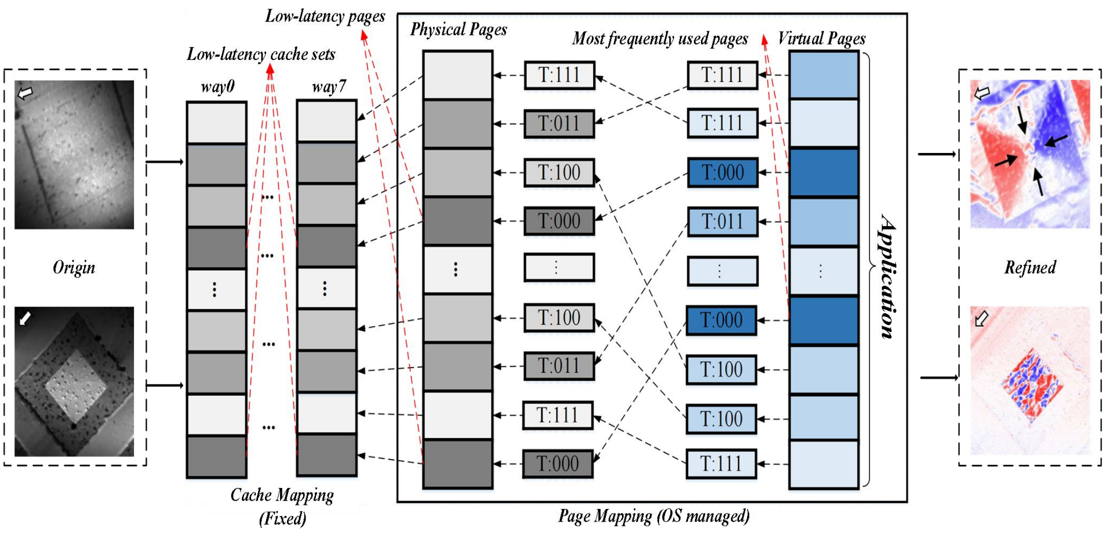

Figure 2. Theoretical Framework and Empirical Research

Figure 2 shows the theoretical framework and empirical research. The overall level of science and technology is backward, and the technology research and development ability are limited. Due to the overall backward level of science and technology, technology research and development capacity is limited, and China has to mainly rely on commercial channels to introduce, which has increased the intensity of carbon emissions. In addition, people's awareness of low-carbon consumption is weak, and they have not developed good consumption habits and lifestyle of energy conservation and emission reduction, which cannot be ignored as one of the restricting factors [13], [14].

As for the methods and work contents of low-carbon industrial planning, different countries and fields have many different perspectives and suggestions. Low-carbon industrial planning mainly includes the following three aspects: first, optimizing industrial structure; second, controlling industrial types with high energy consumption and high pollution from the perspective of energy; third, developing industries to low-carbon and clean types. The adjustment direction of industrial structure can be started from three aspects: the first is technological updating; the second is the adjustment of industry types; the third is the government's policy guidance, focusing on the development of low ecological, formulating regional enterprise access mechanism. The city's low-carbon industrial planning should be traced back to the source. The most important thing is to start from the carbon source, reduce carbon emissions from the root, pay attention to the use of renewable energy, and how to improve the final carbon sink through new means. In terms of the carbon sink, pay attention to improving the carbon sink, excavate ecological potential, and advocate ecological construction, so as to greatly increase the carbon sink.

3. Sustainable Urban Development

A. Low Carbon Cities

In industrial planning, each link is closely linked, from basic analysis to target setting to system construction and then to the final spatial layout is progressive, starting from strategic goals or simple system construction cannot guarantee the realization of low carbon. Only when each step of the implementation process is carried out in accordance with low-carbon standards, can it have a significant effect. Industrial planning includes many aspects, such as industrial system construction, industrial spatial layout, industrial development orientation and so on. These are all the things that make industrial planning tend towards the design aspect of low-carbon development.

Countries are progressively initiating pilot projects for the development of low-carbon cities, with several prominent foreign metropolises like London, Tokyo, and New York taking the lead. Northern European cities, including Copenhagen and Malmo, as well as certain Japanese cities, have also emerged as front runners in the construction of low-carbon urban environments. With zero-carbon cities such as Copenhagen, Aarhus and Senerburg as representatives, the Danish Pre-Release Bureau has proposed a green development model driven by innovation and targeted at zero carbon. In order to strengthen cooperation among the world's major cities and commit to reducing greenhouse gas emissions, in

2005, more than 40 major cities around the world initiated the establishment of the "World Metropolitan Climate Pilot Group" (referred to as C40), which has held three meetings since its establishment, in order to solve the key to climate change in their own hands [15], [16]. Energy consumption exceeds 2/3 of the world, and the annual carbon emissions of cities account for more than 70% of the world's total carbon emissions, so cities should fully and effectively implement policies and measures to address climate change. The formula of the carbon sink is shown in (5):

$$E_{MS} = \frac{1}{n}\sum_{i}^{n} (E_i - P_i)^2 \tag{5}$$

Where E_{MS} represents the distance traveled and P_i represents the unit of carbon emission.

B. Emission Reduction Strategies

As the spatial carrier of productivity and the basic administrative unit of a country, cities bear decisive responsibilities [17], [18]. In terms of urban planning, the problem mainly lies in the fact that urban environmental infrastructure and disaster prevention capacity cannot keep up with the pace of urban economic development. Secondly, from the perspective of the urbanization process, the disparity between the rich and the poor caused by unreasonable urbanization reduces the adaptability of vulnerable groups; Third, the labor transfer mode driven by urbanization and industrialization often intensifies the risk pressure in cities [19]. The formula of urban land compactness is in (6):

$$E_{RMS} = \sqrt{\frac{1}{n}\sum_{i}^{n} (E_i - P_i)^2} \tag{6}$$

Where n represents the number of vehicles, and Pi represents the energy efficiency ratio.

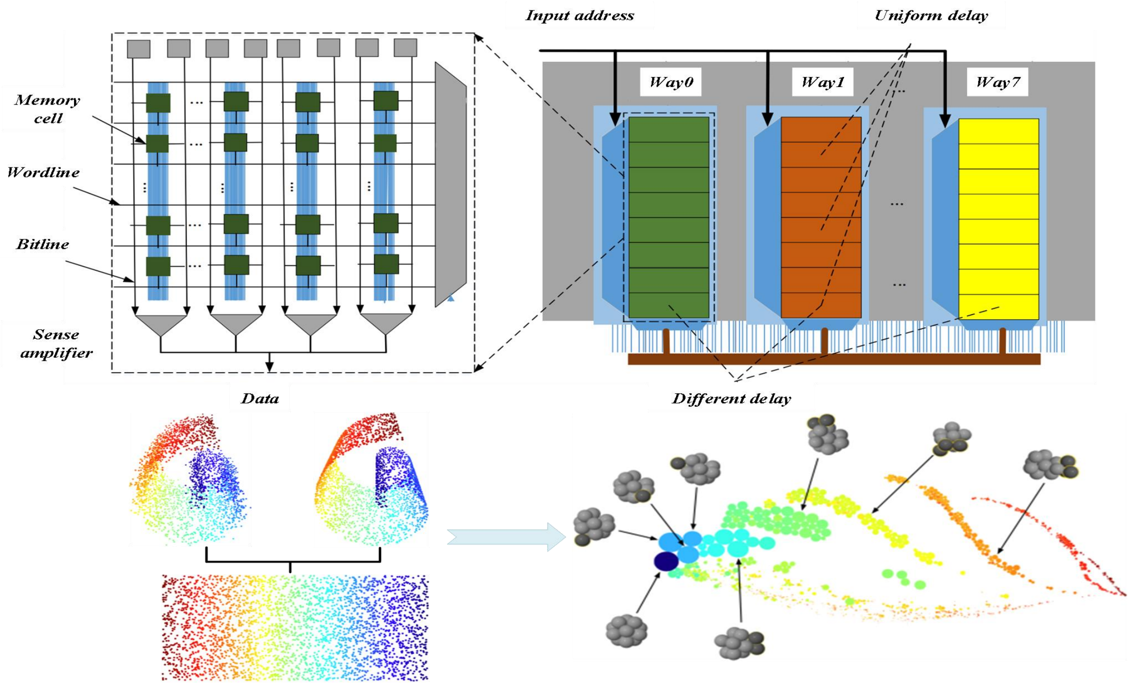

Figure 3. Protocol Design and Evaluation

Figure 3 shows protocol design and evaluation, Protocol design refers to the process of designing and formulating these rules and standards, while protocol evaluation refers to the process of testing and evaluating the performance, safety, reliability and other aspects of the protocol. Building low-carbon cities is a systematic project. From a macro perspective, avoiding large-scale demolition and construction can prolong the life cycle of buildings; Improve urban public spaces and add infrastructure such as charging stations; Control the boundaries of urban development and enable nature to better utilize its absorption capacity; Promote the green transformation of industries, curb high energy consuming and high emission projects, and develop low-carbon industries. Urban construction is related to various fields and links such as municipal facilities, land use, ecological environment, and industrial structure. Specifically, low-carbon cities consist of low-carbon households, communities, and units. Standing at the global level and doing a good job in systematic planning, can we form a joint force to build low-carbon cities?

C. Key Contributors in Urban Environments

Under the background of "double carbon", we should actively build a new power system with new energy as the main body, focus on promoting a high proportion of renewable energy applications, steadily promote the construction of large-scale wind power and photovoltaic bases focusing on deserts, Gobi and desert areas, and strive to give attention to economic development and green transformation. Based on the overall consideration of regional resource endowment conditions, ecological and environmental protection requirements and total energy consumption targets, we will continue to improve the policy system and market mechanism, guide all parties to form consensus, and jointly participate in low-carbon action.

Promote green construction methods and improve building energy efficiency standards. Green construction is an engineering construction activity that follows the requirements of green development, adopts construction methods that are conducive to resource conservation, emission reduction, efficiency improvement, and quality assurance through scientific management and technological innovation, and achieves harmonious coexistence between humans and nature [20], [21]. The concept of green development should be fully reflected in all stages of engineering construction. Improving building energy efficiency cannot be achieved without improving advanced building energy efficiency standards. We need to further improve the building energy efficiency and green building standard system, carry out the formulation and revision of zero carbon building design standards, green building engineering quality acceptance standards, building carbon emission accounting standards, etc., and enhance the public welfare and large-scale public building energy efficiency standards. Carbon-free energy can continuously improve energy security and security capabilities [22]. Moreover, the global response to climate change has triggered fierce competition among countries in politics, economy and trade [23], [24]. The formula for carbon emission coefficient is in (7):

$$y_k = \sum_{j=1}^{1} P_j w_{jk} - c_k \tag{7}$$

Where w_{jk} represents the total building area and c_k indicates the number of years of building operation.

4. Building Low Carbon Industrial System

A. Intensify Technological Innovation in High Carbon Industries

70% of emissions are generated in the production links, which is determined by the basic characteristics of China in its early stages of industrialization. At this stage, the main potential for improving carbon productivity is in the production field. Substantially reducing emissions is the basic task for China to create a low-carbon city in the near and medium term. There are three main ways to build a low-carbon industrial system and improve the productivity of carbon productivity: one is to promote the upgrading of existing industries through technological progress; the other is to increase the proportion of low-energy dependence industries through industrial restructuring; the third is to improve the intensive utilization level and recycling rate of energy, raw materials and intermediate products by developing industrial clusters and extending the industrial chain [25], [26]. We will promote strategic adjustment of the economic structure and implement an innovation-driven strategy The carbon emission intensity formula is in (8):

$$H_z = Iu \int_0^{\infty} \frac{\lambda^2}{\lambda + \lambda_1 / R_1^*} J_1(\lambda r) d\lambda_0 \tag{8}$$

Among them, H_z represents the urban compactness index, and J_1 represents the built-up area. China's mode of economic development is relatively extensive. However, improving energy efficiency through technological progress can significantly reduce energy consumption and carbon emissions. Research shows that in 2015, making technological progress and improving energy efficiency contributed about 47% to energy conservation and emission reduction in the industrial sector [27], [28].

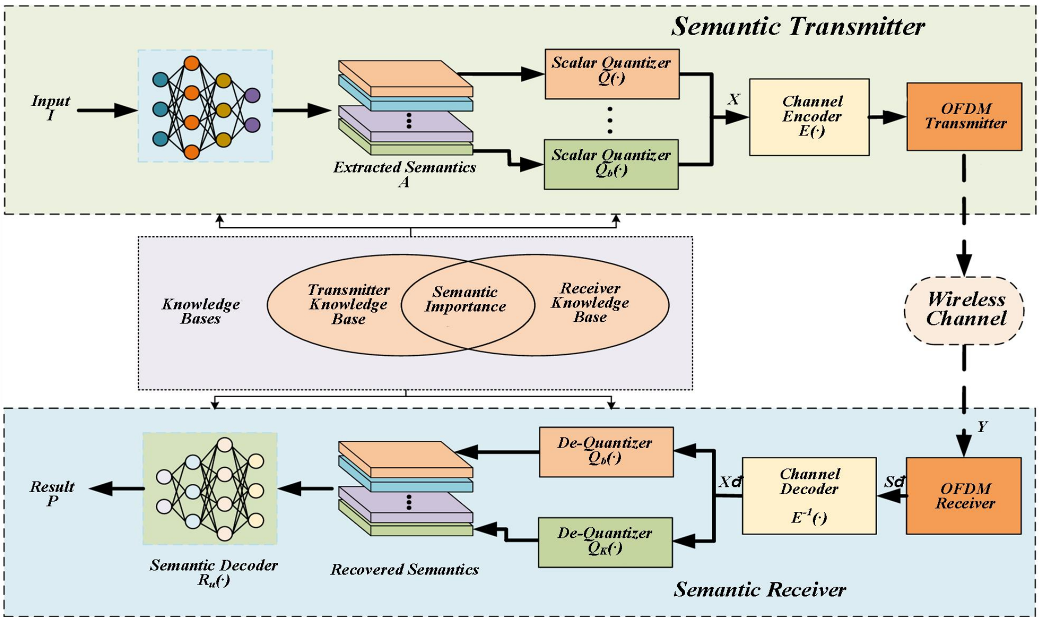

Figure 4. Flow Chart of the Practice and Case Analysis of Low-carbon Urban Spatial Planning

Figure 4 shows the flow chart of the practice and case analysis of low-carbon urban spatial planning. The overall strength of the secondary industry is insufficient, the proportion is low, and the tertiary industry is in a relatively high proportion under the low level of industrialization. Therefore, under the existing industrial structure and economic aggregate, the overall pressure on China's industrial carbon emissions is small. However, manufacturing accounts for about 80% of the secondary industry, and with the rapid development of China's industrialization, the total manufacturing industry will also increase rapidly, so China's manufacturing industry makes a huge contribution to the carbon emissions of China's overall industrial structure. Therefore, to focus on promoting electric power, chemical industry, construction, coal, building materials, paper and other industries energy saving technology transformation, development of energy-saving buildings, the high consumption, heavy pollution, endanger the safety in production, technology backward technology and product compulsory elimination system, closed in accordance with the law to destroy the environment and do not have the enterprise of safe production conditions.

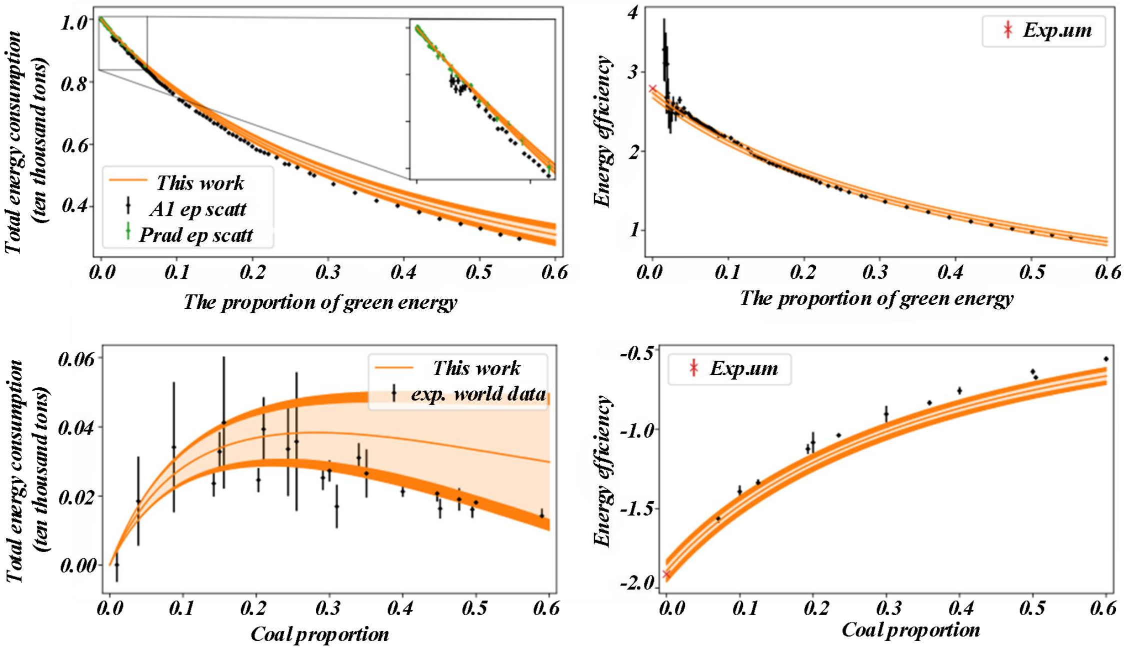

Figure 5. Data Chart of Layout Results

Figure 5 shows a data chart of urban space low-carbon layout and planning. It can be seen that since the implementation of the low-carbon layout, the annual carbon emissions of target cities have decreased from 5 million tons to 3 million tons, or 40%, and the utilization rate of green energy (including solar energy, wind energy, etc.) in cities has increased from 15% to 35%, an increase of 133%. According to the research results of Guangyuan Academy of Forestry Science, the existing carbon sequestration of the ecosystem in Guangyuan is 12.4444 million tons per year; By 2020, the new carbon sequestering potential will be 11.6508 million tons, which will greatly exceed the carbon emission of Guangyuan. According to the national functional area positioning, the establishment and implementation of the national ecological compensation mechanism for the main function zone has provided strong external support for the construction. The formula of the energy consumption is in (9):

$$P_j = f\left(\sum_{i=1}^{n} w_{ij} x_i - c_j\right) \quad (9)$$

Where c_j represents the total urban area and f represents the average travel distance.

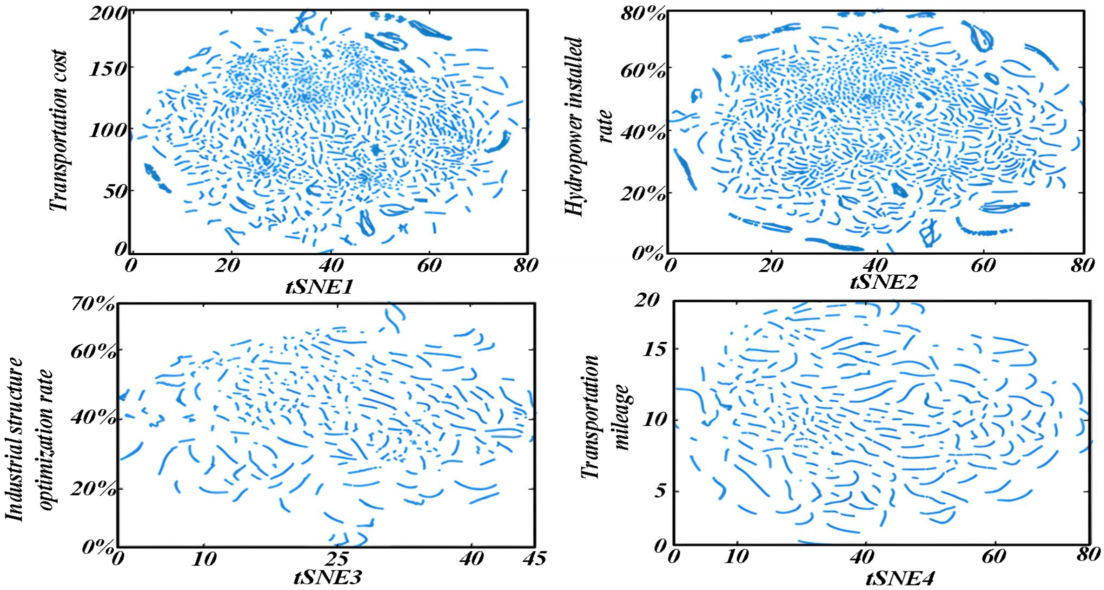

Figure 6. Data Chart of Urban Spatial Planning Indicators Driven by Sustainable Development

The evaluation index system for low-carbon cities is divided into three levels: target layer, criterion layer, and indicator layer. The target layer is the development level of low-carbon cities; The criteria layer includes five aspects: low-carbon development, low-carbon economy, low-carbon environment, urban scale, and energy consumption; The indicator layer includes 22 indicators, including per capita built-up area, regional gross domestic product, annual average PM2.5 concentration, population density, and total nighttime lighting. Figure 6 shows a data chart of urban spatial planning indicators driven by sustainable development. In spite of this, Guangyuan strictly implements the EIA system of reconstruction projects, refuses to approve all enterprises that fail to meet the EIA standards, and implements closure and conversion of enterprises with backward production capacity and substandard emissions. The formula of the carbon footprint calculation is in (10):

$$F = \Upsilon_1 \frac{1}{C_{1_r}} + \Upsilon_{x_2 M} \tag{10}$$

Where c_{1r} represents the rate of change in carbon emission and x_2 represents the carbon emission.

B. Low-carbon Development Mode in Guangyuan City

1) Construction of Industrial Low-carbon System

The relationship between space and industry is very close, which is mainly reflected in the following two aspects. First, the spatial layout affects the spatial structure as a whole. Due to the change of the overall structure of the industry, it will cause a certain degree of aggregation or separation, and then bring about the change of urban spatial structure. Under normal circumstances, if the city is dominated by manufacturing, then the proportion of industrial land is very large, mainly arranged around industry. If the city is dominated by the service industry, then the proportion of the tertiary industry is large, the node position is more critical, and the formation of specialized centers is more. In addition, the urban spatial structure will also bring its reaction force to its industrial structure. The development of urban spatial structure has promoted the urban function pattern that the overall function of the city has been assumed by multiple groups, thus forming a diversified, but to a certain extent, playing a role in promoting and driving the modern city, providing enough space for its industrial structure. In addition, the carrying capacity of some natural elements, such as soil and water, will also cause certain restrictions and constraints on its industrial structure.

Guangyuan's economic development mode is relatively extensive. However, improving energy efficiency through technological progress can significantly reduce energy consumption and carbon emissions. Research shows that in 2015, technological progress and improving energy efficiency in the industrial sector contributed about 47% to energy conservation and emission reduction. Therefore, we should focus on upgrading energy-saving and energy-reducing technologies in the power, chemical, construction, coal, building materials and paper industries, develop energy-saving and land-saving buildings, implement a mandatory phase-out system for processes and products with high consumption, heavy pollution, threats to work safety and backward technology, and close down enterprises that damage the environment or do not meet safe work conditions in accordance with the law. The formula for calculating the benefits of energy conservation is in (11):

$$J_s = \frac{a_s \quad {}^2V_s}{V_s a_s T_s - V_s^2 - S_s a_s} \tag{11}$$

Among them, a_s means low carbon index, and V_s means low carbon energy substitution rate.

2) Build Low-carbon Energy and Resource System

Building a low-carbon energy resource system requires the maximum use of "zero-emission" and low-emission new and renewable energy. Strengthen the low-carbon energy conversion process and the recycling and treatment of carbon dioxide generated in the conversion process. We will continue to speed up hydro-power development and hydro-power construction. In 2015, the installed hydro-power capacity reached 65% of the development capacity, the annual power generation equivalent to 754,000 tce is 1 ton and research on the total amount and set as the energy standard containing 7,000 calories per kilogram of heat); In 2020, the hydro-power installed capacity will reach 80% of the exploitable capacity, and the power generation will be equivalent to 928,000 tce.

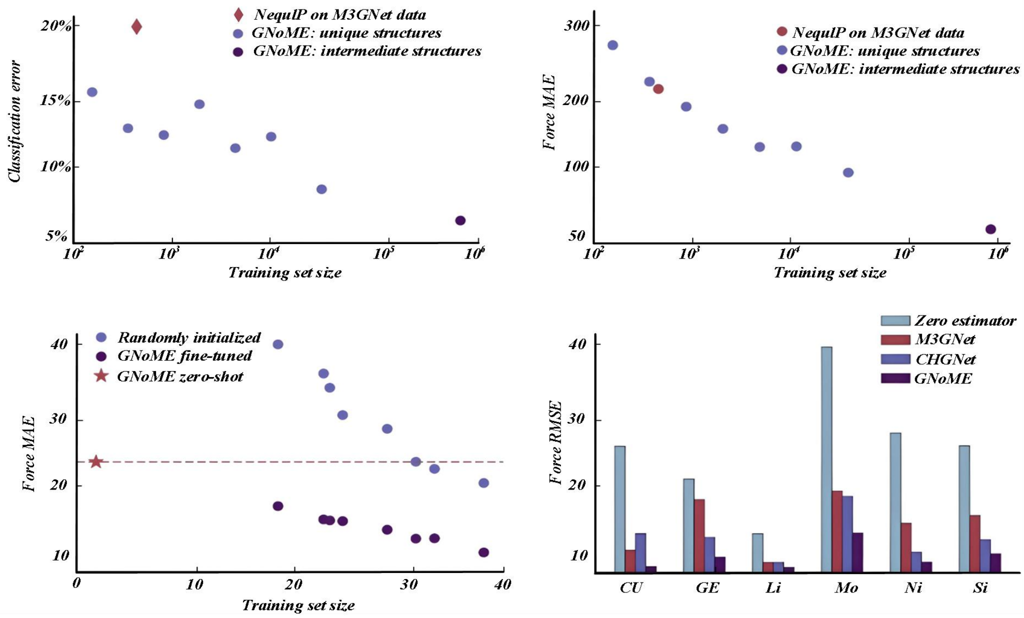

Figure 7. Data Analysis Chart of Low-carbon Layout and Future Development Direction of Urban Space Planning

Figure 7 shows a data analysis chart of low-carbon layout and future development direction of urban space planning. Vigorously promote the use of biological energy (including biogas), and continue to expand the scale and improve the level. It is an inevitable trend to promote the large-scale, centralized and industrialized construction of biogas; Development of biogas power generation. We will explore various ways to use energy-saving stoves, fuel ethanol technology, bio-diesel and direct combustion of straw for power generation. Despite our study achieving remarkable results in Guangyuan City, we are also aware that there may be some limitations in the scalability and applicability of these solutions in different urban settings. In future studies, we will further explore the universality and adaptability of these solutions to provide a more comprehensive and in-depth guidance. There are many ways to evaluate greenhouse gas carbon emissions, and one of the most important evaluation criteria is to calculate the carbon footprint. Through the use of biological energy, we will save 240,000 TCE and reduce 598,000 t CO2 in 2015, and 312,000 tce and 778,000 t CO2 in 2020. The formula for the life cycle assessment is in (12):

$$\theta_H = \frac{(m, + m_5)a_H(L^2 l_1 - l_1^3)}{12E_1 I_1} \quad (12)$$

Where, E_I represents the energy intensity optimization target, and a_H represents the building energy intensity.

5. Conclusion

As a late-developing region, Guangyuan City is faced with arduous challenges in low-carbon development, which are common problems in poor resource-based regions. They are faced with particularly prominent bottlenecks in policy, project, technology, capital and talent. Therefore, it is necessary to adapt to local conditions, based on resource conditions, combine with the industrial transfer in the east, and connect with the local urban and rural overall planning, and gradually build a low-carbon industrial system. Based on the calculation of carbon footprint, this paper makes targeted adjustments and optimization according to the carbon emission intensity of 136 factories, the spatial distribution relationship of carbon footprint and the adaptation analysis of the industrial spatial level. In GIS, the spatial layout of industrial carbon sources is optimized according to the double constraints of ecological constraints and socio-economic constraints. As a guiding basis for the spatial layout optimization of industrial carbon sources. Under the construction of the low-carbon industrial spatial layout, this paper puts forward the adjustment strategy of the spatial layout compact between the enterprise communities and the spatial structure within the enterprise group, obtains the optimization scheme of low-carbon industrial spatial layout, and makes specific low-carbon optimization evaluation on it.

This paper reviews the industrial carbon footprint theory, low-carbon industrial development theory, low-carbon city theory and industrial integration theory. On the basis of traditional industrial planning, low-carbon perspective is introduced from three aspects: analysis of industrial status quo, industrial development objectives and industry system construction, so as to form the basic framework of low-carbon industrial planning. Practice has proved that through the technological progress of the industrial sector and improved energy efficiency, the contribution rate of energy conservation is about 47%, and the savings of 240,000 tce and 598,000t CO2 are achieved, and the savings of 312,000 t and 778,000t CO2 are achieved in 2020. In the face of the pressure of the international community to reduce emissions and the constraints of energy and resources under the trend of heavy chemical industry, China has implemented the best strategic orientation of the scientific outlook on development. This will help give full play to the advantages of latecomers and maintain a sound ecological environment, resolving the conflict between regional construction needs and the constraints of climate change.

In summarizing the research findings of this paper, we make the following specific recommendations for urban planners and policy-makers. First of all, low-carbon guidance on urban spatial layout and planning should be strengthened to ensure that new construction and renovation projects meet low-carbon standards. Second, promote and apply low-carbon technologies and materials, such as green buildings and renewable energy sources, to reduce urban carbon emissions. In addition, to enhance the public's awareness and participation in low-carbon life, and encourage residents to adopt a lifestyle of energy conservation and emission reduction through education and publicity activities

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