Proceedings of CONF-FMCE 2025 Symposium: AI and Machine Learning Applications in Infrastructure Engineering
DOI: 10.54254/2755-2721/2025.MH25096

Analysis of Energy Consumption and Efficiency of Green Buildings Based on BIM Technology

Juanyong Qiu

Chang'an Dublin International College of Transportation at Chang'an University, Chang'an University, Xi'an, China
2024902330@chd.edu.cn

Abstract. This study explores the integration of Building Information Modeling (BIM) technology with green building practices against the backdrop of global building energy consumption and carbon emissions, accounting for significant proportions of total energy use and emissions. The research highlights the importance of BIM in achieving low-carbon and sustainable building development, which is crucial for environmental protection and meeting carbon neutrality goals. This paper examines BIM's applications in daylight analysis, HVAC load calculation, and energy consumption analysis within the building lifecycle. It demonstrates how BIM, combined with energy simulation software like EnergyPlus and IES VE, optimizes building design, construction, and operation for enhanced energy efficiency and reduced carbon emissions. The study reveals that BIM enables precise daylight simulation, optimizing building orientation and design to increase natural lighting and reduce artificial lighting use. In HVAC load calculations, BIM provides detailed building data for accurate load assessments, leading to efficient system designs. Furthermore, BIM's integration with energy analysis tools allows for comprehensive energy consumption prediction and optimization throughout a building's lifecycle, from construction to operation, improving energy management and reducing operational costs. This research underscores the potential of BIM technology to drive innovation in green building practices, offering valuable insights for the construction industry's transition toward sustainability and carbon reduction.

Keywords: BIM, green building, energy consumption, sunlight analysis, Hvac load.

1. Introduction

According to the Global Buildings Tracker published by the International Energy Agency (IEA), the operational consumption of buildings accounts for 30% of global final energy consumption in 2021, and their carbon emissions account for 27% of total energy sector emissions. Specifically, buildings account for 8% of direct carbon emissions, while indirect carbon emissions from the use of electricity and heat in buildings account for 19%. Furthermore, from 2010 to 2021, energy use in buildings increased from 115 exajoules (EJ) to nearly 135 EJ, accounting for 30% of global final energy consumption. This percentage rises to 34% when final energy use associated with cement, steel and aluminum production is included [1]. Energy consumption not only leads to resource

DOI: 10.54254/2755-2721/2025.MH25096

depletion but is also accompanied by greenhouse gas and pollutant emissions, posing a threat to the ecosystem and hindering the green and sustainable development of the economy. Therefore, it is imperative to seek a low-carbon and efficient building model. In this context, green building, with its energy-saving and carbon-reducing advantages, has become a key path to cope with the environmental crisis and help sustainable development.

At present, the world attaches great importance to environmental protection and sustainable development, and green building technology is booming at a high speed with its low-carbonization features. In China, realizing the goal of carbon peak and carbon neutrality (dual-carbon) is a major strategic decision to cope with climate change and promote high-quality development. In the current construction field, the innovative practice of green building construction technology reveals the development direction and technical path for the transformation and upgrading of the construction industry. Meanwhile, the rise and widespread application of building information modeling (BIM) technology have brought transformative opportunities for the whole life cycle management of construction projects. Combining BIM technology with green construction technology not only helps to improve the energy efficiency and environmental friendliness of buildings, but also helps to enhance their environmental friendliness of buildings. By establishing a perfect green construction technology system, promoting the use of new energy-saving and environmentally friendly materials, and deepening intelligent construction management, the resource utilization efficiency and environmental adaptability of convention and exhibition buildings have been significantly improved [2]. Currently, the combination of green building and BIM has made ideal progress, which can not only realize the accurate analysis of building performance, but also optimize the design, construction and operation process, accurately judge its reliability in a carbon environment, and improve the quality of the building [3]. However, whether the application of BIM technology for daylight analysis, HVAC loads and energy calculation in green buildings has the same high performance as in construction and operation needs to be studied in depth. Exploration of these issues is very meaningful in the application of BIM technology in green buildings.

Based on the realization of the dual-carbon target and green building analysis, this study thoroughly explores the key applications of BIM technology in daylighting, HVAC loads and energy consumption, and demonstrates several important directions affecting green buildings with BIM models through simulation analysis and literature research methods to study their practical application significance.

2. Introduction to BIM technology

BIM integrates building models, dataizes and informatizes them, and shares and transmits them during the whole life cycle of planning, operation and maintenance of the project, so that the engineers and technicians included in the project can make a correct understanding and high effective response to all kinds of building information, and provide a basis for collaborative work for the design team as well as for all parties, including the construction and operation units. Currently, BIM technology is widely used in the field of building design, and at the same time, it has ideal application value in daylight analysis, HVAC load and energy consumption calculation.

Nowadays, the construction industry is developing rapidly, and BIM technology has become a powerful force to promote the change of building design, construction and operation and maintenance, which is very advantageous[4].BIM can carry out three-dimensional visual modeling of construction projects, so that all the parties involved can intuitively see the whole picture of the building during the design stage, discover and solve design conflicts in advance, and reduce rework and changes during construction. Its parametric design function makes design modification efficient

DOI: 10.54254/2755-2721/2025.MH25096

and convenient, and one modification can be automatically associated with other related parts, which greatly improves the design efficiency. At the same time, BIM covers the information of the whole life cycle of the building, which can provide accurate data support for the management of the project's cost, schedule, quality and other aspects.

When BIM is combined with the energy simulation software EnergyPlus, which can calculate in detail the energy consumption of heating, cooling, ventilation, lighting, etc., and IES VE, which is good at analyzing the performance of the building, including lighting and thermal comfort, the application prospect is even more promising. Energy simulation software can more accurately simulate and analyze energy consumption with the help of detailed geometric information and material properties of BIM models. At the early stage of design, designers can optimize building orientation, facade design, window size and layout based on the simulation results to improve the natural lighting and ventilation performance of the building, reduce the frequency of air conditioning and artificial lighting, and achieve building energy efficiency. For example, in a large commercial complex project, the design team used BIM and EnergyPlus to find that the cooling load in a certain area of the original plan was too high in summer, and by adjusting the design of the shading system, the energy consumption of the area was significantly reduced.

In the operation and maintenance stage of the building, based on the real-time updated data of the BIM model and the long-term energy consumption monitoring and analysis of the energy consumption simulation software, the operation and maintenance personnel can grasp the actual energy consumption status of the building promptly, discover anomalies and take optimization measures, such as adjusting the operation strategy of the equipment and replacing the energy-saving equipments, etc., which can further increase the energy utilization efficiency of the building, reduce the operation cost and provide a strong guarantee for the sustainable development of the building.

3. BIM technology applications

This paper mainly analyzes the specific application of BIM technology in the field of construction engineering from three aspects: sunlight analysis, HVAC load and energy consumption calculation. In the sunlight analysis, BIM software is used to create a 3D building model, combined with geographic information system (GIS) data, input local latitude, longitude, sun trajectory and other parameters to simulate the sunlight situation of the building at different time periods. The BIM model can accurately reflect the shape of the building, window positions, shading components and other detailed information, so as to realize the accurate calculation of the intensity of sunlight, the sunlight duration and the distribution of shading [5].

In the building design stage, through BIM daylight analysis, architects can optimize the building orientation and layout so that the interior can obtain more natural lighting, reduce the use of artificial lighting time, and reduce lighting energy consumption. At the same time, reasonable daylighting design helps to improve the comfort of the indoor environment, avoid excessive solar radiation leading to overheating indoors, provide a reference basis for the subsequent HVAC design, and thus realize the energy-saving goals of green buildings [6].

Calculating HVAC loads requires a large amount of complex data analysis, which can be improved through the creation of a BIM model, which contains detailed information about the building, such as the geometry of the building, the thermal performance parameters of the envelope materials, the heat dissipation of internal equipment, and the heat generated by the activities of the personnel, etc. These data provide an accurate basis for HVAC load calculation. These data provide an accurate basis for HVAC load calculations, enabling HVAC engineers to perform accurate load calculations based on actual building conditions.

DOI: 10.54254/2755-2721/2025.MH25096

Based on the results of HVAC load calculations from BIM models, designers can reasonably select the models and capacities of air conditioning equipment and design scientific ventilation systems and air distribution methods[7]. Through the simulation and analysis of different design options, the impact on indoor temperature, humidity and air quality is assessed, so as to optimize the design of the HVAC system, improve the operational efficiency of the system, reduce energy consumption, ensure the comfort of the indoor environment, and realize the energy saving of HVAC (heating, ventilation and air conditioning) in green buildings.

Meanwhile, combining BIM model with energy consumption analysis software, BIM technology is able to predict and optimize the analysis of energy consumption during the whole life cycle of a building by constructing a highly accurate 3D digital model. It has a fine parametric design function, which can simulate the impact of different climates, materials, light and other environmental factors on building energy consumption, thus realizing comprehensive monitoring and adjustment of building energy consumption. In addition, BIM also integrates energy management functions to dynamically analyze the energy efficiency of heating, ventilation, and air-conditioning systems, thus improving the building's energy efficiency. The application of BIM in the optimization of building energy efficiency is carried out throughout the stages of design, construction, and operation. In the construction phase, BIM is used as a data base for modeling the selection of building materials and construction processes to reduce carbon emissions during the construction process. In the operation phase, BIM is used as the basis of a digital twin to support the optimization of energy management and maintenance of the building through real-time data feedback to improve the overall operational efficiency [8].

In addition, BIM technology can establish an energy consumption simulation by analyzing the actual operation of the building, and analyze the building's energy consumption pattern and main energy consumption links. Based on the simulation results, corresponding energy-saving strategies can be formulated, such as adopting highly efficient energy-saving equipment and lighting systems, optimizing the building's envelope structure, and reasonably setting the running time of equipment. At the same time, the implementation effect of energy-saving strategies can also be evaluated and optimized to provide a scientific basis for the energy-saving operation of the green building, reduce the operating cost of the building, and improve the building's energy utilization efficiency [9]. The key to applying BIM technology to energy consumption analysis lies in realizing the effective integration of BIM model and energy consumption analysis software. Currently, common energy analysis software on the market, such as EnergyPlus, IES, DesignBuilder, etc. provide interfaces with BIM software (e.g. Revit, ArchiCAD, etc.). Through these interfaces, data such as building geometry information, material properties, equipment parameters, etc., in the BIM model can be read directly by the energy analysis software, thus reducing errors and repetitive workload in the data conversion process.

4. Challenges and prospects

The combination of green building and BIM technologies is revolutionizing the building sector. While the two have achieved some success in optimizing daylighting, HVAC loads and energy consumption, they still face many challenges. One such challenge is data integration, where BIM models require the integration of a large amount of different types of data, including the shape of the building, the insulation properties of the materials, and the parameters of the equipment, to name a few. These data come from a wide range of sources and formats, and are prone to inconsistencies and inaccuracies that can affect the reliability of the analysis.

DOI: 10.54254/2755-2721/2025.MH25096

In practice, some designers and constructors do not have a deep enough understanding of BIM technology and use it only as a drawing tool, without giving full play to its advantages of data collaboration and simulation analysis. This reflects the shortage of professionals. Although some progress has been made in the integration of BIM software with energy analysis software, there is still room for improvement. Errors and duplication of effort in the data conversion process have not been eliminated, which limits the accuracy and efficiency of energy consumption simulation.

However, the future is full of hope. On the one hand, BIM technology will be deeply integrated with advanced technologies such as IoT and big data. Through IoT devices, we can collect real-time building operation data and feed it back into the BIM model, thus realizing real-time monitoring and intelligent regulation of energy consumption, and improving the level of energy management in the operation phase. At the same time, the use of big data analysis can be used to explore the laws in the energy consumption data, providing strong support for the development of energy-saving strategies. On the other hand, interdisciplinary cooperation will be strengthened. Experts in the fields of architecture, energy and environment will work together to solve the challenges in the application of BIM in green buildings. In the future, it is hoped that in-depth application studies will be conducted and customized solutions will be developed for different climatic conditions and building types. In addition, software developers will continue to optimize the functionality and integration of BIM software to provide comprehensive and efficient technical support for the entire life cycle of green buildings.

In short, the integration of green building and BIM technology is developing at a deeper level. Despite the challenges, the future looks bright, and it is expected to inject a strong impetus to the sustainable development of the construction industry.

5. Conclusion

This paper focuses on the innovative application of BIM technology in green buildings and its impact on building performance, and adopts a combination of simulation analysis and literature research to investigate the performance of BIM technology in three key aspects: daylighting analysis, HVAC load calculation, and energy consumption analysis. It is found that BIM technology can accurately simulate the sunlight situation of the building at different times by creating a 3D building model and integrating multi-dimensional data, which can assist in optimizing the orientation and layout of the building, increase the natural lighting, and reduce the energy consumption of the lighting; in the calculation of HVAC loads, the BIM model can provide detailed information about the building, improve the calculation accuracy, and make the design of the HVAC system more reasonable to ensure the indoor comfort and achieve energy saving. In the analysis of energy consumption, BIM technology, with the help of parametric design function, can comprehensively simulate the energy consumption characteristics of the building and realize energy consumption prediction, monitoring and optimization, which can be carried out throughout the whole life cycle of the building, help low-carbon construction in the construction stage, support energy management and maintenance optimization in the operation stage, and significantly improve the efficiency of energy utilization.

In the future, we can further expand the application scenarios of BIM technology in green building, such as the deep integration with Internet of Things, big data and other cutting-edge technologies to realize real-time monitoring and intelligent regulation of building energy consumption; deepen the research on the differentiated application of BIM technology in different climatic zones and different types of buildings; strengthen interdisciplinary cooperation to overcome the problems faced by BIM technology in the field of green building, and promote the deeper

DOI: 10.54254/2755-2721/2025.MH25096

development of the green building industry in an all-round way, so as to provide more solid technological support for reaching the goal of "double carbon". building industry to deepen its development and provide more solid technical support for reaching the goal of "double carbon".

References

[1] Lu, Wenjun. (2025). Analysis of building energy saving and carbon reduction based on BIM technology under the background of "double carbon". New Urban Construction Technology, 34(04), 61-63.
[2] Xu, Yanbin. (2025). Exploration of green building construction technology and sustainable development path of exhibition buildings. China Conference and Exhibition (China Conference), (08), 84-86. doi: 10.20130/j.cnki.1674-3598.2025.08.022.
[3] Liu, Irene. (2025). Research on green low-carbon building energy saving technology innovation based on BIM. China Building Decoration, (08), 88-90.
[4] Jasiński, A. (2020). Impact of BIM implementation on architectural practice. Architectural Engineering and Design Management, 17(5–6), 447–457. https: //doi.org/10.1080/17452007.2020.1854651
[5] Lin, Fengjie. (2024). Application of daylight analysis in the context of urban renewal. China Residential Facilities, (07), 61-63.
[6] Ge, Huafen & Eddie Chen. (2024). Discussion on Building Daylighting Analysis Based on Building Daylighting. Intelligent Building and Smart City, (01), 103-105. doi: 10.13655/j.cnki.ibci.2024.01.031.
[7] Mageshwaran, G., Britto Joseph, G., Sivaji, T., Ravi Teja, V., Durairaj Nithiyanantham, R. B., & Maruthairaja. (2017). Energy saving in an air conditioning system using modified HVAC unit as an energy reducer. International Journal of Ambient Energy, 39(7), 719–725. https: //doi.org/10.1080/01430750.2017.1318790.
[8] Li, Yi-xia. (2024). Research on the Application Problems and Optimization Strategies of Digital Technology in Building Energy Saving. Urban Construction Theory Research (Electronic Edition), (35), 67-69. doi: 10.19569/j.cnki.cn119313/tu.202435022.
[9] Hu, P.. (2025). Research on energy saving management of housing construction projects in the context of green building. Ceramics, (03), 172-174. doi: 10.19397/j.cnki.ceramics.2025.03.047.