

Article

A research on the construction path of ecological city under the concept of carbon neutrality—A case study of Chinese city

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Abstract: Under China's ambitious goal of peaking carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060, we should re-examine the way of urban development, study the key to carbon pollution, change the original urban renewal path, and seek energy-saving and emission reduction. Therefore, this paper takes Xiamen City as an example, through questionnaire survey, mathematical statistics analysis and other methods, combined with the practice of low-carbon city and ecological civilization construction in Xiamen City, this paper makes an in-depth analysis of carbon pollution problems such as transportation carbon emissions, domestic waste disposal carbon emissions and industrial waste carbon emissions in Xiamen City, and puts forward the urban renewal path of Xiamen City to effectively reduce carbon emissions based on the concept of carbon neutrality, which provides a low-carbon plan for Xiamen City's urban renewal and is of great significance for Xiamen City to achieve the dual-carbon goal.

Keywords: carbon neutrality; carbon emissions; ecological city; low-carbon city; urban renewal path

1. Introduction

Against the backdrop of vigorously advocating sustainable development, carbon neutrality, and peak carbon emissions both domestically and internationally, and the growing popularity of the concept that green mountains and clear waters are invaluable assets, Xiamen, as a key ecological city in Fujian Province and one of the first low-carbon pilot cities in China, still has a certain distance from achieving the dual carbon goals and becoming a low-carbon city. In the existing research on eco city construction in Xiamen, the Key Laboratory of Urban Environment and Health of the Institute of Urban Environment of the Chinese Academy of Sciences divided the process of eco city construction in Xiamen into three stages according to the historical process of eco city construction in Xiamen and the main problems it faces, namely, the stage of material resource constraints from the 1980s to the 1990s, the stage of environmental pollution and ecological restoration from the 1990s to the beginning of the 21st century, and the stage of urban spatial pattern optimization and management from the beginning of the 21st century to the present. And summarize the experience of ecological city construction in Xiamen into three aspects: first, the government should attach great importance to it, and relevant departments should integrate leadership; second, relying on the natural environment endowment, urban construction and ecological construction are carried out in parallel; the third is to design the top-level urban development path, integrating multiple regulations [1]. In the article "Discussion on Ecological Concepts Promoting Urban Transformation and

Development: A Case Study of Xiamen City”, Shao and Lin [2] analyzed the prominent ecological problems such as atmosphere and water sources, as well as the imperfect planning system. They proposed measures to strengthen urban ecological civilization construction, such as restoring the ecological environment and formulating long-term plans. Taking Xiamen City as an example, they analyzed practical projects such as the remediation of nine streams outside Xiamen Island, the construction of sponge cities in Haicang Maluan Bay, and the Yunding Road aerial bicycle lane system [2].

The above studies have put forward relevant and specific opinions on the construction of ecological cities in Xiamen. However, there are still theoretical problems in the specific implementation. At the same time, new ecological city construction problems continue to emerge in the rapid development of Xiamen. Therefore, this article aims to supplement the existing problems in the construction of ecological cities in Xiamen based on the summary of existing research and provide reference suggestions.

The research on ecological city construction in foreign countries started earlier, mainly focusing on the study of specific solutions to a certain problem, emphasizing practicality and operability. Therefore, there are many examples of significant progress in ecological city construction in foreign countries.

Feng Qifeng and Cao Ronglin pointed out in their article “Comparative study on ecological city construction at home and abroad” that research on ecological city construction in China mainly focuses on basic research, with a focus on discussing the scientific mechanisms, technical methods, and knowledge of ecological cities. They have studied ecological footprint theory, industrial ecologicalization, urban agriculture, lawn management, and other aspects in Luoyang. There are already comprehensive analysis cases at the urban level, such as Zhuhai and the Yangtze River basin level. Many scholars have made relevant research achievements in the construction of green and low-carbon ecological cities. Xue [3] used Fuzhou City as an example to analyze the difficulties and corresponding policies of ecological city construction under the “dual carbon” goal. Cao [4] reviewed and summarized the construction models and experiences of low-carbon cities in Germany, Singapore, and Brazil and proposed the inspiration of low-carbon ecological city construction in foreign countries for China. Dong et al. [5] deeply demonstrated the main content and advanced level of ecological town planning in the UK by analyzing the case of ecological town construction in Northwest Bister. They reflected and implemented the ways and technical characteristics of the benign operation of urban and external ecosystems and summarized their inspirations for China’s ecological city planning and construction [5]. Xue and Li [6] used Hefei City as an example to explore the high-quality development path of ecological cities under the background of “dual carbon”. Zou et al. [7] combined the China Singapore Tianjin Ecological City project to summarize the directions and measures for reducing costs of near-zero energy buildings, accumulating experience, and providing reference for promoting the building system in cold regions. Ji et al. [8] used the coastal city of Zhoushan as an example to evaluate the low-carbon ecological development status of the target city through model construction and calculation. Based on the evaluation, they attempted to use NbS thinking and practical guidance to construct a scalable low-carbon

ecological development path or model for coastal cities [8]. Yin et al. [9] analyzed the construction of a green building system for low-carbon ecological cities and pointed out that in the process of low-carbon city construction, we should start from the perspectives of energy conservation and emission reduction, improving the construction environment, and organically integrate low-carbon and green ecological concepts to achieve harmonious coexistence among residents, cities, and urban environments. Zang et al. [10] combined relevant theories and practical explorations at home and abroad, summarized urban development strategies under low-carbon goals, and proposed development strategies and implementation paths for ecological cities in the new era from aspects such as spatial environment, green transportation, low-carbon industries, energy recycling, and support systems. Dong et al. [11] analyzed the carbon emissions of buildings throughout their entire lifecycle, including planning and design, construction, operation and maintenance, and demolition and recycling stages, based on the concept of ecological cities. They emphasized the importance of building low-carbon and proposed a low-carbon strategy for buildings based on the concept of ecological cities, providing reference for the development of building low-carbon in China [11].

This article analyzes the serious carbon pollution problems that still exist in Xiamen City, including carbon emissions from transportation, carbon emissions during construction and use in the construction industry, and a single energy structure. Using methods such as questionnaire surveys, literature reviews, and on-site investigations, based on a thorough analysis of the results and reference literature, relevant suggestions were put forward for the carbon pollution problem in Xiamen City. Based on the concept of carbon neutrality, a development path for ecological city renewal and construction was proposed. Due to some respondents being non-indigenous people of Xiamen during the questionnaire distribution process, there is still a problem of an incomplete summary of problem methods.

2. Analysis of urban carbon pollution in Xiamen

2.1. Existing problems of urban carbon pollution in Xiamen City

In recent years, ecological issues have received increasing attention. In 2014, the State promulgated the Opinions on Supporting the In-depth Implementation of the Eco-province Strategy in Fujian Province and accelerating the construction of the demonstration zone for the advancement of eco-civilization; in October 2014, the Fujian Provincial Party Committee and Provincial Government issued the Implementing Opinions on Implementing the Opinions of the State Council on Supporting Fujian Province to Deepen the Implementation of the Eco-province Strategy and accelerating the construction of the advance demonstration zone of eco-civilization; in June 2016, the implementation plan of national ecological civilization pilot zone (Fujian) was adopted, Fujian becomes China's first National Ecological Civilization Experimental Zone. Xiamen Special Economic Zone, as the city and the key to the development of eco-city, from 2002, Fujian Province has begun to quasi-Xiamen Eco-city Conceptual Plan preparation and full implementation of the Strategic Plan for a Beautiful Xiamen in 2014, followed by the implementation of the Regulations on the Construction of Ecological Civilization in the Xiamen Special

Economic Zone in 2015, etc. [12]. Realizing peak carbon and carbon neutrality is a broad and profound systemic change in the economy and society, and Xiamen is one of the first low-carbon pilot cities in China. In order to accelerate the precise empowerment of “peak carbon and carbon neutrality” and to realize ecological construction, it is necessary to carry out research by grasping the existing carbon pollution problems in Xiamen.

2.1.1. Difficulty in solving urban transportation pollution problems

Xiamen is located in a region with limited land area and high population density, resulting in a large number of motorized vehicles per unit area. However, the high intensity of motor vehicle exhaust emissions puts considerable pressure on the atmospheric environment. In November 2021, with the prevention and control of the epidemic entering the “normalization” phase, Xiamen residents’ travel within the city has returned to near-normal levels. In order to scientifically plan and plot Xiamen’s transportation layout and to provide the necessary data support for urban planning, construction, and management, the Xiamen Municipal Department of Natural Resources and Planning and the Xiamen Municipal Department of Transportation carried out the work of the Xiamen Urban Residents’ Travel and Transportation Survey 2021. According to the survey, a total of 27,000 households were surveyed at a sampling rate of 1.2%. The results of the survey show that in 2021, the total number of intra-island trips of Xiamen residents will be about 5.37 million trips per day, an increase of 10.7% from 2015, and the total number of extra-island trips will be about 7.79 million trips per day, an increase of 33.4% from 2015. In particular, the total number of trips made by off-island residents has increased rapidly. Despite the stabilization of total public transportation trips and the continued growth of rail passenger traffic, the share of small car trips is still further increasing, which further led to the continued growth of motor vehicle ownership in Xiamen (**Figure 1**), with a net increase of 109,000 vehicles to 1,864,000, a 6.2% increase from the previous year. As a result of the epidemic, the demand for employment and travel by net carriers grew significantly, with an annual average daily passenger volume of 708,000, an increase of 76.2% year-on-year.

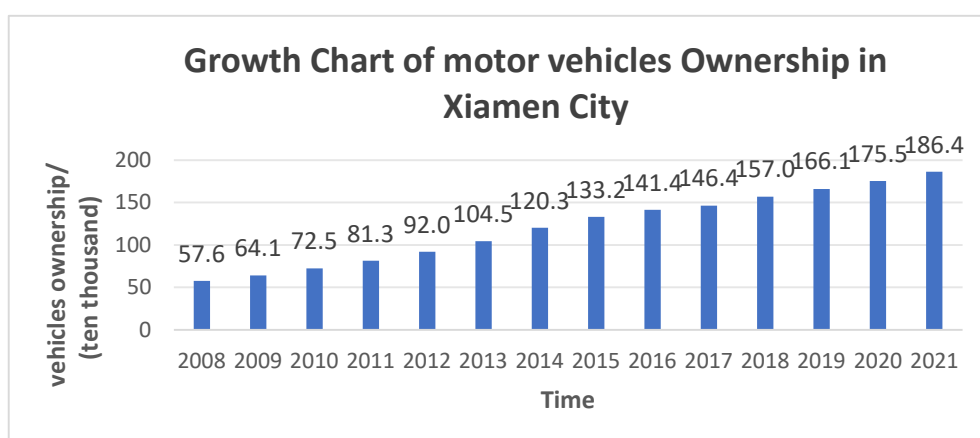


Figure 1. Changes in the number of motor vehicles in Xiamen.

Date source: Xiamen Traffic Police Detachment.

These data reveal the current status and development trends of transportation and

travel in Xiamen, as well as the growth of motor vehicle ownership and the online car rental industry. In order to meet the transportation and environmental challenges, it is necessary to take appropriate planning and management measures to promote sustainable development and improve the quality of the atmospheric environment. (Source of data: Xiamen Municipal Natural Resources and Planning Bureau, Municipal Traffic Police Detachment, Municipal Transportation Department, Land Space and Transportation Research Center).

2.1.2. Carbon emissions in the construction industry are a serious problem

Xiamen is in a rapid development stage, with increasing demand for construction of infrastructure facilities in the off-island districts. According to the Xiamen 2022 National Economic and Social Development Statistics Bulletin, the added value of Xiamen's construction industry amounted to 80.942 billion yuan (**Figure 2**), an increase of 5.5%. The total construction output value of the city's qualification-grade construction enterprises reached 351.348 billion yuan, a year-on-year increase of 9.0%. Among them, the output value of construction works amounted to 320.712 billion yuan, an increase of 6.6%, while the output value of installation works amounted to 20.428 billion yuan, an increase of 20.8%. However, the value of new contracts signed by construction enterprises for the year fell by 4.2% to 306.055 billion yuan.

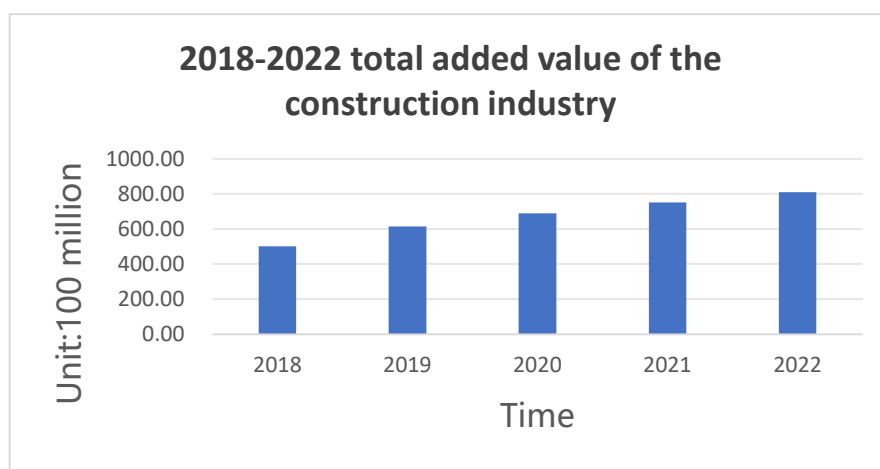


Figure 2. Value-added of construction industry in Xiamen from 2018 to 2022.

Date source: Xiamen Municipal Bureau of Statistics.

(1) Carbon emissions during the building construction phase

The construction industry is one of the three major energy-consuming industries and one of the major sources of carbon dioxide emissions. There are many sources of carbon emissions during the construction phase of buildings: direct emissions, such as the combustion of fuels; indirect emissions, such as the use of electricity and steam; and other indirect emissions, i.e., carbon-containing substances emitted through other means. At the same time, the increase in carbon emissions during construction, often due to the inappropriate use of apparatus and instruments, is quite common, as are the improper use of construction materials and building processes, among other factors. The manufacture of construction materials, such as concrete, steel, and glass, in the manufacturing and transportation process produces serious carbon pollution. The

growth of the construction industry leads to the growth of demands on the demand for raw materials such as steel, concrete, etc. According to statistics, in the process of steel production, the carbon dioxide emissions of each ton of steel production are about 1.8 tons or so, at the same time in the on-site processing of reinforcing bars, the cutting of rebar, welding, and other construction processes. The same will produce carbon pollution gas; each production of one ton of concrete produces about 0.23 tons of carbon dioxide; solid waste pollution in the construction process is equally serious; in the construction process of building engineering, solid waste pollution is mainly living garbage, discarded packaging, and discarded building materials. According to statistics, the total energy consumption of the construction sector accounts for about 7% and 10% of the total national energy consumption and the total energy consumption of the industrial sector, of which the total greenhouse gas emissions represented by CO₂ account for 18% of the total industrial exhaust emissions in the country [13]. According to the annual work summary of the Xiamen Construction Bureau, the construction sector accounted for almost 30% of the city's total CO₂ emissions in Xiamen in 2019, while the total area of housing in the city has reached 200 million square meters. According to statistics, about 0.8 tons of carbon are released for every 1 square meter of completed buildings, which cannot be re-optimized after the buildings are finished being constructed or dismantled. Some studies have shown that for newer buildings, it is expected that by 2030, 74% of carbon emissions will come from the carbon pollution generated by the construction process mentioned above. Recognizing the role that construction phase carbon control plays in a building's total lifecycle carbon emissions is key to the construction industry's ability to reduce its carbon footprint and help mitigate the climate crisis.

(2) Carbon emissions during the use of buildings

The carbon emission of the building use stage is the key point in the calculation of the carbon emission of the project. For different natures of the building, the proportion of the carbon emission of each stage in the total carbon emission of the project is similar, among which the proportion of the operation use and maintenance stage varies between 49% and 96.9% [14]. The issue of carbon emissions during the use phase of a building relates to heating, cooling, electricity for domestic equipment, decoration, hot water supply, and lighting.

Xiamen City does not have the conditions for large-scale development of nuclear power, wind power, hydropower, tidal energy, geothermal energy, and other clean energy. The current use of renewable energy in the energy structure accounts for less than 1% of the energy structure. Optimization and adjustment of the energy structure are difficult. However, with the continuous growth of the construction industry in Xiamen, the number of buildings is rising, greatly increasing the demand for energy consumption in the use of buildings in the process, such as furniture electricity, household natural gas, etc., while Xiamen's hot weather determines the large number of refrigeration home appliances. The elevation of energy consumption is accompanied by a large number of carbon pollution gases, such as CO₂, NO_x, etc.; it is estimated that each consumption of 1 kWh of electricity produces 0.785 kg of CO₂ gas, and every 1 m³ of natural gas consumed produces 0.19 kg of CO₂ gas. Therefore, corresponding energy-saving measures can be considered in the design, such as the use of thermal insulation in the

enclosure structure, shading, natural ventilation technology, etc., and the use of raising the energy-saving awareness of the residents so as to reduce the energy loss of the building's operation phase, thereby achieving the purpose of reducing carbon emissions.

2.2. Questionnaire survey analysis

This questionnaire survey was distributed through Wenjuanxing to investigate the satisfaction level of local residents with the carbon environment in Xiamen. Statistics were also conducted on the causes of carbon pollution and carbon emission pathways in Xiamen. Finally, 112 questionnaires were collected, and after removing invalid or abnormal data, descriptive analysis was conducted on the 100 questionnaires obtained.

By conducting reliability and validity analysis on the questionnaire, Cronbach's α was obtained. The coefficient value is 0.72, indicating that the reliability of the questionnaire is acceptable. The specific analysis results are shown in **Table 1**. The KMO value between 0.7 and 0.8 indicates acceptable reliability. If the KMO value is 0.664 and greater than 0.6, it indicates that there is a correlation between the item variables, which meets the requirements of factor analysis. If the p -value is less than 0.05, it is significant and can be used for factor analysis. The specific analysis results are shown in **Table 2**.

Table 1. Reliability analysis results of questionnaires.

Cronbach's alpha	Standardize Cronbach's alpha	Number of items	Number of samples
0.72	0.703	5	100

Table 2. Results of questionnaire validity analysis.

KMO test and Bartlett test		
KMO value		0.664
	Approximate chi-square	264.546
Bartlett's test of sphericity	df	36
	P	0.000***

2.2.1. Correlation analysis between carbon emissions and resident satisfaction

We first analyze whether carbon pollution affects residents' life satisfaction. Through SPSS correlation analysis, the Pearson correlation coefficient is used as an indicator to judge. We obtained the results as shown in **Table 3**, and the P -value is far less than 0.05, showing significance (note: ***, **, * represent significant levels of 1%, 5%, and 10%, respectively), indicating a correlation between the two variables, with a correlation coefficient of 0.467, indicating a positive correlation between the two variables. So, we reached a preliminary conclusion that the more severe the carbon pollution problem, the lower the satisfaction of residents with their lives, and there is a positive correlation between the two. This also indirectly confirms the importance of building ecological cities and achieving the dual carbon goals.

Table 3. Carbon emissions and satisfaction analysis results.

	What is the current level of carbon pollution in Xiamen	Your satisfaction with life under the current carbon emissions
What is the current level of carbon pollution in Xiamen	1 (0.000***)	0.467 (0.000***)
Your satisfaction with life under the current carbon emissions	0.467 (0.000***)	1 (0.000***)

2.2.2. Value weighting method for analyzing the influencing factors of carbon pollution

We have identified the main factors affecting carbon pollution through investigation and research, including construction waste and related pollution, factory and manufacturing emissions, weak green awareness among the public, private car emissions, population density, and household waste. Based on these factors, we conducted a questionnaire survey and obtained the comprehensive scores of each influencing factor through the weight assignment method in order to determine the importance ranking of these influencing factors. The specific assignment method is: assign 5 points to the first position, 4 points to the second position, and 1 point to the last position. The calculation method is: average comprehensive score of options = $(\sum \text{frequency} \times \text{weight}) / \text{number of people filling out this question}$. In the end, we obtained the analysis results as shown in **Table 4**:

Table 4. Weight analysis diagram of influencing factors of carbon pollution.

Options	Synthesis score	First	Second	Third	Fourth	Fifth	Subtotal
Construction waste and related pollution	3.31	20 (18.52%)	43 (39.81%)	21 (19.44%)	15 (13.89%)	9 (8.33%)	108
Emissions from factories and manufacturing	3.27	35 (32.11%)	27 (24.77%)	13 (11.93%)	13 (11.93%)	21 (19.27%)	109
Low green awareness among the public	2.7	36 (33.03%)	5 (4.59%)	9 (8.26%)	19 (17.43%)	40 (36.7%)	109
Emissions from private vehicles	2.69	11 (10.48%)	18 (17.14%)	39 (37.14%)	23 (21.9%)	14 (13.33%)	105
High population density and household waste	2.66	11 (10.19%)	20 (18.52%)	28 (25.93%)	33 (30.56%)	16 (14.81%)	108

From the final comprehensive score ranking of various influencing factors, it can be seen that the construction industry and factory manufacturing industry are still the most concerned industries in terms of carbon emissions. This also provides us with new ideas to solve the problem of declining resident satisfaction and reducing carbon pollution, that is, starting from the construction industry and factory manufacturing industry, to create a green building industry that integrates green construction, green energy, and green production, green manufacturing industry.

2.2.3. Value weighting method for analyzing carbon pollution solutions

Based on the main influencing factors of carbon pollution, we have proposed targeted solutions, such as promoting zero carbon transportation, green travel, strengthening energy management, establishing digital governance systems, innovating carbon neutrality assessment mechanisms, promoting green buildings, and building urban governance human resources systems. Through questionnaire surveys, we collected data and obtained the weight ranking of these solutions through the

method of assigning weights. The analysis results are as shown in **Table 5**:

Table 5. Results of weight analysis of carbon pollution treatment schemes.

Options	Synthesis score	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Subtotal
A. Advocating zero-carbon transportation and green travel	5.22	57 (53.77%)	8 (7.55%)	10 (9.43%)	10 (9.43%)	12 (11.32%)	8 (7.55%)	1 (0.94%)	106
B. Better energy management	5.03	19 (17.92%)	45(42.45%)	14 (13.21%)	18 (16.98%)	3 (2.83%)	7 (6.6%)	0 (0%)	106
D. Establishing a digital governance system	4.29	16 (16%)	20(20%)	18 (18%)	32 (32%)	7 (7%)	7 (7%)	0 (0%)	100
C. Innovative Carbon Neutral Assessment Mechanisms	4.23	10 (10.1%)	20(20.2%)	38 (38.38%)	14 (14.14%)	8 (8.08%)	9 (9.09%)	0 (0%)	99
E. Promoting green building	3.28	6 (6.12%)	11 (11.22%)	13 (13.27%)	7 (7.14%)	48 (48.98%)	13 (13.27%)	0 (0%)	98
F. Building human resource systems for urban governance	2.71	5 (5.26%)	7 (7.37%)	7 (7.37%)	16 (16.84%)	12 (12.63%)	46 (48.42%)	2 (2.11%)	95
G. Else	0.27	0 (0%)	1 (6.25%)	2 (12.5%)	0 (0%)	1(6.25%)	0 (0%)	12 (75%)	16

3. The urban renewal path of Xiamen City based on the concept of carbon neutrality

In such a severe situation, in order to explore the practical realization of carbon peaking by 2030 and carbon neutrality by 2060, we have learned several ways of energy conservation and emission reduction through consulting data. Based on this, we conducted a questionnaire survey combined with the existing carbon pollution problems in Xiamen and came up with a solution to the carbon pollution problem in Xiamen City.

We put forward several carbon reduction and carbon reduction methods that are more recognized by the public, such as zero-carbon transportation, low-carbon

construction and operation and maintenance, digital governance system, carbon neutral assessment, and zero-carbon community. At the same time, combining the unique geographical advantages of Xiamen City, we put forward the views of sea-water source heat pump and photovoltaic building integration.

3.1. Zero-carbon transportation

The total amount of urban carbon emissions has declined over the past two decades as a result of measures taken by cities around the world to reduce emissions, but emissions from the transport sector have been rising and accounting for an increasing share. In most developed cities, carbon emissions from the transport sector still exceed 20% of total urban carbon emissions.

To achieve zero carbon emissions in the transportation sector means that the total carbon emissions of one or more systems are almost zero. Here, the source and destination of carbon emissions should be taken into account, and carbon emissions can be offset through carbon sinks, the purchase of voluntary emission reductions, and other ways [15]. According to the survey, compact, small-scale downtown is conducive to people's choice of walking or cycling and other modes of transportation, while large-scale or remote suburbs are more likely to adopt motorized transportation. Therefore, during urban construction and planning, unnecessary transportation needs can be fundamentally reduced by optimizing urban spatial structure and diversifying land use. Thus, reducing carbon emissions [16].

In addition, with the development of the city, the scale of urban lighting facilities in Xiamen continues to increase, and energy consumption is growing. The use of smart street lights (**Figure 3**) can greatly reduce the energy consumption of lighting and promote the realization of the city's "carbon emission and carbon neutrality" goal. Smart street lights can be connected to the cloud of the background control center through the Internet of Things to achieve a high degree of interconnection between the lamp poles, which can not only automatically monitor the brightness of each lamp but also intelligently adjust and control the light power according to the traffic flow and road light to achieve the effect of secondary energy saving. Moreover, based on the smart light pole, it can also carry out the application of transportation, municipal, environmental, security, and other aspects, improve the level of urban fine management, and reduce the cost of urban management.

3.2. Zero-carbon building

In 2020, the energy consumption of building operations accounts for about 30% of the total energy consumption of the global terminal, and the carbon emissions account for about 27%. To achieve zero-carbon buildings, a series of measures need to be taken at all stages of the building; the specific measures for each stage are shown in **Figure 4**:

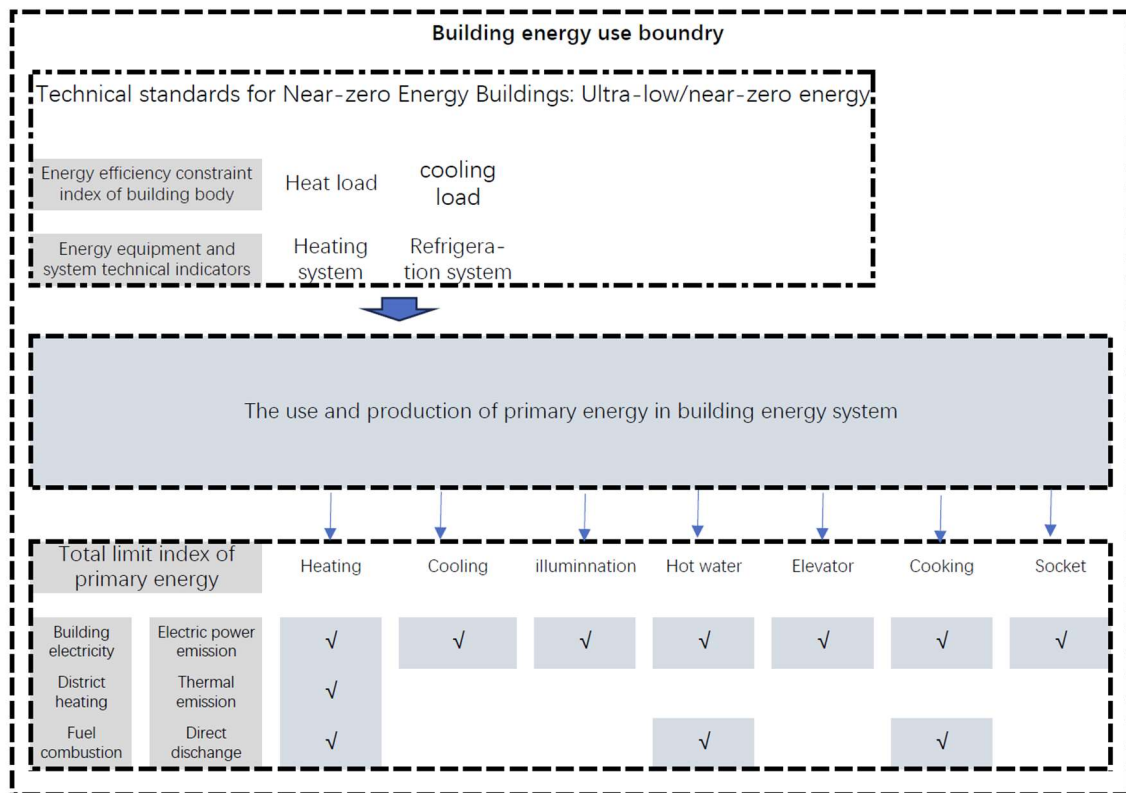


Figure 4. Research on building carbon emission control indicators.

Picture source: Self-painted by the author.

3.2.1. Green building materials

The use of photovoltaic materials to maximize the use of natural light and solar energy, minimizing dependence on non-renewable energy sources. Choose the appropriate building orientation and form so that the building can receive maximum solar radiation while taking into account the measures of shading and insulation in order to reduce the cooling load in summer. The use of photovoltaic building integration (BIPV), photovoltaic photothermal integration (PVT), and other technologies to integrate photovoltaic materials with collectors and building structures, so that it can not only protect the building and improve the photoelectric conversion efficiency, but also use heat energy for heating and hot water, and also generate the electrical energy required by the building. Photovoltaic materials can be applied to the roof, curtain wall, lighting roof, shading components, and other parts using an intelligent control system according to the sun position, weather conditions, building load, and other factors; real-time adjustment of the operating state of the solar system; and optimizing energy utilization efficiency.

At the same time, consider future sustainability by using renewable, recyclable, and reusable materials wherever possible, avoiding single-use materials and high-carbon emitting materials. For example, materials such as bio-based materials and graphene can be used. Adopt low-carbon and environmentally friendly construction methods, use high-efficiency equipment, and reduce the use of cement.

3.2.2. Prefabricated construction

Prefabricated buildings play an important role in reducing carbon pollution

during construction. In the process of construction, it is necessary to evaluate the assembly level, resource saving and environmental protection, personnel health, and comprehensive benefits of prefabricated buildings and standardize the green building effect of assembled buildings. At the same time, it is clear that the technical problems of prefabricated buildings are mainly concentrated in the aspects of component design, on-site assembly, prefabrication, installation quality, etc., and the information model is established through BIM, Revit, and a and a SQL database to carry out hierarchical component information management of prefabricated buildings, optimize the waterproof node design of prefabricated buildings, connection structure design, and other component design problems. Improve the quality of prefabricated buildings.

3.2.3. Green construction management

- (1) The temporary office can be used as a container-type house, which is convenient for demolition and recycling after construction. Color-coated steel plates can also be used in the steel processing area. Under the premise of ensuring the processing quality and process, the construction cost and energy consumption of the site should be reduced as much as possible.
- (2) Minimize the construction of concrete-hardened road ground at the site to prevent the road from cracking caused by long-term extrusion during the construction process, thereby polluting the environment.
- (3) For some standardized construction processes, such as concrete mixing, component prefabrication, steel structure component processing, etc., centralized production and treatment should be carried out before formal construction to reduce resource waste.

3.2.4. Introduction of sea water source heat pump technology

As a famous coastal city, Xiamen's developed tourism industry and the large amount of air conditioning brought by the hot climate have resulted in high carbon emissions and power consumption. However, Xiamen's unique marine environment provides new ideas and methods for the city to improve carbon emissions. Sea water source heat pump technology has a more mature application in foreign countries. Stockholm, the Swedish capital, is recognized as one of the most beautiful cities. Stockholm's earliest district heating dates back decades, but due to rising oil prices and relatively low electricity prices, Sweden is more and more interested in heat pump technology. Stockholm has built the world's largest seawater heat pump station—with a total capacity of 180 MW—for district heating. In contrast, Xiamen, as a developed city on the east coast of China, whether it is economic conditions or from the sea water source heat pump conditions, has the unique conditions to introduce this technology. At the same time, Xiamen is a hot summer and cold winter city, so the introduction of foreign advanced technology and the development of large-scale heating and cooling heat pump units is an effective way to save resources and protect the environment.

Sea water source heat pump as an advanced new energy technology abroad, its working principle as shown in **Figure 5**:

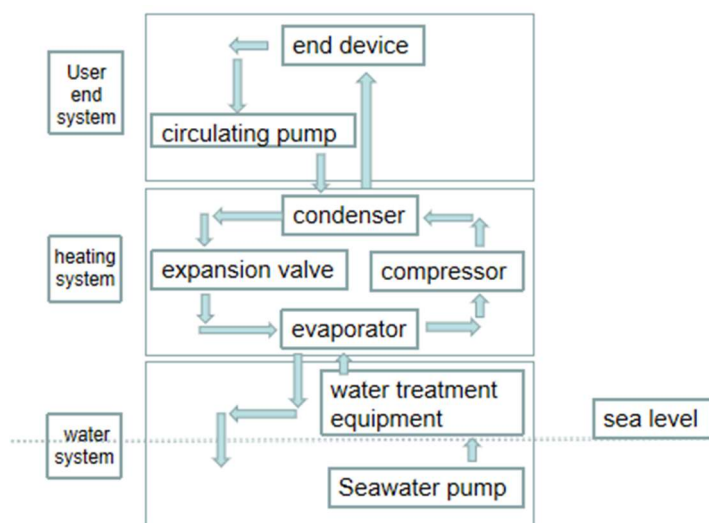


Figure 5. Working principle diagram of seawater source heat pump.

Picture source: Self-painted by the author.

Xiamen City has a large number of sea water sources, which absorb a lot of geothermal energy and solar energy and form low energy storage in them. The working principle of a sea water source heat pump is to use a small amount of high energy—that is, electric energy—to convert the low energy stored in the sea water into high energy. The sea water source heat pump can achieve the regulation of the building temperature according to the different seasons; in summer, the sea water source heat pump takes out the energy inside the building and releases it into the sea water to achieve the function of reducing the building temperature. In winter, the sea water source heat pump takes out the low energy from the seawater to achieve the function of heating the building. Compared with traditional electric energy and fossil fuel heating and cooling, sea water source heat pumps have the following advantages:

- (1) Easy access to raw materials. The sea water source heat pump uses sea water for energy conversion, and sea water itself is clean renewable energy.
- (2) High efficiency and energy savings. According to experiments, the sea water source heat pump can generate 6–7 kWh of heat energy using 1 kWh of electric energy, and such a power supply utility can reduce the cost of heating and cooling caused by 30%–40% of residents using air conditioning.
- (3) Stable operation system. The temperature of seawater does not change much throughout the year, and the stable water temperature enables the seawater source heat pump to maintain stable and reliable operation for a long time [17].

3.3. Innovate carbon neutral assessment mechanism

In order to effectively reduce carbon emissions in the path of urban renewal, it is necessary not only to innovate at the technical level and practice but also to innovate in terms of regional policies and assessment requirements. Government units and enterprises need to formulate higher standards when carrying out construction activities to adapt to the new requirements and goals under the new national policies:

- (1) Formulate reasonable carbon emission caps and allocation standards, establish a carbon emission rights trading mechanism, and encourage key emission units to

reduce carbon emission costs through market means.

- (2) Include the target of carbon peak and carbon neutrality in the performance assessment of central enterprises and local governments, reward those who are effective in their work, criticize and interview those who are ineffective in their work, and strictly hold those who cause serious consequences accountable.
- (3) Improve carbon emission statistics, monitoring, verification, reporting, disclosure, and other systems to ensure the accuracy and openness of carbon emission data and provide a credible basis for carbon neutral assessment.
- (4) Promote the reform and optimization of industrial structure and energy structure, accelerate green and low-carbon transformation and high-quality development, and reduce energy consumption and carbon emissions per unit of output.
- (5) Strengthen scientific and technological innovation and institutional innovation, overcome green and low-carbon key core technologies, improve the supply capacity of high-quality green products and services, and accelerate the promotion and application of green and low-carbon key technology products.
- (6) Develop financial products and services such as green finance, green credit, and green bonds by means of market mechanisms and policy support, guide financial institutions to provide more long-term and low-cost financial support for green low-carbon projects, and implement preferential tax policies and measures for energy conservation, emission reduction, and carbon reduction [18].

Through the above measures (**Figure 6**), we can effectively stimulate the enthusiasm and initiative of all parties to participate in carbon neutrality and form a good atmosphere for the whole society to jointly promote carbon neutrality.

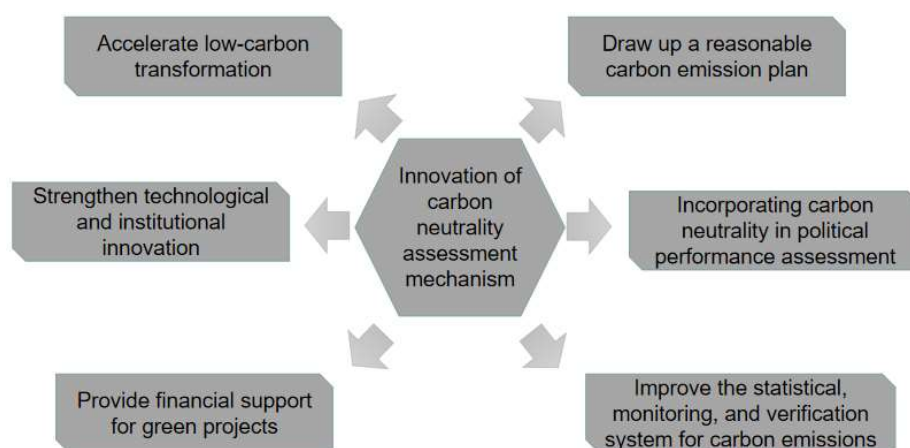


Figure 6. Schematic diagram of carbon neutralization assessment mechanism.

Picture source: Self-painted by the author.

3.4. Establish a digital governance system

The goal of carbon peak and carbon neutrality involves energy, transportation, construction, agriculture, forestry, and other fields. Coordinating and coordinating the advantages of various fields in reducing pollution and carbon can effectively improve the energy efficiency of governance. However, the invisible and untouchable “carbon” has caused great difficulties in the coordination and overall planning of various fields. Therefore, in the face of Xiamen’s urgent demand for carbon peaking and carbon neutral transformation in various fields, a digital enabling platform that can monitor,

sense, and calculate carbon in various fields and all weather can be established by means of digital empowerment (Figure 7), so as to realize full-space digitization, full-state visualization, whole-process intelligence, and all-round collaboration of carbon. The original difficulties in carbon observation and statistics have been solved [19].

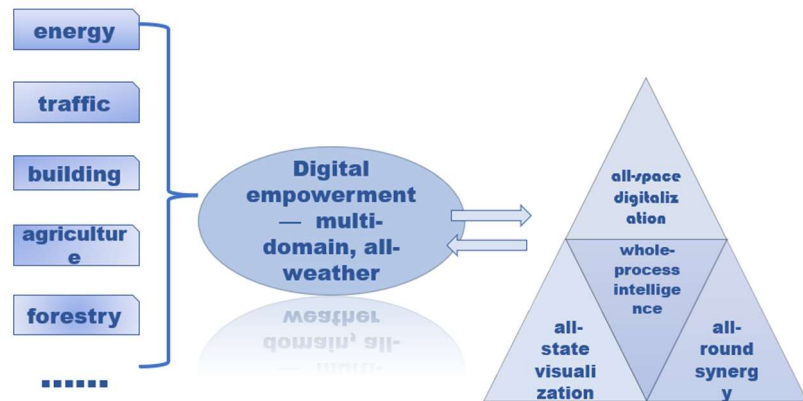


Figure 7. Key points of digital governance system.

Picture source: Self-painted by the author.

This provides effective data support for coordinating and coordinating pollution reduction and carbon reduction in various fields, giving full play to governance energy efficiency, and achieving accurate identification and efficient control of carbon.

3.5. Vigorously build the human resources system of urban governance

Talent is the driving force of innovation and creation and the rapid development of society. In order to promote the high efficiency and high quality of the “double carbon” goal, it is indispensable to actively introduce, pay attention to training, and rationally plan talents in the fields of carbon neutrality, pollution reduction, and carbon control.

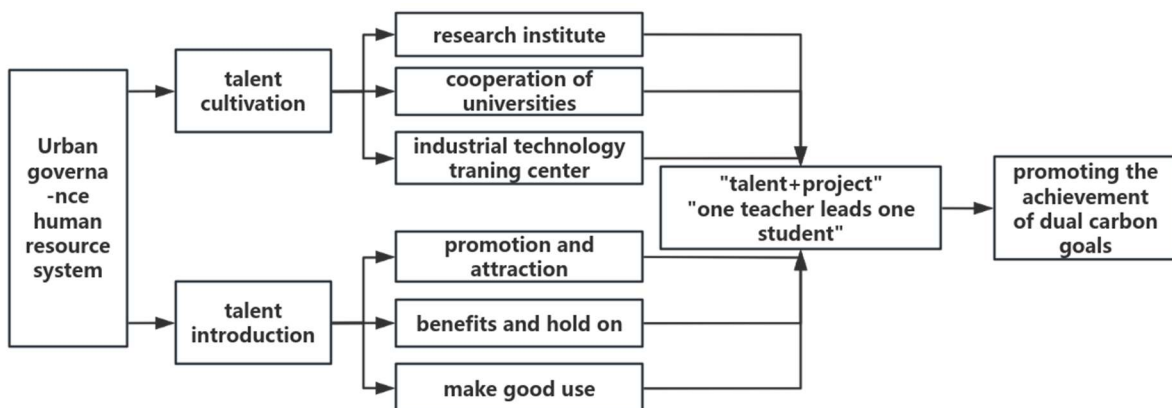


Figure 8. The schematic diagram of urban governance talent system.

Picture source: Self-painted by the author.

First of all, as shown in Figure 8, attention should be paid to the cultivation of high-level and cutting-edge talents needed for carbon neutral governance, such as introducing famous universities at home and abroad and national key research institutes to Xiamen to set up research institutes, industrial technology training centers,

and other personnel training institutions; or cooperating with enterprises and universities in Xiamen City to set up a counterpart specialty to train professional talents. Continue to export high-quality and high-quality talents for the urban carbon emission control team.

At the same time, through the “talent + project”, “one division with a lifetime” and other ways, talents can quickly adapt to the project, effectively play their own advantages and capabilities, promote the development of engineering projects, and promote the realization of the “double carbon” goal [20].

3.6. Build new zero-carbon communities

There are a large number of old residential areas in Xiamen City that produce a large amount of unnecessary carbon emissions in daily operation due to low energy efficiency, old infrastructure, unreasonable community planning, and other reasons. As shown in **Figure 9**, by establishing a zero-carbon community, optimizing the spatial structure model of the community, building a green area that is compatible with the carbon emissions of the community, reducing the use of fossil energy, improving the recycling and recycling utilization of resources, and promoting the popularization of building energy-saving technologies, the carbon emissions generated by various systems in the entire life cycle of the community can reach net zero. At present, many indoor communities in Xiamen are in urgent need of repair and transformation, and the pilot implementation of zero-carbon communities has great advantages and great potential in pollution reduction and carbon reduction [21].

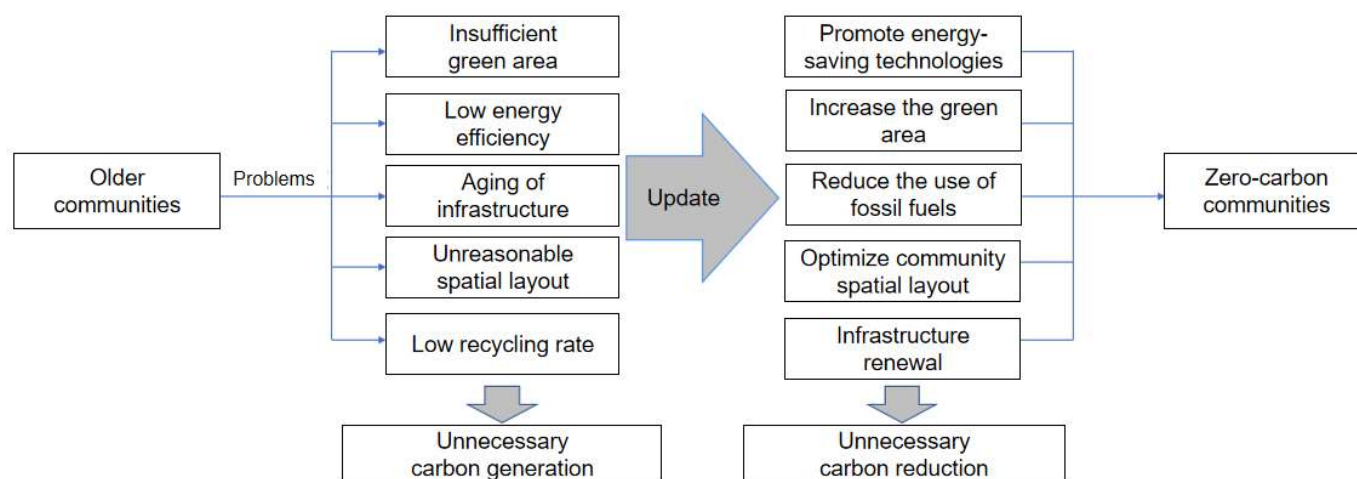


Figure 9. Zero carbon community structure diagram.

Picture source: Self-painted by the author.

4. Conclusion

This study compares and supplements questionnaire surveys with actual research, fully combines the current situation of urban carbon emission governance in Xiamen, and proposes a series of effective urban renewal paths based on the concept of carbon neutrality, aiming to reduce Xiamen’s carbon emissions. These paths cover multiple aspects such as optimizing transportation systems, promoting green buildings, adjusting energy structures, introducing seawater source heat pump technology, and

innovating carbon neutrality assessment mechanisms, providing practical and feasible suggestions for Xiamen to achieve its dual carbon goals. The conclusion is as follows:

- (1) There is a certain degree of traffic congestion in various districts of Xiamen City, and the per capita car ownership is increasing year by year, resulting in huge energy consumption and carbon emissions. Promoting the construction of smart transportation systems in Xiamen City has certain necessity and potential in alleviating traffic congestion and achieving carbon neutrality goals.
- (2) There are a large number of old residential areas in Xiamen, and phenomena such as low energy efficiency, insufficient greenery, and inadequate building functions are very common. The resulting non-essential carbon emissions are also very huge. The application of “zero carbon communities” is an effective method to fundamentally solve this problem.
- (3) Traditional construction generates a large amount of pollution and waste, while using prefabricated construction and green building materials can greatly reduce pollution and waste during the construction process, which has a significant effect on reducing carbon emissions.
- (4) Due to energy endowment and land resource limitations, Xiamen relies on external imports for energy supply and does not have large-scale development capabilities. Therefore, it is necessary to adjust and optimize its energy structure, such as by introducing seawater source heat pump technology, to achieve the goal of “carbon neutrality”. Utilizing Xiamen’s unique marine environment provides new ideas and methods for improving carbon emissions in the city.
- (5) The constraints of policies and corresponding assessment mechanisms are of great significance for the implementation of urban renewal. Both government agencies and enterprises need to set higher standards when carrying out construction activities, leading the way and providing protection for urban renewal based on the concept of carbon neutrality. Stimulate the enthusiasm and initiative of all parties to participate in carbon neutrality, and create a good atmosphere for the whole society to jointly promote carbon neutrality.
- (6) Faced with the urgent demand for carbon peak and carbon neutrality transformation in multiple fields in Xiamen, it is necessary to fully apply emerging technologies and recruit professional talents. Relying on high-level and cutting-edge talents at home and abroad, we promote the development of engineering projects and advance the achievement of the “dual carbon” goal through the use of digital and intelligent technologies.
- (7) By establishing a zero-carbon community, optimizing the spatial structure of the community, constructing green areas that are compatible with the community’s carbon emissions, reducing the use of fossil fuels, improving resource regeneration and recycling rates, promoting the popularization of building energy-saving technologies, etc., the carbon emissions generated by various systems throughout the entire life cycle of the community can reach net zero. The pilot implementation of zero-carbon communities has significant advantages and enormous potential in reducing pollution and carbon emissions.

Carbon neutrality is a consensus reached by humanity to address global climate change, and countries around the world are actively committed to achieving carbon neutrality goals. Urban renewal as a necessary measure to promote the healthy

development of cities has set new goals for “carbon neutrality” in the new era. Carbon-neutral urban renewal should not only ensure the original goals of improving urban functions, optimizing industrial structure, and improving the living environment, but also take into account reducing energy consumption and carbon emissions. In 2022, Xiamen City issued the “Work Plan for Accelerating the Establishment and Improvement of a Green, Low-Carbon, and Circular Development Economic System”, which analyzed and formulated plans from multiple perspectives and levels to ensure the timely achievement of carbon peak and carbon neutrality goals. In the future, we hope that the Xiamen Municipal Government can formulate comprehensive regulations and systems for the areas designed in the “Plan” and build Xiamen into a model city of ecological civilization and a modern international city with high quality and high aesthetic value at a higher level. I hope that the results of this study can provide a theoretical basis for Xiamen’s “carbon neutrality” action and contribute ideas to other regions.

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