Carbon Emission Measurement of Prefabricated Buildings Based on LCA and Research on Energy Saving and Emission Reduction Strategy of Renewable Energy

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Abstract

In the face of diverse quantification methods for building carbon emissions, this article delves into the Life Cycle Assessment (LCA) approach to comprehensively measure the carbon emissions of prefabricated buildings throughout their lifespan. It meticulously identifies the carbon emission sources in prefabricated buildings and analyzes the measurement models relevant to their emissions in both physical and chemical stages. Prefabricated buildings hold profound implications for transforming the construction industry and advancing its sustainable development path. Examining the energy-saving characteristics and emission reduction potential of prefabricated buildings from a life-cycle perspective, this article analyzes the carbon emission measurement model during the prefabricated building transformation stage. This comprehensive analysis of the building atomization path and influential carbon emission factors lays a theoretical foundation for

transitioning prefabricated buildings towards energy-saving and emission reduction strategies. Using the LCA method, carbon emissions were calculated, revealing a positive correlation with building size. Notably, through the prefabricated construction method detailed in this article, carbon emissions were significantly reduced by 30% compared to traditional construction methods.

Keywords: Life cycle assessment, prefabricated buildings, carbon emission measurement, renewable energy.

1 Introduction

As a significant contributor to carbon emissions, the construction industry's sustainable development has become an urgent imperative [1, 2]. Prefabricated construction, an emerging construction method, offers advantages in efficiency, environmental protection, and energy conservation, gradually evolving as a prevailing trend in the construction industry. However, the accurate quantification of prefabricated building carbon emissions and the adoption of effective energy-saving and emission reduction strategies remain pressing challenges that require urgent attention.

At present, research on life cycle assessment mainly focuses on the following aspects: Method research: including research on the framework and methodology of life cycle assessment, research on input-output analysis methods, and research on data collection methods. These studies mainly address the theoretical and methodological issues of evaluation, providing theoretical support for practical applications. Application research: involves the application of industry and product life-cycle assessment, environmental management, and decision support systems. This research mainly focuses on specific products and industries, and by evaluating their life-cycle, reveals the main sources of environmental impact and key areas for improvement. Research on standards and guidelines: including the development of domestic life cycle assessment related standards and guidelines, as well as the study and comparison of international standards. The research in this area is mainly aimed at standardizing China's life cycle assessment system, improving the credibility and comparability of research.

Prefabricated buildings can effectively save building materials and reduce construction energy consumption due to their mass industrialization

of building components and modular mechanical installation mode. The research on building carbon emissions in China mainly involves theoretical research, analytical models, and carbon emission evaluation indicators. Most of them are in the theoretical analysis stage, and quantitative data is relatively limited. This article will conduct relevant research based on the carbon emission calculation of prefabricated buildings.

In the low-carbon transformation of the construction industry, there are two main problems at present: First, there are many links, and it is difficult to realize refined whole process management. China's construction industry is still dominated by traditional production methods, with a relatively low degree of industrialization, and there is still room for improvement in construction technology. It is a long way to go to realize low-carbon development in the production, transportation and on-site construction of building materials such as steel, cement and glass [3, 4]. Second, affected by population and other factors, China has a large building stock and high carbon emissions. China is the country with the largest number of existing buildings and new buildings every year in the world. Many buildings have high energy consumption and high emission. Under the background of "double carbon", if the construction industry wants to realize low-carbon transformation, it must first start from the root and change the production mode. The new production mode should promote the transformation of construction enterprises to the whole industrial chain mode, from design, production to construction, and form an integrated whole industrial chain working mode. For example, prefabricated buildings, the main structural components of such buildings are all modularization in the assembly line of housing factories, which saves the complicated working procedures of traditional processing and greatly shortens the project period. The most important thing is that this way is green, environmentally friendly and recyclable.

Secondly, it is the innovation of construction methods in the construction industry [5]. From the existing technology, prefabricated buildings will be the most potential innovation direction in the construction industry. Compared with the traditional decoration, the prefabricated decoration has greatly reduced the consumption and loss of materials, and the carbon reduction has exceeded 50%. The third is the reform of development mode [6, 7]. The purpose of this study is to calculate carbon emissions based on the LCA method and propose effective emission reduction strategies using assembly technology.

2 Application of LCA in Carbon Emission Measurement of Prefabricated Buildings

2.1 LCA Technology

Life Cycle Assessment (LCA) is a systematic method used to assess the impact of a product, service, or activity on the environment throughout its entire life-cycle. Life cycle assessment considers all stages from raw material collection, production, use to disposal, aiming to comprehensively understand the environmental performance of the evaluated object. It then assesses the impact of these consumption and emissions on the environment. Finally, it identifies and evaluates potential opportunities to mitigate these environmental impacts [8, 9].

There are three types of LCA: panel system, skeleton enclosure system, and module system. The difference between panel systems and skeleton enclosure systems lies in whether the wall panels bear the building load, or more precisely, whether there is an independent skeleton to bear the load-bearing function, considering the dichotomy between structure and enclosure. Due to the lack of enclosure function, the members inevitably need to cooperate with the enclosure when forming a building space. After disassembling prefabricated buildings into modules, the modules are generally stacked, but the modules themselves may be panel systems, skeleton enclosure systems, or even further disassembled into smaller modules. It is also common for a module to become a standalone building unit.

LCA can provide a comprehensive evaluation of renewable energy projects, considering the entire life-cycle from raw material extraction, production, transportation, installation, operation, maintenance to waste disposal, in order to develop more effective strategies. In Figure 1, we present a comprehensive analysis of feature extraction in prefabricated renewable energy systems. This analysis offers insights into the critical characteristics of renewable energy systems, including their efficiency, reliability, and environmental impact. By optimizing design and achieving equal results, reducing the use of building materials such as concrete and steel can greatly reduce the generation of carbon emissions; Secondly, it is advisable to choose low-carbon building materials as much as possible, such as waste materials such as fly ash and phosphorous, recycled building materials with construction waste as aggregates, and bio carbon sequestration building materials; Furthermore, in the process of building materials processing, it is important to promptly replace high-efficiency and energy-saving equipment.
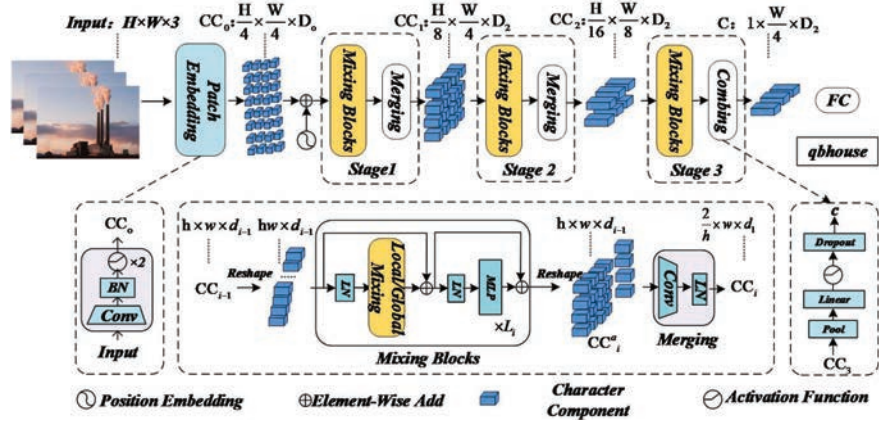
Figure 1   Feature extraction analysis of assembled renewable energy.

2.2 Construction Technology of Prefabricated Building

For different precast slabs, the number and position of connecting steel bars should be consistent. Accurate docking needs to be ensured. After the steel bars of precast slab beams are connected, the design scheme and construction scheme shall be disclosed. When fixing the position of components, the layout of electronically pipelines should be fully considered to prevent the secondary loss of electronically pipelines during fixing. Therefore, when fixing components, it should be compared with the remote transmission pipeline layout.

Prefabricated buildings first appeared in the last century. At first, they were limited by technology, and the components produced were not fine enough, which led to some problems in operation, resulting in unsatisfactory safety and stability of prefabricated buildings in the early stage [10, 11]. At present, with the continuous development of science and technology, although the construction technology and technology of prefabricated buildings still need to be improved, the components of prefabricated buildings all meet the relevant standards. In prefabricated buildings, interior wall panels and exterior hanging panels are processed and manufactured in batches in factories, while in building assembly and construction, only steel bars at the bottom of floor slabs are prefabricated and poured on site, which effectively reduces the shortage of seismic performance of prefabricated buildings and improves the seismic performance of buildings and the overall seismic performance.
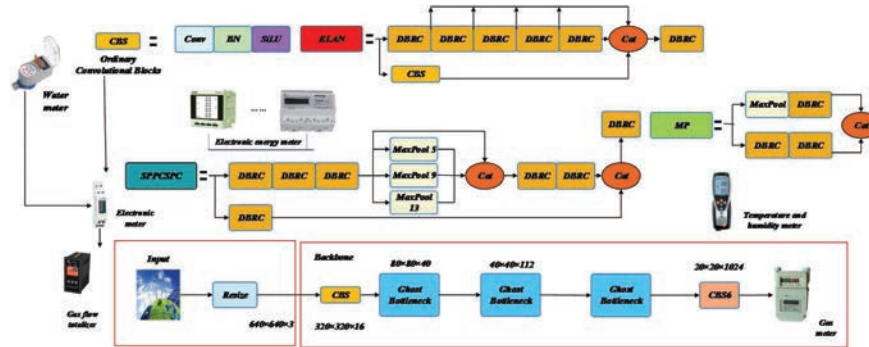
Figure 2   Technical analysis of prefabricated building construction.

Figure 2 presents an analysis of prefabricated building construction technology, in which prefabricated construction technology has good sustainability. In the process of construction, if the components do not meet the standards, they can be removed immediately. The main reason is that the workshop produces prefabricated components, which will not delay the construction progress in the process of demolition and installation. The most important thing is that dust and garbage will not be produced in the production process, which reflects the characteristics of sustainable development of prefabricated buildings. Make use of the advantages of industrialization to form the integration of design, production and construction, and make the technical system more standardized. The prefabricated assembly rate reaches 80%, and the assembly height is over 100 meters. It is beneficial to save resources. Compared with the past, the building saves water by 60%, materials by 20%, energy by 20%, and construction waste by 80%, thus promoting the sustainable development of building economy.

2.3 Implementation Steps in Carbon Emission Measurement of Prefabricated Buildings

Using the carbon mass balance method based on specific facilities and process processes to calculate emissions can reflect the actual emissions where carbon emissions occur [12, 13]. It can not only distinguish the differences between various facilities, but also distinguish the differences between individual and partial equipment. Especially when the equipment is constantly updated in the current year, this method is simpler. The main accounting method for corporate carbon emissions is the emission factor method, which can be selected based on the situation in industrial production processes, such
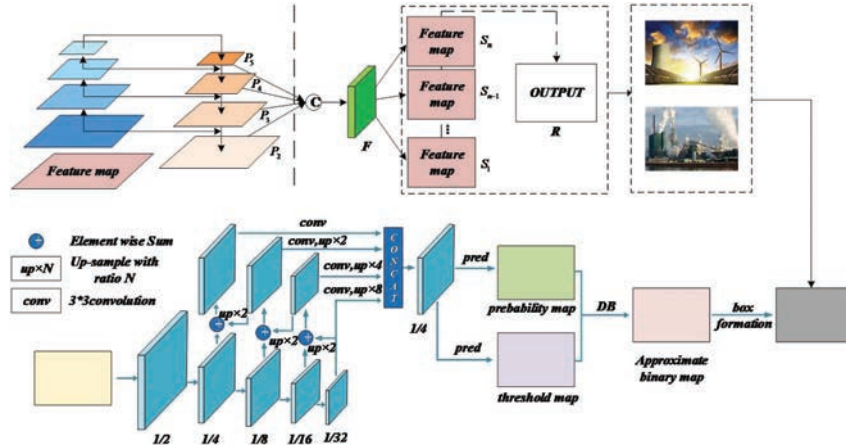
Figure 3 Analysis of implementation steps in carbon emission calculation of prefabricated buildings.

as desulfurization process emissions, chemical production enterprise process emissions, and other non fossil fuel combustion processes.

Figure 3 shows the analysis of the implementation steps in the calculation of carbon emissions of prefabricated buildings. The measured method is based on the measured basic data of emission sources, and the relevant carbon emissions are summarized. There are two actual measurement methods, namely, on-site measurement and off-site measurement [14]. In-site measurement, a carbon emission monitoring module is generally installed in the continuous monitoring system of flue gas emission (CEMS), and its emissions are directly measured by continuously monitoring concentration and flow rate; Off-site measurement is to collect samples and send them to relevant monitoring departments, and use special detection equipment and technology for quantitative analysis. Compared with the two methods, the accuracy of on-site measurement is obviously higher than that of off-site measurement because of the adsorption reflection and dissociation of sampled gas during off-site measurement. LCA carbon emission calculation formula and solar photovoltaic power generation formula are shown in Equations (1) and (2). The formulas of wind power generation and building energy consumption are shown in Equations (3) and (4).

$$LCA = E \times SC \times EF \tag{1}$$

$$E\_sol = A \times T \times K \tag{2}$$

$$E\_wind = A \times V \times T \times D \tag{3}$$

$$E\_build = P \times t \tag{4}$$

3 Energy Saving and Emission Reduction Strategy of Renewable Energy in Prefabricated Buildings

3.1 Formulation and Implementation of Renewable Energy Application Strategy

Relying on the actual project, the carbon emissions of cast-in-place and assembly construction methods in the building stage are compared. Starting from the four major systems of assembly structure system, peripheral protection system, equipment and pipeline system and interior installation, a technical evaluation index system with carbon emissions as the core is formed by combing the commonly used technologies of assembly [15, 16]. This study explores the integration of assembly technology and green low-carbon technology from four aspects: green building technology, low-carbon building materials technology, ultra-low energy consumption technology, and renewable energy technology. From the perspective of the entire life cycle of buildings, the concept of assembly based on zero carbon goals is proposed.

Figure 4 shows the feature extraction and implementation analysis of renewable energy application strategy. Through in-depth research and calculation, the following schemes are put forward: First, give priority to low-carbon building materials. It is necessary to strengthen the popularization and
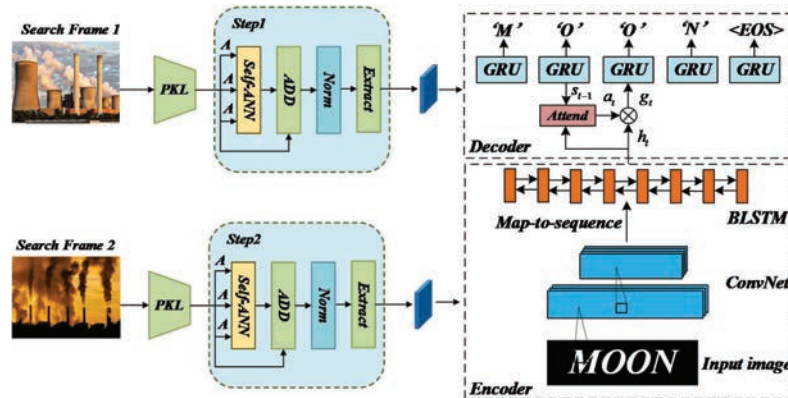

Figure 4 Feature extraction and implementation analysis of renewable energy application strategy.

application of steel-wood structure, high performance concrete, lightweight aggregate and lightweight concrete; Reduce the amount of cement and concrete.

Second, aiming at the recycled building materials, technical research is carried out to improve the reuse rate and processing level of parts and components. Moderate technological innovation and process optimization are also helpful to improve the recycling efficiency of assembled parts and components. At the same time, prolonging the life of buildings can greatly reduce the average annual carbon emission intensity of buildings in the whole life cycle and reduce the impact on the environment [17].

Third, pay attention to the integration and development of assembly technology, ultra-low energy consumption technology and renewable energy technology. Among them, we should focus on: the optimization design of building shape; Structural measures of building insulation and decoration integrated exterior wall and ultra-low energy consumption exterior window: Balcony heat-cut bridge technology; Photovoltaic integrated prefabricated components of prefabricated buildings; Photovoltaic curtain wall, photo-voltaic sunshade, etc. The formulas of renewable energy utilization rate and carbon emission reduction are shown in Equations (5) and (6). The formula of energy consumption reduction and the formula of return on investment of renewable energy are shown in Equations (7) and (8).

$$\eta\_RE = E\_RE/E\_total \times 100\% \qquad (5)$$

$$\Delta C = C\_old - C\_new \qquad (6)$$

$$\Delta E = E\_old - E\_new \qquad (7)$$

$$ROl = (E\_RE - C\_inv)/C\_inv \times 100\% \qquad (8)$$

3.2 Evaluation and Optimization Scheme of Energy Saving and Emission Reduction Effect

Initially, comparing carbon emissions between prefabricated and traditional buildings under identical conditions clarifies the advantages and improvement potential of prefabricated buildings in carbon reduction. Real-time monitoring of energy consumption aids in identifying major energy-wasting links, providing a basis for subsequent optimization. Beyond carbon emissions, other environmental impacts like water pollution and air quality must be considered for a more comprehensive environmental comprehensive benefit assessment [18].

Low carbonation is used in component production, and the production process of prefabricated components is continuously optimized to form modular and standardized assembled components. Improve the application of clean and renewable energy in the production process of components, such as laying solar photovoltaic modules on the roof of the factory building, and using the electricity generated to meet some of the electricity demand in the production process; Replacing gas boilers with steam type air source heat pumps to reduce fossil energy consumption; Increase the recovery of steam condensate after maintenance [19].

Drawing from carbon emission measurement results and real-time monitoring data, optimization schemes can be crafted. Design plays a crucial role in energy saving and emission reduction. By optimizing design, buildings' thermal insulation performance can be enhanced, reducing energy demand. Additionally, actively utilizing renewable energy like solar and wind to replace traditional fossil fuels can slash carbon emissions. Stringent management of building operation energy consumption and regular monitoring and auditing are essential to ensure effective implementation of energy conservation and emission reduction measures. Finally, conduct energy conservation and emission reduction training to enhance environmental awareness and skills among personnel, ensuring long-term implementation of these strategies.

$$\eta\_save = (E\_old - E\_new)/E\_old \times 100\% \tag{9}$$

$$CI = C/GDP \tag{10}$$

$$EQI = \Sigma(Ci/Bi)/n \tag{11}$$

$$EI = \alpha \times CI + \beta \times EQI \tag{12}$$

The equations for calculating energy saving rate and carbon emission intensity are presented in Equations (9) and (10), respectively. The formulas for assessing environmental quality index and comprehensive evaluation index are given in Equations (11) and (12).

3.3 Optimization of Energy Saving Based on LCA

It is crucial to choose appropriate renewable energy sources tailored to local conditions and building needs [20, 21]. Solar, wind, and geothermal energy are common options that can be judiciously utilized based on the situation. Integrating multiple renewable energy systems enhances energy

stability and utilization. For instance, combining solar photovoltaic power with wind power allows for complementary energy use, boosting overall efficiency. Technology updates and equipment modernization are also essential for conservation efforts. Adopting advanced renewable energy technologies and equipment further improves conversion efficiency, stability, and emission reduction. Additionally, establishing an energy management and monitoring system is vital. Real-time monitoring ensures stable renewable energy supply, efficient utilization, and prompt identification and resolution of potential issues [22, 23].

To effectively implement these strategies, it's imperative for governments, enterprises, and research institutions to collaborate and invest in training. Policies, increased research funding, and technical exchange and training programs can jointly propel the advancement of renewable energy in prefabricated buildings. By optimizing energy-saving and emission-reduction strategies informed by LCA, we can significantly curb carbon emissions, enhance energy efficiency, and foster a greener construction industry. This not only meets national carbon reduction targets but also contributes to global climate action efforts.

4 Experimental Results and Analysis

4.1 Design and Implementation of Renewable Energy Application Scheme

In this section, the evolution of the calculation process of carbon emissions is combined with practical cases, and the results are analyzed. A resettlement area project is a local key construction project, including 38 residential buildings, 2 kindergartens and 1 nursing home. The assembly rate of residential buildings is 55%, the assembly rate of a kindergarten is 63%, and the assembly rate of nursing homes is 70.4%. This paper takes the nursing home project as an example. The building has 6 floors above ground and 1 floor underground, with a total construction area of 13,339 m square meters. There are different types of prefabricated components, including columns, composite beams, prestressed hollow panels, composite panels, stairs, air conditioning panels, etc.

Collect data required for carbon emission calculation at each stage, including the consumption of building materials, electricity consumption during processing, and fossil energy based on the production records of the component factory. The transportation distance of the components is based

on the actual distance between the component factory and the project location. The actual consumption of building materials and components on the construction site is obtained through research on engineering and technical information such as the procurement list and bill of quantities of the construction project. However, the energy data of mechanical consumption during the construction process cannot be obtained. Therefore, this article uses relevant information from the construction plan for estimation. The carbon emission factors of the main fossil fuels and building materials are sourced from GB/T51366-2019 and related literature. The carbon emission factors of electricity are based on the benchmark data of the regional power grid where the project is located. The carbon emissions during the component production stage come from the consumption of building raw materials such as concrete, steel bars, cement, and the electricity and fossil energy consumption generated by the operation of machines and conveyor belts during the component processing. In the production process of the components of this project, the main mechanical equipment includes a 10t bridge double beam crane, a 20t bridge double beam crane, a laminated plate production line, a comprehensive production line, a CNC steel bar straightening and cutting machine, a CNC steel bar straightening and cutting machine, a CNC bar shearing machine, a vertical double head bar bending machine, a CNC truss bar welding production line, a concrete mixing station, an air compressor, etc. The energy consumption types of the machinery used in the component factory are mainly diesel and electricity.

Based on LCA evaluation results, the application of renewable energy has become the key to reduce carbon emissions of prefabricated buildings. The design and implementation of the scheme requires comprehensive consideration of building needs, local resource conditions and environmental impacts [24].

Initiating with a thorough demand analysis, we gain clarity on the energy needs of buildings, spanning electricity, hot water, and heating. This informs our decision-making on renewable energy implementation. We evaluate local solar and wind resources to guide system design [25]. Drawing from demand and resource assessments, we devise an appropriate renewable energy system, encompassing equipment selection, layout, and control. Concurrent with this, we conduct environmental impact assessments to ensure program sustainability and environmental friendliness. Implementation commences with purchasing and installing renewable energy equipment as per the design blueprint. We integrate subsystems, test, and fine-tune the
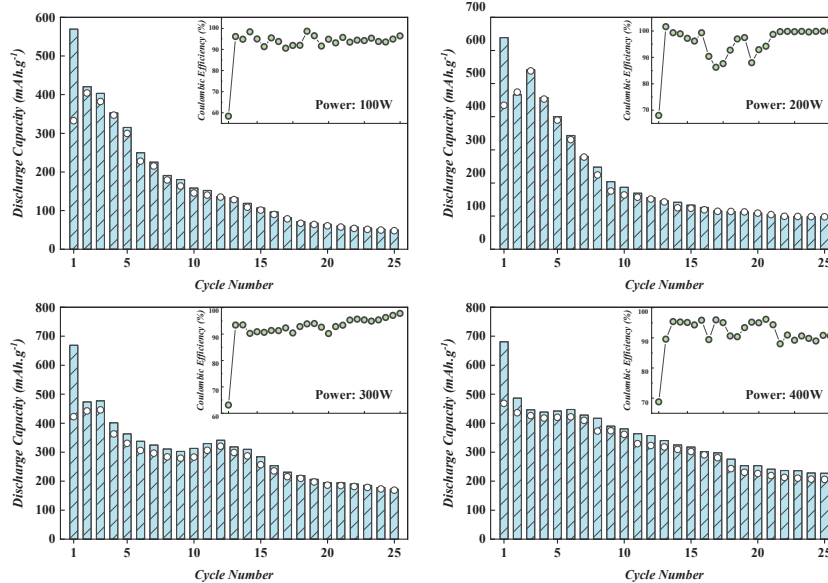
Figure 5 Analysis of energy saving and emission reduction strategy of assembled renewable energy.

system for seamless operation. We maintain real-time monitoring of system performance, adjusting as needed.

Figure 5 reveals that the integration of renewable energy in prefabricated buildings offers significant potential for energy conservation and emission reduction. Solar and wind energy, the two primary sources, demonstrate remarkable carbon emission reduction capabilities. By implementing solar photovoltaic power generation and solar water heating systems in these buildings, carbon emissions can be reduced by approximately 20% and 15% yearly, respectively. Meanwhile, wind energy utilization in ventilation systems and power generation can contribute to a 10% annual carbon emission reduction.

4.2 Evaluation and Calculation of Emission Reduction Effect

After the implementation of renewable energy application scheme, it is very important to evaluate and calculate the emission reduction effect. By comparing the carbon emission data before and after the application of renewable energy, we can analyze the emission reduction range and contribution rate.

The commonly used carbon emission calculation methods currently include: carbon emission factor method, mass balance method, and actual measurement method. The most widely used method currently is the third carbon emission factor method, also known as the carbon emission coefficient method. This method involves multiplying the activity data corresponding to different carbon emission sources by their corresponding carbon emission factors to obtain a single carbon emission amount [26, 27]. The carbon emission calculation of prefabricated buildings in the materialization stage involves multiple processes and carbon sources, and the calculation process of carbon emission factor method is more applicable. Therefore, the carbon emission factor method is chosen as the carbon emission calculation method in this article, and the selection of actual data should be as complete as possible.

This article calculates the list of raw materials and energy consumption per unit weight of each component based on the obtained consumption of building materials, electricity, and fossil energy, as well as the proportion and hollow ratio of each component [28]. The carbon emissions per unit weight of each component in the production stage are then calculated.

Figure 6 offers a breakdown of carbon emissions in each phase of prefabricated building life cycles. Notably, material production generates the highest carbon emissions at 300 kg CO_2/m^2, accounting for 37.5% of the total. These emissions stem mainly from raw material mining, processing, and transportation, highlighting the importance of supply chain optimization and low-carbon raw material selection in reducing prefabricated building emissions. Transportation contributes 80 kg CO2/m2, or 10%, emphasizing
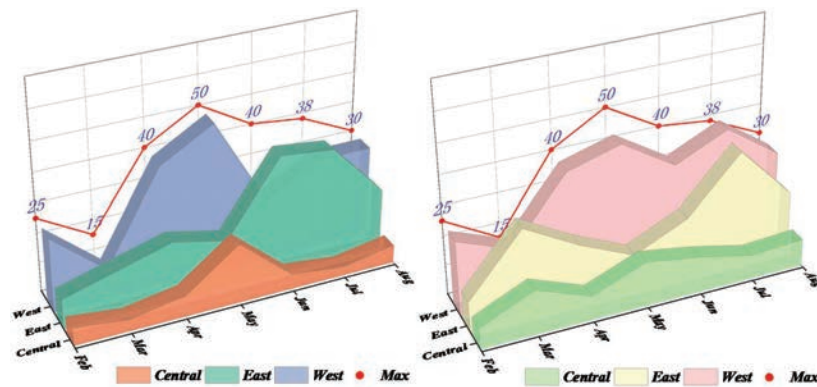

Figure 6 Carbon emission measurement and analysis.

the need for optimized routes and low-carbon transportation. Construction emissions stand at 150 kg CO_2/m^2 (18.75%), pointing to the effectiveness of advanced construction techniques and electric equipment. Operation and maintenance emissions account for 400 kg CO_2/m^2 (50%), highlighting the potential of renewable energy, energy-saving technologies, and efficient building management to slash emissions and enhance energy efficiency. Hence, strategic use of renewable energy and rigorous energy conservation are pivotal in reducing prefabricated building carbon emissions.

The carbon emissions during transportation are mainly influenced by two factors: component weight and transportation distance from the factory to the construction site [29, 30]. The transportation of components in this project is carried out by road, and according to calculations, the transportation distance is 229.3 km. Calculate based on the specific gravity and porosity of the components. The main mechanical equipment used for on-site installation of components in this stage includes tower cranes, truck cranes, electric grouting machines, and aerial vehicles, for vertical lifting, grouting, and auxiliary manual operations. The main types of energy used are diesel and electricity. By calculating the working time of machinery, the carbon emissions per unit weight of each component during the construction phase of the building site can be calculated. The prefabricated column has the highest carbon emission per unit weight, which is 43.06 kg CO_2.

Figure 7 delves into the evaluation of emission reduction achieved through renewable energy and energy-saving strategies in prefabricated buildings. It's evident from the figure that judicious use of solar and wind energy has significantly reduced carbon emissions. Solar photovoltaic and water heating systems slash emissions by 20% and 15% annually. Furthermore,
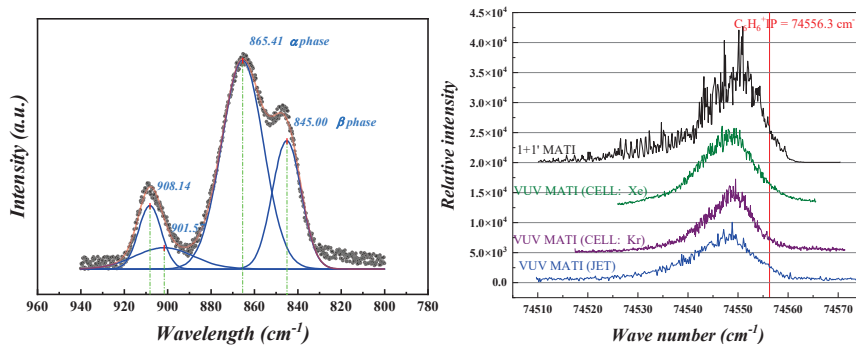

Figure 7 Evaluation and analysis of emission reduction effect.

high-performance insulation materials, optimized building layouts, and intelligent management systems contribute to further emission reductions of 5%, 8%, and 12% each year. Collectively, these measures have led to significant emission reductions in prefabricated buildings, strongly supporting the construction industry's sustainable development and global green transformation efforts.

In conclusion, a cost-benefit analysis is conducted to assess the financial viability and economic benefits of renewable energy application schemes in prefabricated buildings. Accurate evaluation and calculations are essential to understanding the emission reduction potential of these energy sources, thereby providing a scientific basis for further optimization and promoting the green and sustainable development of the construction industry. This approach also supports national carbon emission reduction targets and contributes positively to global efforts to address climate change.

5 Summarize

This study is based on the Life Cycle Assessment (LCA) method and constructs a suitable carbon emission calculation model for the prefabricated building stage. The carbon emission factor method is adopted and reliable carbon emission factors are selected. According to the actual situation, appropriate methods are used to track and obtain the required carbon source activity data for calculation, which can improve the accuracy of empirical results. Empirical analysis was conducted on the carbon emissions calculation of prefabricated buildings based on a case study of a certain nursing home's prefabricated construction project. The research results showed that from the perspective of the entire process of materialization, improving the assembly rate of buildings is conducive to reducing the carbon emissions of buildings. Among them, the carbon emissions in the component production stage are the highest, reaching 88.1%. A detailed analysis of the carbon emissions in the production stage showed that carbon emissions of prefabricated columns and beams are relatively large compared to other components, Its main contribution comes from the consumption of concrete and steel bars. The collection and acquisition of carbon emission activity data is a difficulty in carbon emission calculation. Production and construction should strengthen data recording management, and if conditions permit, add data monitoring systems to promote low-carbon development of buildings and related research work. Taking into account the production and use of building materials, the production and use of prefabricated components, the transportation of

building materials and components, and the low-carbon aspects of on-site construction, this paper proposes low-carbon ideas and measures for the prefabricated building stage.

References

[1] Xu, L., Dong, T., and Zhang, X. (2022). Research on the impact of industrialization and urbanization on carbon emission intensity of energy consumption: evidence from china. Polish Journal of Environmental Studies.

[2] Zhang, Y., Ge, T., Liu, J., Sun, Y., Liu, Y., and Zhao, Q., et al. (2021). The comprehensive measurement method of energy conservation and emission reduction in the whole process of urban sewage treatment based on carbon emission. Environmental Science and Pollution Research, 1–14.

[3] Ming, Y. (2020). Research and application of computer data mining technology in energy saving and emission reduction of thermal power plant. 2020 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE).

[4] Yue, M., Wenxian, L. I., Cheng, X., Chen, Y., and Shi, Y. (2019). Study on energy conservation and carbon emission reduction design of timber structure building. The Journal of Engineering, 2019(9), 5455–5466.

[5] Gao, Y. (2020). Research on new technology of energy conservation and emission reduction based on environmentally sustainable buildings. Journal of Physics Conference Series, 1549, 022077.

[6] Zou, M., Liu, M., Liu, D., Jia, H., Su, S., and Peng, X., et al. (2021). Research on carbon emission reduction calculation and user subsidy mechanism of electric vehicles. IOP Conference Series: Earth and Environmental Science, 791(1), 012168 (7pp).

[7] Omoregbe, O., Mustapha, A. N., Steinberger-Wilckens, R., El-Kharouf, A., and Onyeaka, H. (2020). Carbon capture technologies for climate change mitigation: a bibliometric analysis of the scientific study duration 1998–2018. Energy Reports, 6, 1200–1212.

[8] Jiang, H. X. Y. (2020). Economic structural change, renewable energy development, and carbon dioxide emissions in china. Mitigation and Adaptation Strategies for Global Change, 25(7).

[9] Thornburg, N. E., Feng, X., Zigler, B. T., Day, M. S., Yellapantula, S., and Narumanchi, S. (2023). Model assessment of synthetic jets for

turbulent combustion experiments. Flow, Turbulence and Combustion, 111(1), 201–209.

[10] Pantaleone, F., and Fazioli, R. (2022). Lock-in effects on the energy sector: evidence from hydrogen patenting activities. Energies, 15.

[11] Ehtesham, M., and Jamil, M. (2020). Control techniques for enhancing performance of pv system under dynamic conditions. International Journal of Energy Sector Management, ahead-of-print (ahead-of-print).

[12] Wang, S., Chen, G., and Huang, D. (2021). Can the new energy vehicle pilot policy achieve green innovation and emission reduction? – a difference-in-differences analysis on the evaluation of china's new energy fiscal subsidy policy. Sustainability, 13.

[13] Wang, L. (2022). Research on the dynamic relationship between china's renewable energy consumption and carbon emissions based on ardl model. Resources Policy, 77.

[14] Long, Y., and Han, C. (2020). Transaction processing and value evaluation of carbon emission rights based on wavelet transform image and deep learning. Journal of Intelligent and Fuzzy Systems, 39(4), 5821–5832.

[15] Su, R. (2019). Research on energy accounting under energy conservation and emission reduction policies. IOP Conference Series Materials Science and Engineering, 677, 032113.

[16] Zhou, Q., Shahidehpour, M., Sun, T., Feng, D., and Yan, M. (2019). Cooperative game for carbon obligation allocation among distribution system operators to incentivize the proliferation of renewable energy. IEEE Transactions on Smart Grid, 6355–6365.

[17] Acciardo, E., Tabasso, S., and Cravotto, G. (2022). Process intensification strategies for lignin valorization. Chemical Engineering and Processing (171–), 171.

[18] Kushwaha, P. K., and Bhattacharjee, C. (2022). Integrated techno-economic-enviro-socio design of the hybrid renewable energy system with suitable dispatch strategy for domestic and telecommunication load across india. Journal of Energy Storage.

[19] Group, E. A. P. C. (2022). Lula to reposition petrobras for transition. Energy Argus petroleum coke (38), 22.

[20] Varelas, P., Contino, F., and Parente, A. (2021). Is covid-19 pandemic a "black swan" event? the impact of the pandemic on the energy market. ULB Institutional Repository.

[21] Masi, R. F. D., Gigante, A., Festa, V., Ruggiero, S., and Vanoli, G. P. (2021). Effect of hvac's management on indoor thermo-hygrometric

comfort and energy balance: in situ assessments on a real nzeb. Energies, 14.

[22] Nagarajan, S., Skillen, N., Robertson, P., and Lawton, L. (2021). Cellulose photocatalysis for renewable energy production.

[23] Aziz, M. M. A., Kassim, K. A., Shokravi, Z., Jakarni, F. M., Liu, H. Y., and Zaini, N., et al. (2020). Two-stage cultivation strategy for simultaneous increases in growth rate and lipid content of microalgae: a review. Renewable and Sustainable Energy Reviews, 119.

[24] Hashemi, B., Sarker, S., Lamb, J. J., and Lien, K. M. (2020). Yield improvements in anaerobic digestion of lignocellulosic feedstocks. Journal of Cleaner Production, 288(80), 125447.

[25] Li, S., Li, Y., Chen, X., Jiang, W., and Li, T. (2020). Control strategies of grid-connection and operation based on active disturbance rejection control for virtual synchronous generator. International Journal of Electrical Power & Energy Systems, 123, 106144.

[26] Barter, G. E., Robertson, A., and Musial, W. (2020). A systems engineering vision for floating offshore wind cost optimization. Renewable Energy Focus, 34, 1–16.

[27] Lu-Hua Zhang, Mathew, S., Hessels, J., Reek, J. N. H., and Yu, F. (2020). Homogeneous catalysts based on first-row transition-metals for electrochemical water oxygenation. ChemSusChem.

[28] Madon, M., and Pierson, J. M. (2020). Integrating Pre-Cooling of Data Center operated with Renewable Energies. IEEE International Conference on Green Computing and Communications; IEEE International Conference on Internet of Things; IEEE International Conference on Cyber, Physical and Social Computing; IEEE International Conference on Smart Data; IEEE Congress on Cybermatics.

[29] Qiuhong, X. (2018). Research on education strategies for energy conservation and emission reduction in primary schools. Guangzhou Environmental Science.

[30] Nabielek, P., Dumke, H., and Weninger, K. (2018). Balanced renewable energy scenarios: a method for making spatial decisions despite insufficient data, illustrated by a case study of the vorderland-feldkirch region, vorarlberg, austria. Energy Sustainability & Society, 8(1), 5.

Biography

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