International Journal for Housing Science and Its Applications
Publish August 10, 2025. Volume 46, Issue 4 Pages 6696-6703

https://doi.org/10.70517/ijhsa464570

# Application and teaching of computers in green building design: a case study of smart housing as an example

**Tinghong Gao[1,*] and Junhui Zhao[1]**
[1] Yishui Campus of Linyi University, Linyi, Shandong, 276400, China
Corresponding authors: (e-mail: gaoth_1017@163.com).

**Abstract** This study systematically explores the innovative application of computer technology in green building design using smart housing as a carrier. It combines BIM technology, parametric structural modeling and octree forest optimization algorithm to enhance design efficiency and building performance. Through the case study of a low-carbon demonstration community, we quantitatively compare the differences in energy consumption, system stability, and operation and maintenance costs between traditional design and intelligent algorithm-driven design by combining the Internet of Things (IoT) sensing and digital twin technology. The results show that the overall energy consumption of smart housing is reduced by 22.75% compared to traditional housing, the system stability and reliability reach the expected target, the number of operation and maintenance personnel is reduced by 66.67% compared to traditional housing, the maintenance response time is shortened by 66%, and the annual operation and maintenance cost is reduced by 39.2%. All energy consumption is significantly reduced, user satisfaction is increased by 27.23%, and the energy saving effect is outstanding.

**Index Terms** green building, BIM technology, parametric structural modeling, octree forest, smart housing

## I. Introduction

With the rise of emerging technologies, industrial technology has begun to develop vigorously, many factories need to exploit and utilize natural resources to complete the transformation of their own technology, this phenomenon is becoming more and more serious, resulting in ecological environment has been greatly damaged [1]-[3]. In the context of people's strong call to stop the current pollution of nature to prevent the already less optimistic ecological environment continues to deteriorate, the construction industry put forward the “green building design” as an environmentally friendly architectural design concept, has been praised by many [4]-[7]. This design concept requires that in the design process, the use, construction and maintenance of the building, demolition and relocation of the building is closely related to environmental protection, in order to ensure that the minimum consumption of ecological energy under the premise of the design of the building [8]-[10].

The concept of “green building design” not only slows down the rate of energy depletion, but also cultivates the innovative thinking and ability of architectural designers, and leads the development of the construction industry to a new path [11]-[13]. With the popularization of this concept, the traditional way of architectural design has not been able to meet the design program, architectural designers began to use the computer for design, assisting the completion of the green building design program [14]-[16]. And the computer according to its own characteristics, fully utilized in the architectural design, achieved remarkable results [17].

This paper firstly analyzes the core role of BIM technology in site modeling and form optimization, and elucidates how it achieves design accuracy through simulation analysis and parameter linkage. The technical advantages of parametric structural modeling are explored to achieve efficient processing of building information models. A new octree storage algorithm is designed for 3D data structure to optimize the 3D model data. Intelligent housing is analyzed as a case study to verify the significant advantages of intelligent housing. Finally, five typical scenarios are designed to test the performance robustness of smart housing in multi-dimensional scenarios.

## II. Computer technology-driven green intelligent building design

Under the dual pressures of the global climate crisis and energy transition, green building has evolved from a technical advocacy to an industry consensus. However, traditional building design methods have significant limitations in dynamic environmental response, multi-system synergistic optimization, and whole-life management: first, site analysis and form design rely on manual experience, making it difficult to quantitatively assess environmental suitability; second, structural parameter adjustment and energy simulation are fragmented, resulting in inefficient design iterations; third, data silos are prominent in the operation and maintenance phase, and the system's dynamic adjustment capability is Insufficient. The breakthrough of computer technology provides an innovative path for the above pain points, and promotes the evolution of green building towards intelligence and dynamization.

## *II. A.Application of BIM technology in green intelligent buildings*

### II. A. 1) Site model construction and analysis based on BIM technology

Site design is a crucial step to ensure that the building realizes green and intelligent. With the help of BIM technology, the establishment of green intelligent building site model, designers can have a more intuitive understanding of the actual situation of the site, so as to be able to formulate a reasonable building design program and make scientific adjustments to the relevant details. Specifically, it is that the technicians first collect various parameters related to the construction site, and then input the organized parameters into the BIM software to create a building site model that is compatible with it. Due to the simulation and visualization characteristics of BIM technology, designers can get a comprehensive understanding of the actual situation of the construction project site and make necessary analysis on the created site model.

### II. A. 2) Building massing design based on BIM technology

Ultra-large-scale and odd-shaped buildings continue to emerge, and new challenges have been posed to the construction requirements of green intelligent buildings. In order to carry out scientific and reasonable green intelligent building body design, architectural design practitioners begin to focus on BIM technology. Due to the simulation and visualization characteristics of BIM technology, with the help of BIM technology, the body structure of green intelligent buildings is analyzed on the BIM model, and then the optimization of green intelligent design is carried out under the basis of ensuring the smoothness and safety of the building structure in order to further achieve the design purpose.

## *II. B.Parametric structural modeling*

Parametric structural modeling transforms building components into a tunable model system through digital means, thus realizing the intelligence of structural design, and the technical process of parametric structural modeling is shown in Figure 1. In the modeling process, designers need to determine the key control elements, including geometric dimensions, material properties, and load parameters, and establish the constraints between parameters to construct a complete parametric model. Structural parametric design follows the principle of “top-down”, from the overall layout planning to the detailed design of components. For frame structure, the standard column network arrangement should meet the parameterized relationship requirements, i.e., the total length of the building $L$ is controlled by the number of column network axes $n$, the standard column spacing $a$ and the end column spacing $b$, and the parameter composition should meet the requirements of the building's use function. In addition to the column network arrangement, the parametric design of floor height is also crucial, which needs to take into account the net height requirements of the use of space, mechanical and electrical equipment piping space, the thickness of the floor structural system and the positioning of the building function and other factors, to establish an organic link between the parameters. In terms of component optimization, the analysis method based on characteristic parameters is used to determine the optimal component size in combination with the actual stress conditions; for structural node design, parametric family technology is used to establish the node construction detailing model to ensure that the node design meets the stress transfer and construction requirements. This parametric-based modeling technology breaks through the limitations of traditional structural design, makes the design process more flexible and intelligent, and can quickly respond to design changes and optimize the scheme, which significantly improves the quality and efficiency of structural design.

## *II. C.3D model based on octree forest optimization*

On the basis of the aforementioned parametric structural modeling technology to realize intelligent design of building components, the efficient management and dynamic optimization of 3D models have become the key link to improve the efficiency of design collaboration. Traditional 3D model processing methods are often limited in computational efficiency due to data structure redundancy in the face of massive spatial data and multi-system collaboration requirements. In order to better reduce the number of parameters in the model and construct an effective octree structure, this paper proposes an octree construction method for 3D models.

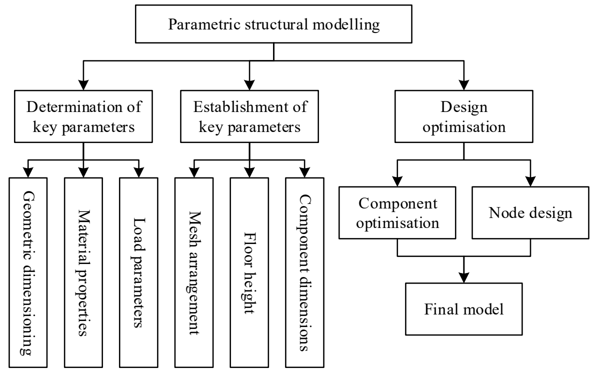


Figure 1: Parametric structure modeling technology process

### II. C. 1) Basic 3D Modeling

The three-dimensionalization operation of a model refers to the movement and scaling of the model's 3D coordinate system, which mainly includes the in-plane movement of the model, the scaling of the model as a whole, and the rotation of the model along the axes, as will be described in detail below.

Let us assume that a four-dimensional vector is represented by a point $(x,y,z,w)$ and a three-dimensional vector $(x/w,y/w,z/w)$, and that a point on the three-dimensional model is $P=(x_p,y_p,z_p,1)$, and that when the model is moved on the $X$-axis, $Y$-axis, $Z$ axes, let the distance they move be $t_x,t_y,t_z$, and the point after moving is $P_1=(x_p+t_x,y_p+t_y,z_p+t_z,1)$, and the corresponding translation matrix $T$ of the model as a whole is shown in Eq. (1).

$$T\times P=\begin{bmatrix}1&0&0&t_x\\0&1&0&t_y\\0&0&1&t_z\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}x_p\\y_p\\z_p\\1\end{bmatrix}=\begin{bmatrix}x_p+t_x\\y_p+t_y\\z_p+t_z\\1\end{bmatrix} \tag{1}$$

When scaling the 3D model, you need to scale the point $P$ on the 3D model with the origin as the axis, assuming that the scale ratio is $u_x$, $u_y$, and $u_z$, then the corresponding scaled coordinate value of the $P$ point is $P'\left(x_pu_x,y_pu_y,z_pu_z,1\right)$, and its scaling matrix $U$ As shown in Equation (2):

$$U\times P=\begin{bmatrix}u_x&0&0&0\\0&u_y&0&0\\0&0&u_z&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}x_p\\y_p\\z_p\\1\end{bmatrix}=\begin{bmatrix}x_p*t_x\\y_p*t_y\\z_p*t_z\\1\end{bmatrix} \tag{2}$$

When a perspective transformation is performed on a 3D model, it is divided into two cases. First, the model body is used as the axis to do the rotation, when the model is rotated along different axes according to clockwise or counterclockwise respectively, assuming that the rotation angle is $\beta$, the different rotation matrices $I_x$, $I_y$, $I_z$ are shown in Eqs. (3), (4), (5):

When the model is rotated on the $x$ axis:

$$I_x\times P=\begin{bmatrix}1&0&0&0\\0&\cos\beta&-\sin\beta&0\\0&\sin\beta&\cos\beta&0\\0&0&0&1\end{bmatrix}\times\begin{bmatrix}x_p\\y_p\\z_p\\1\end{bmatrix}=\begin{bmatrix}x_p\\y_p\cos\beta-z_p\sin\beta\\y_p\sin\beta+z_p\cos\beta\\1\end{bmatrix} \tag{3}$$

When the model is rotated on the $y$-axis:

$$I_y \times P = \begin{bmatrix} \cos\beta & -\sin\beta & 0 & 0 \\ 0 & 1 & 0 & 0 \\ \sin\beta & \cos\beta & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix} = \begin{bmatrix} x_p \cos\beta - z_p \sin\beta \\ y_p \\ x_p \sin\beta + z_p \cos\beta \\ 1 \end{bmatrix} \quad (4)$$

When the model is rotated on the $z$ -axis:

$$I_z \times P = \begin{bmatrix} \cos\beta & -\sin\beta & 0 & 0 \\ \sin\beta & \cos\beta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix} = \begin{bmatrix} x_p \cos\beta - z_p \sin\beta \\ x_p \sin\beta + z_p \cos\beta \\ z_p \\ 1 \end{bmatrix} \quad (5)$$

Utilizing the above basic transformation operations, different operations can be combined according to the actual operational needs.

**II. C. 2) Octree forest based optimization**

The 3D model can be described in a tree structure using the octree algorithm. The octree has a root node, under which eight leaf nodes are connected and each leaf node corresponds to a storage space to store the 3D model data. When the data reaches the maximum depth, a leaf node is used to store the end information, and the maximum depth of the octree is recorded $L$; if a space region contains multiple data nodes, the data in the space is divided into eight equal parts. Continuously iterate the above process, and then use the octree to slice and save the whole 3D model data, the structure of the octree model is shown in Figure 2. In the realization of octree, it is divided into two methods, one is pointer octree and the other is linear octree. Pointer octree has the advantage of query speed, but because of the need to store each pointer information, so it will consume a lot of space resources. Linear octrees have a more compact structure and can save a lot of storage space.

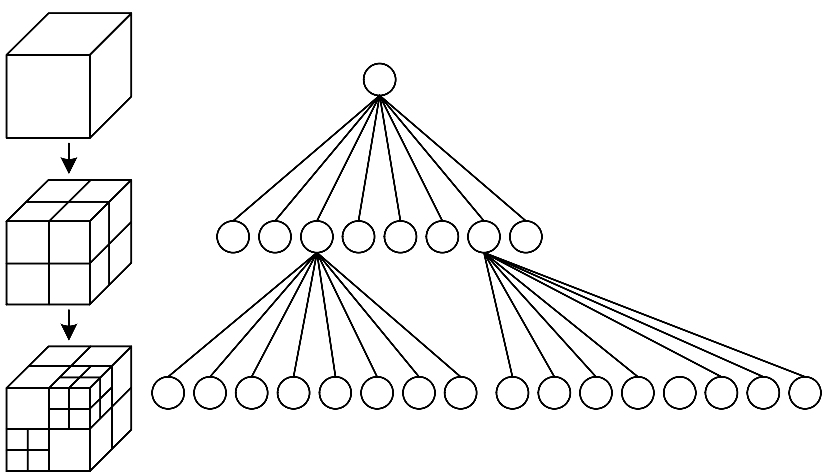

Figure 2: Structure of the octree model

In this paper, according to the structural characteristics of the 3D model, the octree principle is used to manage the 3D model, with the general framework of the building as the root node, and all kinds of systems and molds inside it as the leaf nodes, and its construction rules are shown in Figure 3.

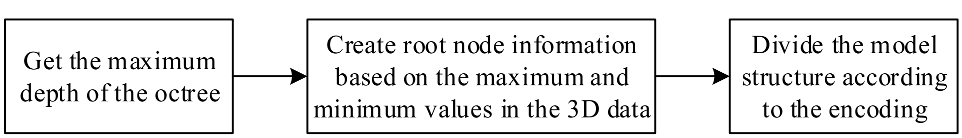


Figure 3: Octree construction rules

# III. Computer technology-driven smart housing case studies

## III. A. Case Studies

This case study focuses on a green and intelligent housing project integrating intelligent sensing, energy self-control and dynamic regulation in a low-carbon demonstration community. The building has a total floor area of about 1,200 m2, and its core design goal is to realize parametric modeling and performance simulation of the whole life cycle of the building through BIM technology, and to optimize the 3D spatial data structure by combining with the octree forest algorithm to cope with the demand for collaborative control of multi-systems in complex environments. The data collection cycle of this paper is 3 months, and during the research process, the building operation data is collected in real time by deploying IoT sensor networks and edge computing nodes, and the virtual mapping model is constructed by using the digital twin platform, which compares and analyzes the difference in energy consumption and the effect of system stability enhancement under the driving of the traditional design method and the intelligent algorithm.

## III. B. Effectiveness evaluation

### III. B. 1) Daily electricity consumption

The comparison of the average daily power consumption of the smart housing with that of the traditional housing over a period of 3 months is shown in Figure 4. It is obvious from the figure that the smart housing power consumption is reduced to different degrees in all time periods, especially in the peak power consumption period (18:00-24:00), the reduction is more significant, and the smart housing is 3.589kWh lower than the average power consumption of traditional housing at 18:00.

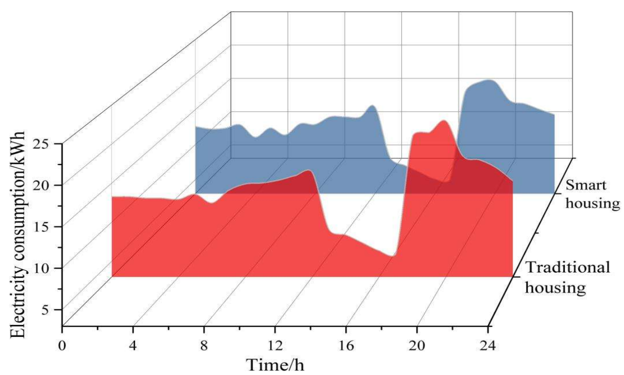


Figure 4: Comparison of Power consumption

### III. B. 2) Effectiveness of system operation

Comparison of the operating effects of smart housing and traditional housing systems is shown in Table 1. By collecting system operation data, the system is evaluated in three dimensions: energy efficiency, system performance, and operation and maintenance effectiveness. In-depth analysis of the system operation data reveals several performance advantages. The application of intelligent control algorithms enables the air-conditioning system to dynamically adjust the operating parameters according to the indoor personnel density and outdoor temperature, realizing precise temperature control. The lighting system, through linkage with the security system, can automatically adjust the lighting brightness according to the flow of people in the area, further reducing energy consumption. The energy management system monitors the energy consumption of each area in real time, and warns and takes measures in time when abnormal energy consumption is found. The overall energy consumption of intelligent housing is 22.75% lower than that of traditional housing, and the stability and reliability of the system meets the expected goal. The number of operation and maintenance personnel in intelligent housing was reduced by 66.67% compared with traditional housing, maintenance response time was shortened by 66%, and annual operation and maintenance costs were reduced by 39.2%.

Table 1: Comparison of System Operation Effects

| Evaluation dimension | Evaluation indicators | Traditional housing | Smart housing | Change |
|---|---|---|---|---|
| Energy efficiency | Overall energy consumption/% | 100 | 67.25 | Reduce by 22.75% |
| System performance | Platform response time/s | 3.37 | 0.53 | Reduce by 84.27% |
| | Data collection success rate/% | 93.78 | 99.54 | Increase by 5.76% |

| | | | | |
|---|---|---|---|---|
| Operation and maintenance effect | The number of operation and maintenance personnel | 18 | 6 | Reduce by 66.67% |
| | Maintain response time/min | 50 | 17 | Reduce by 66% |
| | Annual operation and maintenance cost/ten thousand yuan | 99.47 | 60.48 | Reduce by 39.2% |

### III. B. 3) Main system parameters

A comparison of the parameters of the main systems of the smart and conventional housing is shown in Table 2. For the air-conditioning system, the cooling and heating performance coefficients of the smart housing reached 4.33 and 4.05 respectively, which were 36.2% and 46.7% higher than those of the traditional housing of 3.18 and 2.76 respectively. As for the lighting system, the illumination power density of the smart housing is 6.4W/m², which is only 47.4% of the 13.5W/m² of the traditional housing, while the dynamic dimming range (0~100%) significantly expands the environmental adaptability compared to the traditional fixed output mode. The difference in data collection capability of the sensor network is even more striking: the 3,000 sensors deployed in the smart housing are 714% more than the 350 deployed in the traditional housing, which, combined with a 10-minute data collection interval (compared to 1.5 hours), enables the system to capture indoor and outdoor environmental parameters, equipment status and user behavioral characteristics in real time. At the control system level, the introduction of AI optimization algorithms enables the smart housing to perform multi-objective optimization based on historical data and real-time feedback, while the implementation of energy consumption prediction function further optimizes equipment scheduling strategies. Overall, through the synergistic effect of high-precision sensing, real-time data processing and intelligent decision-making system, the smart housing achieves systematic breakthroughs in the three dimensions of energy efficiency enhancement, environmental comfort guarantee and management efficiency optimization.

Table 2: Parameter Comparison of the main systems

| System | Parameters | Traditional housing | Smart housing |
|---|---|---|---|
| Air conditioner | Refrigeration COP | 3.18 | 4.33 |
| | Heating COP | 2.76 | 4.05 |
| Lighting | Illumination power density | 13.5W/m$^2$ | 6.4W/m$^2$ |
| | Dimming range | Fixed output | 0~100% |
| Sensor network | Number of sensors | 350 | 3000 |
| | Data acquisition interval | 1.5h | 10min |
| Control system | Control strategy | Fixed mode | AI optimization |
| | Energy consumption prediction | No | Yes |

### III. B. 4) Energy saving effect of main systems

A comparison of energy savings between smart and conventional housing is shown in Table 3. By implementing intelligent systems, smart housing has significantly reduced all energy consumption, with an overall energy saving of nearly 1,400 kWh, a reduction of 6 average faults, and an increase of 27.23% in user satisfaction. At the same time, the operational efficiency of each system is significantly improved.

Table 3: Comparison of Energy Conservation Situations

| | | Monthly average energy consumption/kWh | Monthly average number of failures | User satisfaction/% |
|---|---|---|---|---|
| Intelligent lighting | Traditional housing | 2008.27 | 3 | 63.47 |
| | Smart housing | 1763.63 | 1 | 89.73 |
| Intelligent heating and cooling | Traditional housing | 4426.49 | 2 | 69.37 |
| | Smart housing | 3929.53 | 0 | 93.28 |
| Intelligent security | Traditional housing | 2194.38 | 0 | 62.18 |
| | Smart housing | 1859.28 | 0 | 92.66 |
| Parking traffic | Traditional housing | 2024.26 | 2 | 65.79 |
| | Smart housing | 1706.38 | 0 | 94.05 |
| Total | Traditional housing | 10653.4 | 7 | 65.20 |
| | Smart housing | 9258.82 | 1 | 92.43 |

### *III. C. Technical application testing*

The experiments are based on five typical scenarios for multi-dimensional validation of smart housing, covering emergency evacuation simulation, extreme weather adaptation, etc., numbered S1 to S5, etc. The test metrics include: the system response time measures the time from the receipt of data to the completion of the system's feedback processing, in seconds. Data processing accuracy evaluates the system's ability to accurately process real-time sensor data, usually expressed in error rate. Real-time feedback accuracy reflects the system's ability to provide feedback on real-time data changes, with higher accuracy representing the more effective feedback mechanism of the system. Failure warning rate indicates the frequency of warning that the system can give before a failure occurs, the higher the warning rate, the more effective the system is in preventing potential construction risks; False alarm rate measures whether the system will alarm incorrectly, the lower the false alarm rate is, the more accurate the system is, and the test data are shown in Table 4.

In terms of response time, the response time of the system in each scenario is less than 0.6 seconds, which meets the real-time requirements, among which the emergency evacuation simulation scenario (S1) verifies the system's fast decision-making ability in unexpected situations with an optimal response speed of 0.274 seconds. The data processing accuracy presents scene-dependent characteristics, and the S1 scene verifies the reliability of the system in a structured environment with an accuracy of 99.38%. The real-time feedback accuracy remains high overall (mean value 98.21%), and the fault warning system realizes the highest warning rate of 90.28% in the S2 scenario, and the false alarm rates all remain below 4%.

Table 4: Test Data

| Group | System response time/s | Data processing accuracy/% | Real-time feedback accuracy/% | Fault prediction rate/% | False alarm rate/% |
|---|---|---|---|---|---|
| S1 | 0.274 | 99.38 | 99.83 | 87.12 | 2.11 |
| S2 | 0.382 | 97.12 | 98.37 | 90.28 | 3.98 |
| S3 | 0.541 | 95.24 | 96.32 | 88.46 | 3.12 |
| S4 | 0.328 | 98.08 | 99.06 | 87.22 | 2.35 |
| S5 | 0.487 | 96.16 | 97.45 | 89.93 | 3.83 |
| Mean value | 0.402 | 97.20 | 98.21 | 88.60 | 3.08 |

## IV. Conclusion

This study demonstrates the transformative value of computer technology in green building design through theoretical analysis and empirical testing.

Intelligent housing power consumption is reduced to different degrees in all time periods, especially in the peak period of power consumption (18:00-24:00), the reduction is more significant. In the dimension of operation effect, the overall energy consumption of smart housing is reduced by 22.75% compared with traditional housing, the stability and reliability of the system meets the expected goal, the number of operation and maintenance personnel is reduced by 66.67% compared with traditional housing, the maintenance response time is shortened by 66%, and the annual operation and maintenance cost is reduced by 39.2%. As for the main system parameters, the cooling and heating performance coefficients of intelligent housing reach 4.33 and 4.05 respectively, the illumination power density is 6.4W/m², the dynamic dimming range (0~100%) significantly expands the environmental adaptability compared with the traditional fixed output mode, and at the same time, the performance of sensor network and control system is also better than that of traditional housing. The energy consumption of smart housing is significantly reduced, user satisfaction is increased by 27.23%, and the energy saving effect is outstanding.

Based on the five typical scenarios for multi-dimensional verification of intelligent housing, the system response time of each scenario is lower than 0.6 seconds, the real-time feedback accuracy remains high (average value of 98.21%), and the fault early warning system realizes the highest warning rate of 90.28% in the S2 scenario, and the false alarm rate remains below 4%.

## References

[1] Prasetyo, H., & Diniyanto, A. (2021). Law Enforcement in the Aspects of Natural Resources and Environmental Damage. Law Research Review Quarterly, 7(1), 43-52.

[2] Huo, J., & Peng, C. (2023). Depletion of natural resources and environmental quality: Prospects of energy use, energy imports, and economic growth hindrances. Resources policy, 86, 104049.

[3] Chen, N., & Usman, M. (2025). Energy Use, Energy Depletion, and Environmental Degradation: Exploitation of Natural Resources. In Natural Resources Forum. Oxford, UK: Blackwell Publishing Ltd.

[4] He, Y., Kvan, T., Liu, M., & Li, B. (2018). How green building rating systems affect designing green. Building and Environment, 133, 19-31.

[5] Nguyen, T. H., Toroghi, S. H., & Jacobs, F. (2016). Automated green building rating system for building designs. Journal of Architectural Engineering, 22(4), A4015001.
[6] Abdelaal, F., & Guo, B. H. (2021). Knowledge, attitude and practice of green building design and assessment: New Zealand case. Building and Environment, 201, 107960.
[7] Ding, Z., Fan, Z., Tam, V. W., Bian, Y., Li, S., Illankoon, I. C. S., & Moon, S. (2018). Green building evaluation system implementation. Building and Environment, 133, 32-40.
[8] Wei, T., & Chen, Y. (2020). Green building design based on BIM and value engineering. Journal of Ambient Intelligence and Humanized Computing, 11, 3699-3706.
[9] Alwisy, A., BuHamdan, S., & Gül, M. (2018). Criteria-based ranking of green building design factors according to leading rating systems. Energy and Buildings, 178, 347-359
[10] Deshpande, N. A., Pagare, N. A., & Tomar, N. A. (2024). Assessing the efficacy of green building design strategies in minimizing energy consumption in commercial buildings of Mumbai: A building performance analysis. International Journal of Science and Research Archive, 11(1), 031-039.
[11] Olubunmi, O. A., Xia, P. B., & Skitmore, M. (2016). Green building incentives: A review. Renewable and Sustainable Energy Reviews, 59, 1611-1621.
[12] Cole, L. B. (2019). Green building literacy: a framework for advancing green building education. International Journal of STEM Education, 6, 1-13.
[13] Gou, Z., & Xie, X. (2017). Evolving green building: triple bottom line or regenerative design?. Journal of Cleaner Production, 153, 600-607.
[14] Neyestani, B. (2017). A review on sustainable building (green building). Int. Jour. of Eng. Scie. & Res. Tech., 6(1).
[15] Zhang, Y., Wang, W., Wang, Z., Gao, M., Zhu, L., & Song, J. (2021). Green building design based on solar energy utilization: Take a kindergarten competition design as an example. Energy Reports, 7, 1297-1307.
[16] Ikudayisi, A. E., Chan, A. P., Darko, A., & Adegun, O. B. (2022). Integrated design process of green building projects: A review towards assessment metrics and conceptual framework. Journal of Building Engineering, 50, 104180.
[17] Liu, Y., Li, T., Xu, W., Wang, Q., Huang, H., & He, B. J. (2023). Building information modelling-enabled multi-objective optimization for energy consumption parametric analysis in green buildings design using hybrid machine learning algorithms. Energy and Buildings, 300, 113665.