

Research Review on the Influencing Factors of Carbon Emissions in Existing Communities

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Abstract: Community is an important part of the city and the basic unit of human life and work. Reducing the total and intensity of carbon emissions in the community is an important part of achieving carbon peaking and carbon neutrality in the city. On February 24, 2022, at the press conference held by the State Council Information Office, the Ministry of Housing and Urban-Rural Development stated that it would focus on green and low-carbon development and build green and low-carbon communities [1]. Reducing community carbon emissions has become a key task in the field of housing construction in China. Although the pilot construction of low-carbon communities and near-zero-carbon communities is advancing rapidly and orderly, and relevant research has discussed the definition, boundary and calculation content of the community, there are still gaps in the proportion of carbon emissions in each part of the community, the identification of influencing factors, and the carbon emission intensity index. How to conduct a reasonable and reliable evaluation of the carbon emission situation of existing communities is an important issue in the research on the low-carbon development of existing communities.

Keywords: Existing communities; influencing factors of carbon emission; community carbon emission.

1. Research Background

The continuous growth of carbon emissions and the resulting problems such as climate change and global warming have brought huge challenges to the sustainable development of the whole society, and carbon reduction has become an important strategic goal of many countries. Since 2021, China has successively issued documents such as "Opinions on Promoting the Green Development of Urban and Rural Construction", "Opinions on Fully, Accurately and Comprehensively Implementing the New Development Concept and Doing a Good Job in Carbon Peaking and Carbon Neutrality", "Carbon Peaking Action Plan before 2030", and "14th Five-Year Plan for Comprehensive Energy Conservation and Emission Reduction", making it clear that the green and low-carbon development of urban and rural construction is an important part of achieving the "double carbon" goal. As the basic social-spatial unit of the city, the community is the main concentration of urban energy consumption and carbon emissions. For example, the carbon emissions of existing communities in the UK account for 1/3 of the total national carbon emissions [2]; more than 80% of the energy consumption and carbon emissions in the US come from consumer demand and the economic activities it induces [3]. In 2019, the carbon emissions in the whole process of construction in China accounted for more than half of the total carbon emissions, and the average annual growth rate of carbon emissions from urban residential buildings was 6% from 2005 to 2020 [4]. Driven by urbanization and consumption growth, the proportion of direct and indirect energy consumption and carbon emissions of Chinese households has expanded significantly, becoming the main source of carbon emission growth. In 2022, the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission jointly issued the "Carbon Peaking Implementation Plan in the Field of Urban and Rural Construction", emphasizing the key role of green and low-carbon community and residential construction in the modernization of carbon emission governance in the field of

urban and rural construction. Therefore, starting from the goals of energy conservation, emission reduction and sustainable development, based on the current situation of carbon emissions in existing urban communities, studying the influencing factors of carbon emissions in existing communities, exploring the focus of community carbon reduction, and proposing an operable low-carbon evaluation system and carbon reduction path for existing urban communities, providing decision-making basis for urban community planning and the formulation of community carbon reduction plans, is of great significance for China's low-carbon development and the achievement of the "double carbon" goal.

2. Research Objectives and Significance

2.1. Research Objectives

1. Clarify the community elements that have a significant impact on carbon emissions

The community contains a variety of elements, and not all elements can have an impact on carbon emissions. This research explores the correlation between each element and carbon emissions through quantitative analysis, clarifies the specific elements that have a significant impact on carbon emissions, and explores their impact mechanisms.

2. Explore the reasons why community elements affect carbon emissions

On the basis of clarifying the impact mechanism of each community element and carbon emissions and the internal correlation between community elements, through theoretical research summary and comparison, combined with quantitative analysis, the reasons why each community element affects carbon emissions are deeply explored.

3. Construct an evaluation index system for carbon emissions in existing communities

Based on the analysis of the influencing factors of community carbon emissions, an evaluation index system for carbon emissions in existing communities is established to

provide a certain reference and basis for the evaluation and grading of existing urban communities in China.

4. Propose low-carbon community strategies to help reduce carbon emissions

Combine the research conclusions with the existing low-carbon policies, summarize the deficiencies and shortcomings of the existing community elements in low-carbon management and control, and on the basis of exploring the impact reasons and action mechanisms of community elements on community carbon emissions, propose planning strategies for low-carbon construction in residential areas.

2.2. Research Significance

1. Theoretical Significance

(1) Provide new research ideas for the comprehensive evaluation of carbon emissions in existing communities

Most of the existing research on carbon emission evaluation systems focuses on the post-evaluation of the implementation effect of specific low-carbon communities, and there are few evaluation practices for the carbon emissions of existing communities. Moreover, the content of the existing carbon emission assessment system is relatively empty and the operability is not strong. Therefore, constructing a relatively complete comprehensive evaluation system for carbon emissions in existing communities has certain theoretical significance.

(2) Clarify the internal relationship between the influencing factors and carbon emissions in existing communities

As the basic unit of the city, the community contains a wide variety of elements related to community carbon emissions. Based on the carbon emissions of existing communities and combined with the existing carbon emission evaluation system, the influencing factors related to the carbon emissions of existing communities are screened out. Then, through SPSS software, the degree of correlation and action mechanism are analyzed to explore the internal relationship between the influencing factors and community carbon emissions in existing communities from the aspects of single element and multiple element interaction.

2. Practical Significance

(1) Propose strategies for energy conservation and carbon reduction renovation and construction of existing communities

There are a large number of existing communities, and most of these built communities have not carried out targeted carbon reduction through comprehensive carbon emission evaluation. In the context of the sustainable development of low-carbon cities, corresponding carbon reduction strategies for existing communities can be proposed by combining the research data results and the existing deficiencies to reduce community carbon emissions.

(2) Provide suggestions for the low-carbon design of new communities

The existing planning indicators have weak control over the low-carbon construction of new communities and lack specific construction guidance and implementation standards. Through the investigation and evaluation of the carbon emission situation of existing communities, the impact mechanism of each influencing factor on community carbon emissions in existing communities is analyzed to provide suggestions for the low-carbon design of new communities.

3. Research Contents and Research Methods

3.1. Research Contents

The research contents of this paper mainly include the following four aspects:

1. Accounting for carbon emissions in existing communities

The carbon emissions of the community include the carbon emissions in the whole process of its construction, use and abandonment. However, the most important and longest stage is the carbon emissions during the operation and use stage of the community. According to relevant research, the carbon emissions during the operation and use stage of the community account for 50% - 90% of the total carbon emissions in the whole life cycle[5]. Therefore, this paper mainly calculates and evaluates the carbon emissions during the operation and use period of existing communities. The accounting method adopts the carbon emission coefficient method. The community carbon emissions are comprehensively calculated from two aspects: household terminal carbon emissions and community green carbon sinks. The household terminal carbon emissions mainly include the energy consumption of household water, electricity and gas.

2. Analysis of the influencing factors of carbon emissions of each element in existing communities

Summarize and sort out the elements of existing communities, classify them into morphological elements and non-morphological elements, combine the relevant research on the influencing factors of carbon emissions in existing communities at home and abroad, and use qualitative and quantitative analysis methods to preliminarily assume and select the elements that may have an impact on the carbon emissions of residential areas. Quantify and statistically analyze them according to scientific methods to explore the key points of the influencing factors of carbon emissions in existing communities.

3. Establish a comprehensive evaluation index system for carbon emissions in urban communities

On the basis of the analysis of the influencing factors of carbon emissions in urban communities, establish a comprehensive evaluation index system suitable for carbon emissions in urban communities, and use the multi-level comprehensive evaluation method to establish the index weights.

4. Case study on the comprehensive evaluation of carbon emissions in urban communities

Apply the comprehensive evaluation model established in this paper to the case community for case study, comprehensively evaluate the current situation of carbon emissions in the community, propose carbon reduction improvement measures suitable for the case community, and analyze the economic, environmental and social benefits brought by carbon reduction.

3.2. Research Methods

1. Literature Research

By using Internet platforms such as CNKI, Wanfang and VIP to consult relevant research results in journal papers and master's and doctoral thesis libraries, sort out the influencing factors of carbon emissions in existing communities, summarize the advantages and disadvantages of the existing results, and deeply understand the problems. Query relevant data through official websites such as the National Bureau of

Statistics, the Ministry of Housing and Urban-Rural Development of the People's Republic of China, and the Department of Housing and Urban-Rural Development of Hebei Province.

2. Combination of Quantitative and Qualitative Analysis

The qualitative and quantitative analysis method mainly combines relevant theories with data to deeply analyze and study problems. Through the comprehensive use of qualitative and quantitative methods, the accuracy and comprehensiveness of the research can be improved.

3. Field Research

Based on the theoretical analysis, preliminarily determine the influencing factors of carbon emissions in existing communities and design a research questionnaire; collect relevant data on the influencing factors of carbon emissions in existing communities through field research to understand the operation characteristics and carbon emission status of existing communities and provide a data basis for the subsequent analysis of influencing factors.

4. Case Study

Based on the field research data, verify the feasibility and effectiveness of the comprehensive evaluation model of urban community carbon emissions, and on this basis, propose improvement measures for carbon reduction.

4. Definition and Selection of Influencing Factors of Carbon Emissions in Existing Communities

4.1. Definition of Influencing Factors of Carbon Emissions in Existing Communities

The influencing factors of carbon emissions in existing communities refer to various factors that affect the carbon emissions in the production and living processes of the communities that have been built and put into use in urban areas. Carbon emission factors include building characteristics such as building materials, building combination forms, building orientations, building floors, and green space ratios; energy structure characteristics such as energy types and utilization ratios; and factors that comprehensively affect the carbon emission level of the community, such as family size and production and living styles.

4.2. Selection Principles of Influencing Factors of Carbon Emissions in Existing Communities

The identification of the influencing factors of carbon emissions in existing communities is the prerequisite for systematically analyzing the relationships between the influencing factors. When selecting the influencing factors, the following principles should be followed:

1. Scientific Principle

Since carbon emissions are affected by multiple layers of factors, and there are complexity and uncertainty among the influencing factors. When identifying the influencing factors of carbon emissions in existing communities, not only should factors be selected from different perspectives, but also the mutual relationships between various factors should be noted to ensure that the selected influencing factors can comprehensively and scientifically reflect the carbon emissions of the community.

2. Systematic Principle

In the process of identifying the influencing factors of carbon emissions in existing communities, the impact of factors existing in each stage on the overall carbon emissions should be considered, and the reduction part of community carbon emissions by the renewable energy system should also be considered. The selected influencing factors can reflect the connections between each stage and each factor.

3. Representativeness Principle

The selected influencing factors should be representative among similar factors, not only can they truly affect the carbon emissions of existing communities, but also can be collected in the form of data. By collecting data, an analysis system of carbon emission influencing factors can be constructed to better evaluate the influencing factors of carbon emissions.

4. Authenticity and Reliability Principle

The selected influencing factors should have an actual impact on the carbon emissions of existing communities; in the selection process, a practical method for selecting carbon emission influencing factors should be used to extract the carbon emission influencing factors; the selected influencing factors should be real and easy to understand.

4.3. Selection Methods of Influencing Factors of Carbon Emissions in Existing Communities

The influencing factors of carbon emissions in existing communities can be selected through methods such as field research data collection, statistical method data analysis, model construction and quantitative analysis, and expert review and optimization of results. Different methods cover different main directions, and the specific contents are as follows:

1. Data Collection Method

To comprehensively select the influencing factors of carbon emissions in existing communities, in-depth field research is required. By designing scientific and reasonable questionnaires and combining on-site visits and observations, data on building characteristics, energy use, production and living styles, and residents' living habits in existing communities are collected.

2. Data Analysis Method

By using SPSS single-factor variance analysis method and multiple linear regression analysis method, the community elements are related to the community carbon emissions to clarify the key morphological elements affecting carbon emissions, rank the influence degree of a single element, and further explore the impact mechanism of community elements on the carbon emissions of residential areas.

3. Modeling Analysis Method

Based on the data analysis, an identification model of the influencing factors of carbon emissions in existing communities is constructed. By using methods such as partial least squares regression analysis and principal component analysis, various influencing factors are quantified and classified. It can not only clearly understand the contribution degree of each factor to the carbon emissions of existing communities, but also provide a scientific basis for formulating carbon reduction strategies.

4. Expert Evaluation Method

To ensure the accuracy and reliability of the identification results of the influencing factors, experts in relevant fields can be invited for review. The experts confirm and correct the

identified influencing factors based on their professional knowledge and experience to optimize the identification results and make them more in line with the actual situation.

In summary, the methods for selecting the influencing factors of carbon emissions in existing communities can start from four aspects: in-depth research, data analysis, model construction, and expert evaluation. Through the comprehensive use of the above methods, the influencing factors of community carbon emissions can be more accurately identified and analyzed, providing a scientific basis for formulating efficient carbon reduction strategies.

5. Research Status at Home and Abroad

5.1. Research on Community Carbon Emissions

1. Research Status Abroad

The research on low-carbon communities in foreign countries started relatively early. N. Foletta and S. Field sorted out and completed a horizontal comparison of eight mature low-carbon communities in Europe[6]. Melia. S focused on low-carbon community transportation and discussed the differences between "car-free" and "less-car", believing that "less-car" benefits policymakers more[7]. T. N. Mdluli and C. H. Vogel studied the challenges faced in developing low-carbon communities in South Africa[8]. J. Innes and D. Booher studied the building theory and layout of sustainable communities and concluded that the construction of low-carbon communities requires the joint action of community overall assessment, policy planning measures, and feedback mechanisms.

2. Research Status in China

For the research on community carbon emissions in China, Sun Qizhen [9] (2018) believed that community carbon emissions mainly consist of three parts: carbon emissions from community buildings, carbon emissions from community residents' households, and carbon emissions from the community environment. The carbon emissions from community buildings mainly include the carbon emissions generated in the whole life cycle of construction, operation and use, and final abandonment of residential buildings and community public buildings; the carbon emissions from the community environment refer to a series of carbon emissions caused by community public services and environmental maintenance, including the maintenance of the greening system, solid waste disposal, etc.[10]; the carbon emissions from residents' households refer to the carbon dioxide emissions caused by the energy consumption of all consumption of residents in the community, that is, it includes the carbon dioxide emissions directly consumed by using energy such as gas, and also includes the carbon dioxide emissions indirectly consumed by the energy consumption of household materials, products and services[11]. Zhang Jie et al.[12] (2015) believed that the carbon emissions from residents' households refer to the energy used in urban residential buildings to provide heating, ventilation, air conditioning, lighting, cooking, domestic hot water, and other services for family members or users. For this part of the energy used by family members or users, most scholars divide it into direct energy consumption carbon emissions and indirect energy consumption carbon emissions. Among them, direct carbon emissions mainly include household direct carbon emissions, carbon emissions from the community

external environment, and carbon emissions from community internal transportation, specifically referring to the carbon emissions generated in the process of using carbon-based energy; while indirect carbon emissions mainly refer to the carbon emissions from clothes, food, etc. generated by household material consumption, specifically referring to all the carbon emissions generated in the production, delivery, and waste disposal processes of the products and services consumed by residents' households[13].

5.2. Influencing Factors of Community Carbon Emissions

5.2.1. Research Status Abroad

Z. G. Liu et al.[14] (2015) studied the carbon emission factors of urban civil buildings by using the logarithmic mean divisor index method and concluded that the carbon emission factors of urban civil buildings include urban population, per capita building area, building structure, building energy intensity and carbon emission coefficient, among which population and per capita building area are the main influencing factors. Yin Zhang et al.[15] (2016) established a quantitative life cycle model for carbon emission accounting based on the life cycle assessment (LCA) theory and evaluated the material production, construction, use and maintenance, and demolition stages through the building system carbon emission model. It was concluded that the use and maintenance stage and the material production stage are the most important factors in the life cycle carbon emissions of the building system. Hongting Ma et al.[16] (2016) used the eQUEST software to analyze the influencing factors of energy consumption in public buildings and concluded that the lighting density, air conditioning system and building envelope are the main influencing factors, and different functional public buildings have different energy consumption changes and carbon emission indexes. Peng Wu et al.[17] (2019) used the LMDI model analysis method to evaluate the carbon emissions of the construction industry from the perspective of the life cycle, including extraction, manufacturing, construction, construction-related transportation and building operation. It was determined that the industrial structure, energy efficiency, development density and energy structure are the main influencing factors. Tengfei Huo et al. [18] (2020) systematically explored the multiple impacts of urbanization on urban building carbon emissions from the dimensions of quantity and structure based on the STIRPAT model and determined that population, economy and space are the main influencing factors. Chen Zhu et al.[19] (2021) analyzed population, affluence and technology from the perspective of supply and demand based on the stochastic impact model and concluded that the building construction area and indirect emission intensity have the greatest impact on building carbon emissions, and total factor productivity, energy intensity, building materials and construction technology are all important influencing indicators. Yang Sihui et al.[20] (2021) studied the influencing factors of regional carbon emissions by using the LMDI model and concluded that economic scale, per capita economy, energy consumption per unit area, comprehensive carbon emission coefficient, urbanization effect and per capita building area are the main influencing factors of carbon emissions from civil buildings. Xiaoyu Luo et al.[21] (2022) analyzed the impact of carbon emissions in the renovation of old communities by using the life cycle assessment method, comprehensively considered the materialization, demolition

and use stages in the renovation process, and evaluated five systems such as landscape greening, single building, water resources, solid waste and infrastructure. Sensen Zhang et al.[22] (2022) studied the influencing factors of carbon emissions in the construction industry in Jiangsu Province by using the energy balance sheet splitting method, STIRPAT model, grey correlation method and GA - BP neural network model and concluded that the permanent population, urbanization rate, steel output, average distance of road transportation and labor productivity of construction enterprises have a catalytic effect on building carbon emissions, while per capita GDP and the added value of the tertiary industry have an inhibitory effect.

5.2.2. Research Status in China

The research on the influencing factors of community carbon emissions in China is mainly based on building groups, and the main influencing factors are determined according to the factors of the overall carbon emissions of buildings in the country, region or city. It can be roughly divided into five aspects: population, energy, economy, technology and lifestyle. Many scholars use analysis methods such as STIRPAT model (stochastic impact assessment model of environment), LMDI model (logarithmic mean Divisia index decomposition method) and Granger method (Granger causality test method) in the research. Ma Xiaowen et al.[23] (2017) analyzed the statistical data of energy consumption of Shenzhen residents over the years, summarized the overall situation and future change trend of energy consumption in Shenzhen buildings, and concluded that three factors, namely social and economic development level, urban temperature and economic growth mode, are the main macro influencing factors. Ren Hong et al. [24] (2017) used the STIRPAT model to construct an analysis model of the influencing factors of energy consumption in urban buildings and obtained six major influencing factors through mathematical operation analysis, namely per capita building area, total population, development level of the tertiary industry, consumption level of urban residents and urbanization rate. Liu Xinghua et al.[25] (2019) quantitatively analyzed the influencing factors of carbon emissions in public buildings and existing community residential buildings respectively based on the STIRPAT model. According to the degree of influence, it was concluded that the factors affecting the carbon emissions of public buildings are the public building area, the added value of the tertiary industry, the permanent population and the unit consumption of public buildings; the factors affecting the carbon emissions of existing community residential buildings are the permanent population, the residential building area, the unit consumption of residential buildings and the consumption level of residents. Feng Guohui et al.[26] (2022) calculated the carbon emissions of the case building system by using the whole life cycle theory and combined with the literature and survey data to determine six indicators such as the type, thickness, service life of building insulation materials, window type, window - wall area ratio and heating system form as the influencing factors of carbon emissions in the building system.

6. Review of Research Status

In summary, although there has been some research on low-carbon communities and community carbon emissions at home and abroad, the research scale is mainly macro, and there are few investigations on micro communities. The

research on carbon emissions in existing communities is relatively weak. In the research on carbon emissions in existing communities, most of the models used are international general models, and the carbon emission factors in the calculation models are also directly applied with international general carbon emission factors. In fact, the energy consumption structures and consumption types of different countries are different, and their carbon emission factors are also slightly different. The community carbon emissions calculated by the general model cannot reflect the real situation of carbon emissions in Chinese communities. The research objects of carbon emissions in existing communities mainly focus on direct energy consumption, and indirect energy consumption is less considered. In addition, there is no systematic analysis of the influencing factors of carbon emissions in existing communities, and the influencing factor index system has not been completely established. The influencing factors of carbon emissions in existing communities in China mainly focus on family attribute characteristics, economic characteristics and housing characteristics, lacking indicators at the levels of community morphological elements, transportation modes and lifestyle consumption modes. However, community spatial form, transportation travel and accessibility are important indicators that can be directly or indirectly controlled by urban planning means. In addition, most of the analyses of carbon emissions in existing communities are limited to one or several items that produce carbon emissions such as energy, food and transportation, and there is no systematic summary and comprehensive coverage of all the components of carbon emissions in existing communities. There is no reasonable induction and classification in the extraction of the influencing factors of carbon emissions in existing communities, and most of the research only focuses on several selected influencing factors.

Therefore, this paper attempts to clarify the composition and relationship of the influencing factors of carbon emissions in existing communities, establish a carbon emission accounting model and evaluation system suitable for China according to the current energy use situation in China, statistically calculate the carbon emissions of existing communities through the surveyed data, explore the impact of factors such as household carbon emissions, spatial form, transportation mode, green carbon sink and building energy-saving measures in existing communities on carbon emissions from the perspective of urban planning by using quantitative analysis methods, deeply interpret the analysis results, and discuss how to reduce the carbon emissions of existing communities from the aspects of the influencing factors and evaluation of carbon emissions in existing communities, so as to provide reasonable strategic references for the future planning and construction of low-carbon communities.

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