PROCEEDINGS OF THE
INTERNATIONAL CARBON NEUTRALITY TRAINEESHIP PROGRAM
Volume.02, Number.1, 2024, 114-122

Low-Carbon Buildings Development and Application in Europe

Wenzheng SUN

Dalian Maritime University, Dalian, China, 116026

Email: sun_wenzheng_icnt@iie.world

***Corresponding author**

Abstract

The Earth is the home for human survival and development. With social progress and rapid economic development, global energy demand has sharply increased. The concentration of carbon dioxide is rising year by year, and the destruction of the ecological environment is becoming increasingly severe. Reducing energy consumption and lowering carbon dioxide emissions are among the important tasks humanity currently faces. For the energy-intensive and highly-polluting construction industry, achieving building decarbonization is a crucial step towards sustainable development, and the development of low-carbon buildings is the inevitable path to address the low-carbonization of the construction industry. It is pointed out that as one of the human activities with the highest energy consumption, the construction industry has a significant impact on the environment throughout the process of design, construction, use, maintenance, and demolition. By comparing and studying examples of low-carbon building construction in European countries, taking into account their respective characteristics and the low-carbon technologies used, we can summarize the advanced low-carbon concepts and technologies employed in typical low-carbon buildings in Europe. This provides a positive outlook for the future development prospects of low-carbon buildings.

Keywords: Carbon neutrality; climate change; low-carbon buildings; European cases; energy-saving technology.

1. Low-carbon buildings development and application in Europe

Currently, the building stock is rapidly increasing on a global scale. It is projected that by 2060, the increase in building area every five days will be equivalent to the size of Paris. Carbon neutrality in the construction industry is a crucial aspect in achieving climate goals. In Europe, buildings account for approximately 40% of total energy consumption and contribute to about 36% of total greenhouse gas emissions (Huseynov, 2011). In the face of the growing building area and energy consumption, decarbonization of the building sector is of paramount importance in achieving climate targets.

Currently, in Europe, there are numerous old and energy-inefficient buildings. Statistics show that approximately 35% of housing in EU member states is over 50 years old, and 75% of buildings are assessed as low-energy efficiency. Furthermore, the primary energy consumption in buildings is attributed to heating and hot water, with a relatively smaller proportion for cooling. However, with global climate warming, the potential demand for cooling will continue to rise. In EU member states, heating and hot water alone account for nearly 80% of energy consumption in households, and approximately 75% of the energy supply still relies on fossil fuels, further complicating the decarbonization of the building sector(Li, 2011).

Germany, as one of the EU member states, also faces similar challenges. Statistics indicate that in 2018 alone, existing buildings in Germany consumed 839 TW·h of final energy for heating, hot water, lighting, and air conditioning. Residential buildings accounted for about two-thirds of the energy consumption, while non-residential buildings accounted for approximately one-third (CLG, 2008). Although the carbon emissions from buildings have decreased since 1990, there has been a stagnation in the trend over the past decade, and the rate of renovation for old buildings is not optimistic (BMWi, 2021).

The Paris Agreement, which was signed at the United Nations Climate Change Conference (COP21) in December 2015 (Agreement, P, 2015) is the first legally binding comprehensive global climate protection agreement. According to the agreement, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) commit to keeping the global average temperature rise well below 2 degrees Celsius above pre-industrial levels and to making efforts to limit the temperature increase to 1.5 degrees Celsius.

Under the threat of continuously rising global temperatures, major developed countries around the world have formulated corresponding policies based on their own social backgrounds and economic strengths, with energy and climate change at their core (Fetting, 2020). These countries are transitioning towards low-carbon industries and moving towards a low-carbon society through different development models. Particularly in Europe, it has been a champion and promoter of energy efficiency, emission reduction, and low-carbon economy worldwide. Europe embraces a low-carbon lifestyle and guides people to live, learn, and produce in the right low-carbon manner. Moreover, Europe has conducted research in the field of low-carbon buildings for a long time and has prioritized achieving low-carbonization in building technologies.

Among these efforts, the construction of low-carbon and zero-carbon buildings in the UK and the construction of passive houses in Germany are successful examples. These projects have achieved significant results in energy conservation, environmental protection, and greenhouse gas emissions reduction.

Low-carbon buildings align with the trend of energy conservation and emission reduction. They not only effectively improve the comfort of living environments but also represent the inevitable path for achieving energy efficiency and emission reduction in modern cities. Low-carbon buildings will undoubtedly be the direction for future development in the construction industry and the necessary choice for countries to achieve emission reduction targets, protect the ecological environment, and reduce carbon dioxide emissions. In today's competitive international environment, carbon emissions rights are critical to a country's future development. The development of low-carbon buildings is beneficial for countries to strategically reserve carbon emissions trading resources, promote domestic economic development, and drive the development of related sectors. Achieving low-carbon buildings serves as the starting point and cornerstone for developing urban low-carbon emissions and a low-carbon economy (Anderson, 2006).

As the low-carbon and environmental-friendly concept gradually penetrates into the daily lives of ordinary people, it is crucial to explore how to utilize low-carbon technologies, combined with management, policies, and other measures, to address the potential adverse environmental impacts during the construction process. Additionally, it is important to explore future building development and construction models to achieve the goal of "building decarbonization." This is currently a pressing matter for both human development and environmental protection. The success of low-carbon buildings and technologies in Europe undeniably lays a foundation for the development of low-carbon buildings.

2. Method

The research framework begins by examining the interrelationships and interactions between people, environment, energy, and buildings. It focuses on studying the relationship between carbon dioxide emissions reduction and buildings, highlighting the crucial role of low-carbon technologies in reducing energy consumption in buildings and exploring the necessity for the construction industry to adopt a low-carbon path. Subsequently, the research delves into the theoretical foundations of low-carbon buildings and conducts a comprehensive and thorough analysis of European low-carbon building examples and the application of low-carbon technologies. By studying the development of low-carbon buildings in Europe and the application of various low-carbon building technologies under different conditions, the research aims to identify the optimal path for adopting low-carbon technologies.

The research primarily adopts a combination of literature review and case analysis methods to summarize low-carbon technologies based on different aspects of low-carbon buildings. The following guiding principles are proposed based on the summary:

(1) Literature review:

Extensive literature review is conducted, including books, papers, journals, online resources, and specialized literature, to gather information on the development process and examples of low-carbon buildings. The focus is on the technological advancements in low-carbon buildings. Through the review of literature, the research gains in-depth understanding of the development trends in low-carbon buildings, particularly focusing on the development and construction trends in European countries. The essence extracted from the literature serves as necessary references for future development of low-carbon buildings and provides guidance.

(2) Comparative analysis of case studies:

Based on the collection of relevant case study materials from various European countries, a comparative analysis is conducted both horizontally and vertically. By comparing representative cases from different European countries, the characteristics, technical approaches, development trends, and innovations of these cases are summarized, laying the foundation for improving and optimizing technical approaches.

(3) Data analysis:

Data from yearbooks, reports, literature, planning documents, and regulations are analyzed to examine the quantity, regions, timeframes, regulations, and other specific indicators of low-carbon building examples in Europe. Regularities, development trends, and existing technical approaches are derived from the analysis of data.

(4) Inductive summarization:

The basic characteristics of European low-carbon building technologies and design techniques are summarized, forming a complete theoretical framework.

(5) Typological approach and typical argumentation:

Classical cases are analyzed to provide a typological analysis and a more essential generalization from a rational cognitive perspective.

In conclusion, through the collection of theoretical materials on low-carbon buildings, the research organizes and categorizes the theories of low-carbon buildings. By conducting horizontal and vertical comparisons of significant milestones in low-carbon building cases from different countries, conclusive theoretical concepts regarding low-carbon buildings and technologies are derived.

The development of low-carbon buildings in developed countries such as Europe and the United States started early. It is considered an important strategic goal for national low-carbon development, and its growth has been rapid. These countries are at the forefront in terms of building legislation, practices, and low-carbon technologies. Due to the shared political, economic, and social development systems in European countries, they have many similarities in the ways and experiences of developing low-carbon buildings. These include promoting widespread adoption of low-carbon concepts among the public, establishing medium- to long-term low-carbon development goals, implementing comprehensive legal and regulatory frameworks, implementing tax policies and various forms of public financial support to facilitate the development of the low-carbon building market, and establishing robust systems for low-carbon building assessment standards.

Developed countries in Europe and America have already established a strong presence and expertise in low-carbon building development within the international construction industry. Therefore, their concepts and experiences in the development of low-carbon buildings and technologies are worth analyzing and studying. For this research, representative low-carbon building cases from the United Kingdom, Germany, and Spain have been selected for analysis.

3. Result

3.1. The practice of low carbon buildings in UK

With the continuous development of its economy, the United Kingdom is making practical efforts to address the challenges of climate change. It was the first country in the world to propose a reduction in carbon dioxide emissions and establish legally binding medium- to long-term targets. It is also the first country in the world to legally require buildings to achieve zero emissions and zero energy consumption.

Located in Western Europe along the eastern coast of the Atlantic Ocean, the UK has a typical temperate maritime climate. Influenced by the mid-latitude westerlies and the North Atlantic Drift, it receives abundant precipitation throughout the year, with a relatively even distribution. The lowest temperatures usually do not drop below -10°C, and the highest temperatures do not exceed 32°C. Due to the shorter daylight hours and ample rainfall during winter, the heating season in the UK is relatively long. Taking advantage of this characteristic, the BedZED community fully utilizes waste, sunlight, air, and water to engage in sustainable dialogue with modern people and buildings. Through various low-carbon technological measures, it aims to reduce building heat loss and maximize the use of solar thermal energy, ultimately achieving the goal of eliminating traditional heating methods (Dunster, 2013).

All the residences in the BedZED zero-carbon community face south, and each unit has a glass sunspace. The roof, exterior walls, and floors are insulated with 300mm thick insulation material. The windows are made of triple glazing with argon gas filling, allowing them to absorb heat as much as possible during winter. In summer, these designs minimize the conduction of outdoor high temperatures, eliminating the need for air conditioning. The window frames are made of wood with excellent thermal insulation properties, reducing heat transfer and cleverly recycling thermal energy. Another method of maintaining indoor temperature is through roof greening. A succulent plant called “sedum” covers the rooftops, greatly reducing heat loss during winter. This is a major reason why residents in BedZED save 90% of energy in heating and cooling compared to conventional homes, effectively achieving “zero heating.”

The construction materials used in the houses, including timber, glass, and 95% of the steel, are recycled. Choosing wooden frames for windows alone reduces carbon dioxide emissions by over 10% (approximately 800 tons) during the manufacturing process.

A significant factor in the community’s low energy consumption is the combined heat and power (CHP) plant, which plays a crucial role. It generates electricity for the community by burning wood waste and utilizes the heat produced during this process to supply hot water. Each unit is equipped with solar photovoltaic panels, which, although costly, are used for multiple purposes. The warm sunshine provides hot water and charges electric cars. On the roofs, there are rows of peculiar-looking “wind cowls” that continuously bring fresh air into the first room. These passive ventilation devices are entirely driven by wind and rotate according to the wind direction, providing fresh air to the interior and expelling stale air. Additionally, they contain heat exchangers that can recover 50% to 70% of the heat in exhaust gases, preheating the cold fresh air from outside.

Figure 1. BedZED zero carbon community

In today's world, where energy issues are of great concern, the completion of the BedZED zero-carbon community offers hope for future human living patterns. Its advanced sustainable design concepts and comprehensive utilization of environmentally friendly low-carbon technologies have made this community an exemplary zero-carbon residential neighborhood in the UK.

3.2. The practice of low carbon buildings in Germany

Germany experiences mild summers and moderate winters. Nevertheless, nearly one-third of the country's primary energy products are consumed by residential heating. In the search for energy-efficient and environmentally-friendly building technologies, a 70-year-old existing building in Germany was transformed into the country's first "3-liter house" through modern low-carbon technology. Currently, the "3-liter house" serves as a global model for energy retrofitting of existing buildings (Erhorn, 2015). The name "3-liter house" originates from the fact that after the renovation, the annual heating oil consumption per square meter does not exceed 3 liters (equivalent to approximately 4.5 kg of coal).

Figure 2. 3-liter house in Germany

During the retrofitting process, four major low-carbon energy-saving technologies were employed: enhancing the thermal insulation performance of the building envelope, utilizing phase change energy storage insulation mortar with an inner wall "air conditioning system" function, implementing a ventilation system with heat recovery, and integrating a fuel cell unit as a small-scale power station.

Following the modernization, the heating oil consumption of the "3-liter house" decreased from 20 liters to 3 liters. For a 100 m² apartment, the annual heating cost decreased, and the carbon dioxide emissions reduced by 80%. These improvements showcase significant economic and environmental benefits.

3.3. The practice of low carbon buildings in Spain

Spain, located in southern Europe, has a Mediterranean climate characterized by warm winters and hot summers. Ventilation and air conditioning systems are major energy consumption points in this region. The construction of Atika residences adopts a prefabricated modular structural system. The first sample of an Atika residence was assembled in the city of Bilbao, Spain, and there are plans to transport it by car to different countries for assembly in the future. This modular prefabricated system can save approximately one-third of construction time while ensuring a more precise architectural structure even after multiple disassemblies(Guo, 2012).

Figure 3. Atika house in Spain

In addition, other low-carbon energy-saving technologies are employed in the design. The thickness and density of the exterior walls are adjusted to provide insulation and thermal insulation. White lime boards are used as the best reflective material for sunlight. Overhangs or blinds on windows are utilized to create shading. Narrow streets and balconies are designed to ensure shaded areas and airflow. The cooling effect is achieved by utilizing flowing water.

Atika residences incorporate sloping roof technology, low-energy strategies, comprehensive solar energy systems, intelligent building management systems, and modular construction techniques. They represent a new type of energy-efficient housing in Europe and serve as a model for future residential developments in the region.

The nature of low-carbon buildings determines that low-carbon construction supported by low-carbon technologies is inevitably energy-saving, environmentally friendly, and low-emission. Achieving a harmonious building environment that aligns with the living environment is the optimal approach for energy efficiency and emission reduction through low-carbon technologies in low-carbon buildings.

European policymakers actively promote the innovation and application of low-carbon and energy-saving technologies in the construction industry, encouraging the development and implementation of new energy technologies. In terms of existing examples of low-carbon buildings in Europe, the implementation of low-carbon building technology transformation and innovation in Europe focuses on two main technical breakthroughs: energy-saving and emission reduction.

(1) Decarbonization of building structures:

European low-carbon buildings achieve energy efficiency and carbon emission reduction by designing the orientation of buildings in a rational manner. Effective insulation and thermal insulation of building envelopes can also contribute to energy savings. Furthermore, reducing the energy consumption of heating, air conditioning, and other equipment helps reduce carbon dioxide emissions.

Natural ventilation systems are installed to exchange indoor and outdoor air while recovering heat to minimize energy loss. Suitable daylighting techniques are also chosen. Proper building orientation, as seen in the three case studies, significantly contributes to energy efficiency and carbon emission reduction.

Additionally, effective insulation and thermal insulation of building envelopes can effectively reduce carbon dioxide emissions.

(2) Selection of appropriate renewable energy sources:

During the design and construction of buildings, renewable energy utilization technologies such as solar energy, wind power, and biomass energy should be fully utilized based on local environmental conditions and building usage characteristics to increase the utilization rate of renewable energy. The utilization of solar energy should consider local sunshine duration and intensity, while wind energy utilization should take into account wind speed and direction.

(3) Use of locally sourced environmentally friendly building materials:

When constructing buildings, prioritize the use of green and environmentally friendly building materials sourced locally. Additionally, maximize the utilization of recyclable materials such as wood, steel, and glass to reduce emissions. Choosing locally sourced building materials also reduces the transportation distance, thus minimizing carbon emissions generated during transportation.

(4) Increasing carbon sinks and reducing overall emissions:

In the process of decarbonizing buildings, besides reducing carbon emissions through energy-saving measures, it is essential to increase carbon sinks and reduce overall emissions. The most practical method to increase carbon sinks in buildings is through greening.

By considering the absorption of carbon dioxide, increasing carbon sinks can be achieved. To achieve carbon balance in nature, plants absorb carbon dioxide through photosynthesis. Applying carbon sequestration techniques in low-carbon buildings by utilizing plants helps increase the carbon sinks of buildings.

(5) Rainwater collection and utilization:

Low-carbon buildings should consider the collection and utilization of rainwater and domestic wastewater. Designing water reuse systems not only conserves water resources but also indirectly reduces emissions.

These measures reflect the European approach to low-carbon building technology transformation and innovation, emphasizing energy efficiency, emission reduction, and sustainable practices.

4. Discussion

The world is constantly evolving, and the destructive effects of global warming and environmental pollution are increasing. Driven by rapid urbanization, low-carbon buildings have the advantages of resource conservation and protection of the natural environment. However, low-carbon buildings also face significant development challenges, stemming not only from the speed and scale of their construction but also from the appropriate application of low-carbon technologies. Taking Europe as an example, the region has limited internal resources and a high dependency on imported energy. Faced with increasingly fierce international competition, its spatial development will inevitably expand into the field of clean energy and low-carbon technologies. However, the current global development of the construction industry is not conducive to energy saving, emission reduction, and ecological conservation. Instead, it exacerbates the contradiction between carbon dioxide emissions and environmental energy. Therefore, in the study of low-carbon buildings and the application of technologies, particularly the focus on energy saving and emission reduction, and harmonious coexistence with nature, are of great significance for energy efficiency in buildings and the sustainable development of cities. The formulation of Europe's low-carbon strategy and the development of low-carbon buildings are successful examples. In the process of their development, low-carbon building technologies play a crucial role in the utilization of new energy sources and environmental protection, serving as a technical guarantee for achieving energy-saving and emission reduction in the construction industry while balancing environmental resource capacity.

How to implement the application of low-carbon technologies in the sustainable development of buildings is of great importance for a country and a city. On the one hand, low-carbon building technologies can address conflicts with environmental protection in building planning, design, construction, use, and maintenance. On the other hand, low-carbon building technologies are resource-efficient in terms of energy, land, materials, water, etc., and they actively promote the utilization of renewable energy. Therefore, further analysis and research are needed for the application system of low-carbon building technologies. In conclusion, the development of low-carbon buildings has a strategic significance that transcends generations for countries and urban development.

The following are some of the ideas discussed in this article, presented as conclusions:

(1) Low-carbon buildings are a new concept.

Therefore, this article analyzes and studies them from the perspective of the concept of low-carbon buildings, presenting their characteristics. Low-carbon buildings focus on the efficient and resource-saving use of energy, materials, water, and other resources throughout their lifecycle, and they extensively incorporate new technologies such as renewable energy. Based on the analysis of classic cases of low-carbon buildings, new approaches for the application of low-carbon building technologies are proposed.

(2) Guiding optimized construction in urban buildings.

This mainly involves setting the goal of constructing buildings with low carbon emissions and utilizing appropriate low-carbon building technologies to minimize ecological damage and energy consumption, forming a complete system of building energy-saving and emission reduction technologies.

(3) Promoting the rapid development of low-carbon building technologies.

This primarily involves using low-carbon building technologies to achieve energy efficiency, material conservation, water conservation, carbon reduction, and fostering harmonious and orderly coexistence between buildings and the environment.

In conclusion, low-carbon building technologies are not only the focus of the construction industry but also a concern for human survival and development. Starting with the concept of low carbon, it changes the means by which humans utilize technology. It is a manifestation of human progress and serves as a medium for the harmonious development of humans, buildings, and the environment.

To envision the future of architectural development is, more precisely, to envision the future of human survival and development. Humanity should realize that the current high-energy consumption and high-pollution development could have serious consequences for future human development. The development and construction of low-carbon buildings provide broad space for the development of urban construction industry and also offer solutions to environmental pollution and energy consumption issues. How to handle the contradiction between economic development and environmental protection in construction is not only a concern for cities but also a concern for nations.

The ultimate goal of discussing the fate of low-carbon building technologies is to improve the quality of the living environment and achieve energy conservation and emission reduction. The development of low-carbon buildings is an ongoing process of innovation and the application of low-carbon technologies. With technological advancements and the continuous emergence of new low-carbon building technologies, there will be a more comprehensive system of low-carbon building technologies in the future. Establishing a global repository of low-carbon building technologies will facilitate the selection and application of appropriate low-carbon technologies in planning and constructing low-carbon buildings. This is a necessary approach to achieve building decarbonization. While relying on low-carbon technologies, buildings also need to consider factors such as economics, society, regional environment, and climate differences. Most importantly, the demands of residents should be considered, reflecting the concept of "people-oriented low-carbon building."

With the continuous development of international low-carbon strategies, the improvement of energy-saving policies in the construction industry, and the progress of global carbon trading mechanisms, the low-carbon market is gradually forming and maturing. Low-carbon buildings will have significant development and the low-carbon building market will move towards a healthy interaction between supply and demand. Low-carbon buildings will become an important part of people's daily lives, and the construction industry will no longer be a major consumer of energy and emitter of greenhouse gases. Instead, it will be an inevitable result that promotes global economic, social, and political development.

References

[1] Agreement, P. (2015, December). Paris agreement. In Report of the Conference of the Parties to the United

Nations Framework Convention on Climate Change (21st Session, 2015: Paris). Retrived December (Vol. 4, p. 2017). HeinOnline.
[2] Anderson, B. (2006). Energy performance of buildings directive. BRE, April.
[3] BMWi (Federal Ministry of Economics and Technology, Germany) (2021). Integrierter nationaler energie-und klimaplan Deutschland. www.bmwi.de/Redaktion/
[4] CLG (Communities and Local Government) (2008) Energy Performance of Buildings. www.communities.gov.uk/planningandbuilding/theenvironment/energyperformance/
[5] Dunster, B. (2013). BedZED: Beddington zero-fossil energy development. In Sustainable Urban Design (pp. 157-174). Taylor & Francis.
[6] Erhorn, H., Erhorn-Kluttig, H., & Reiß, J. (2015). Plus energy schools in Germany–Pilot projects and key technologies. Energy Procedia, 78, 3336-3341.
[7] Fetting, C. (2020). The European Green Deal. ESDN Report, December.
[8] Guo, S. R., & Liu, A. F. (2012). Reflections Based on the Concept of Low Carbon Building Design. In Applied Mechanics and Materials (Vol. 193, pp. 103-106). Trans Tech Publications Ltd.
[9] Li, W. (2011). Sustainable design for low carbon architecture. Procedia Environmental Sciences, 5, 173-177.
[10] Oglu Huseynov, E. F. (2011). Planning of sustainable cities in view of green architecture. Procedia Engineering, 21, 534-542.