

# Research on the Application of Sustainable Building Design in Civil Architecture

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**Abstract.** With the development of the global economy and the growth of the population, the construction industry accounts for an increasing share of global energy consumption and carbon dioxide emissions. Therefore, there is an urgent need to reduce energy consumption and carbon emissions. However, people are increasingly demanding higher quality of the built environment and pursuing healthy, comfortable and safe living and working environments, and green buildings and sustainable buildings are effective means to meet these demands. Starting from the application of sustainable building design in civil buildings, this paper discusses the connotation and principle of green building design, as well as the application of green building design in site selection, lighting, ventilation, water saving, window energy saving, solar photovoltaic and other aspects. The conclusion shows that in the context of national carbon neutral strategy, green buildings can reduce emissions, protect the environment, and improve living comfort and human health, thus achieving energy saving goals.

**Keywords:** Sustainable building, civil architecture, architectural design, application.

## 1. Introduction

The emergence of sustainable building design in recent years signifies its gradual integration into the realm of residential construction, thereby emerging as a pivotal criterion for urban dwellers when selecting their living environment. With the continuous improvement of residents' daily living conditions, people's requirements for the living environment are also higher and higher, more and more in the pursuit of living comfort in the building, green building design has also become one of the results of the continuous promotion of the construction of ecological civilization. Due to China's initial coal, stainless steel plate and other industrial management, high energy-consuming enterprise development as the core, ignoring the environmental pollution problem on the permanent urban economic development checks and balances, resulting in the country's environmental degradation is more serious. Therefore, with the emergence of happy cities, people put forward more requirements for the health of the living environment. Sustainable architectural design is usually based on the logic of traditional architectural planning and design, integrating the concept of sustainable design and operation management. For example, the use of new low-pollution, zero-pollution and recyclable raw materials in the design of civil building schemes, in a passive, low-energy way, and strive to reduce the energy consumption of civil buildings. At the same time, sustainable architectural design relies on natural landscape planning to beautify the living environment, and ultimately achieve the purpose of saving energy and maintaining the natural environment. In addition, sustainable building design is the specific development direction of the future construction industry, and it is also the necessary design method that the architectural design company must fill and understand in order to enhance the competitiveness, which is also the only way to meet the development of the society.

## 2. The Essence of Sustainable Building Design

As an important means of energy conservation and emission reduction, green building technology adopts energy-saving, environmentally friendly and circular economy technologies, which can significantly reduce the energy consumption and carbon emissions of buildings and contribute to the realization of carbon emission reduction targets [1]. Moreover, the promotion of Sustainable Building

fosters sustainable development within the construction industry by advancing initiatives related to energy conservation, emission reduction, and circular economy practices, while simultaneously enhancing building longevity and reducing maintenance costs. Additionally, sustainable building initiatives offer substantial opportunities and advantages for the growth of environmental protection, energy conservation, and construction industries. Notably, sustainable building focus on human habitat and comfort, providing a healthier and more comfortable indoor environment with minimal energy consumption and improving the quality of life for residents.

In short, sustainable building is an important way to promote sustainable development and environmental protection goals in the context of a carbon-neutral strategy, with the following specific connotations:

### **2.1. Environmental Friendliness**

Environmental friendliness is one of the core concepts of sustainable building design. At the site selection stage, sites with good air quality, convenient traffic and excellent surrounding environment should be chosen, so as to minimize damage to the original ecosystem and enhance the greenness and sustainability of the buildings. In the design stage, the surrounding environment and climate characteristics should be fully considered, and renewable energy and sustainable materials should be used to reduce pollution and damage to the environment.

### **2.2. Energy Conservation and Emission Reduction**

Energy conservation and emission reduction is another core sustainable of green building design. In the design of lighting, ventilation, air-conditioning and HVAC, passive building design makes full use of natural resources and technological means to minimise the demand for lighting, heating and air-conditioning. At the same time, active technologies such as solar photovoltaic power generation systems, energy-saving lamps and high-efficiency heat-insulating materials will be used to improve the efficiency of the building's energy equipment and systems and reduce emissions.

### **2.3. Health and Comfort**

Ensuring health and comfort are paramount objectives of Sustainable Building design [2]. Considerations for indoor air quality, lighting, temperature, and humidity are integral to design deliberations, with a focus on enhancing indoor environmental quality and comfort levels. Implementation of measures such as air purification systems, ventilation solutions, and incorporation of greenery aid in mitigating indoor air pollution and associated health risks.

### **2.4. Sustainability**

The overarching goal of sustainable building design is sustainability. Sustainable Buildings should be capable of providing enduring ecological environments, optimizing resource utilization efficiency, and delivering societal benefits over the long term. Design considerations prioritize building longevity and maintenance costs, employing renewable and recyclable materials, and economically viable design strategies to enhance sustainability.

In conclusion, the essence of sustainable building design encompasses environmental friendliness, energy conservation and emission reduction, health and comfort, and sustainability. With the advent of carbon neutrality strategies, sustainable building is poised to become a pivotal direction for future architectural design and development. Practitioners must diligently consider these facets to continually refine design approaches and achieve optimal Sustainable Building outcomes.

### **3. Principles of Sustainable Building Design**

#### **3.1. Energy and Resource Conservation**

Sustainable buildings should be designed to conserve energy and resources. For example, choosing energy-efficient building equipment and materials, optimizing building layouts to take advantage of natural resources such as natural light and ventilation, and adopting renewable energy and resources such as solar energy and rainwater harvesting systems [3].

#### **3.2. Optimizing Indoor Environment**

Sustainable building designs must prioritize the establishment of indoor environments that foster comfort and well-being. This entails the meticulous design of robust ventilation systems, utilization of eco-friendly materials and furnishings, and meticulous attention to optimizing indoor air quality and acoustic conditions.

#### **3.3. Minimizing Environmental Impact**

It should strive to minimize adverse environmental impacts. This necessitates proactive measures to reduce building waste and emissions, mitigation of disturbances to surrounding ecosystems during construction, and preservation of natural habitats and biodiversity.

#### **3.4. Enhancing Sustainability**

Sustainability considerations must lie at the core of sustainable building designs. This entails designing buildings with long-term viability in mind, integrating sustainable building materials and energy-efficient systems wherever possible, adhering to principles of energy and resource conservation, and ensuring the comprehensive sustainability of the built environment [4].

#### **3.5. Promoting Social and Economic Sustainability**

Sustainable buildings should actively contribute to social and economic sustainability. This encompasses the creation of conducive and healthy living and working environments, reduction of operational costs and resource inefficiencies, enhancement of building value and durability, and fostering overall social and economic resilience.

In conclusion, the principles of sustainable building design aim to cultivate a harmonious coexistence between built structures and the natural environment. By embracing measures such as energy efficiency, water conservation, material recycling, environmental stewardship, and occupant well-being, it is possible to mitigate the environmental impact of buildings, enhance their sustainability, and align with the objectives of sustainable development [5].

### **4. Application of Sustainable building design in Civil Architectural Design**

#### **4.1. Site Selection Phase**

The process of site selection significantly influences a building's capacity to efficiently utilize natural resources and minimize its environmental impact. During this phase, priority should be given to locations characterized by good air quality, convenient transportation access, and visually appealing surroundings. The aim is to minimize disruption to existing ecosystems while enhancing the building's green and sustainable characteristics. Additionally, ensuring the legal and environmental compatibility of site selection is essential [6].

##### **(1) Principle of Environmental Friendliness**

Emphasis should be placed on selecting locations with minimal impact on existing ecosystems. For instance, site selection for buildings should avoid disturbing local habitats and migration corridors of flora and fauna, refraining from construction within designated nature reserves, wildlife sanctuaries,

and ecologically sensitive areas. Moreover, measures should be taken to protect and prevent pollution of surrounding water bodies to safeguard water quality and the ecological environment.

#### (2) Principle of Transportation Convenience

Transportation convenience plays a vital role in site selection. In today's rapidly urbanizing world, transportation accessibility significantly influences building quality and residents' quality of life. Therefore, factors such as public transportation coverage, road infrastructure, and traffic flow should be carefully considered to ensure the accessibility and convenience of the building.

#### (3) Principle of Surrounding Environment

Preference should be given to locations with aesthetically pleasing surroundings [7]. For example, site selection for buildings should avoid areas with adverse environmental conditions such as urban landfills, high-voltage power lines, swamps, polluted areas, and heavy industrial zones. Careful consideration should be given to the landscape and ecological value of the surrounding environment, guiding the selection of appropriate architectural forms to preserve local cultural heritage and historical buildings.

#### (4) Principle of Sustainability

In site selection, priority should be given to locations with minimal environmental impact, coupled with the adoption of sustainable building designs and construction methods. This ensures the sustainability and longevity of buildings while safeguarding the local natural ecological environment.

### 4.2. Daylighting Design

Daylighting design plays a pivotal role in sustainable building design, contributing not only to enhanced building comfort and occupant health but also to the achievement of energy efficiency and emission reduction objectives.

#### (1) Orientation and Aspect

The orientation and aspect of a building are critical determinants of daylighting effectiveness. Generally, rooms facing south receive greater sunlight exposure, whereas those facing north receive less. Thus, efforts should prioritize orienting main activity areas towards the south or east-west directions whenever feasible. Additionally, minimizing windows on the north side can mitigate heat loss.

#### (2) Size and Layout of Windows and Skylights

The size and layout of windows and skylights significantly influence daylighting. Design considerations should ensure sufficient natural light penetration while preventing excessive glare and overheating.

#### (3) Sun Shading and Dimming Measures

Sun shading and dimming strategies are essential for controlling indoor lighting levels. For instance, during hot summer months, transparent sunshades or blinds can reduce solar heat gain, while blinds or curtains can adjust indoor lighting intensity as needed [8].

### 4.3. Ventilation Design

Effective ventilation design is essential for maintaining indoor air quality and comfort, thereby reducing reliance on air conditioning and contributing to energy efficiency and emission reduction goals.

#### (1) Surrounding Environment and Climate Characteristics

Ventilation design must account for surrounding environmental and climatic conditions, including geographical location, climate, wind patterns, and speed. Tailored ventilation approaches, such as mechanical ventilation in hot, humid regions and natural ventilation in cooler areas, are advisable.

#### (2) Ventilation Methods

The selection of ventilation methods directly impacts indoor air quality and comfort. Options range from natural ventilation to mechanical and hybrid systems, each with distinct advantages and considerations.

#### (3) Ventilation System Design

Ventilation system design should optimize indoor air circulation and purification, incorporating considerations such as inlet and outlet placement, fan selection, and filter specifications to ensure effective air exchange and pollutant removal.

#### (4) Air Quality Monitoring

Installation of air quality monitoring equipment is essential for ensuring ventilation system functionality and indoor air quality stability. Monitoring parameters such as temperature, humidity, and CO<sub>2</sub> levels enable timely adjustments and maintenance to uphold indoor air quality standards [9].

### 4.4. Water Conservation Design

Water conservation design is integral to sustainable building practices, offering opportunities to safeguard water resources and reduce energy consumption.

#### (1) Equipment Selection

Prioritizing cost-effective and energy-efficient water-saving equipment, such as low-flow faucets, showers, and toilets, is essential for effective water conservation.

#### (2) Water Management

Adopting scientific water management practices, including leak detection and water usage optimization, is vital for minimizing water consumption and promoting sustainability in building operations. Consideration of water quality requirements for different applications further enhances water conservation efforts.

### 4.5. Energy-Efficient Window Design

Windows represent a significant area in buildings susceptible to energy loss, mainly due to their inadequate insulation properties. In cold winters, external cold air easily infiltrates through windows, resulting in heightened energy consumption. Conversely, during hot summers, direct sunlight penetrating windows elevates indoor temperatures, leading to increased reliance on air conditioning.

#### (1) Material and Model Selection

When focusing on energy-efficient window design, priority should be assigned to the selection of window materials and models compliant with national standards. Wood windows demonstrate superior insulation performance among common materials, followed by aluminum alloy windows, while PVC windows exhibit inferior insulation properties. Glass, being the component most vulnerable to energy loss, necessitates meticulous selection. Prominent high-performance glass types include LOW-E glass, offering optimal insulation, and double and triple-glazed glass, effectively enhancing window insulation and reducing energy consumption.

#### (2) Insulation Design for Window Frames

In addition to glass selection, the insulation design for window frames stands as another pivotal aspect of energy-efficient window design. The insulation performance of window frames not only impacts the overall insulation effectiveness but also influences their longevity and operational life span [10].

### 4.6. Solar Photovoltaic Design

Solar photovoltaic technology stands as one of the widely adopted renewable energy sources, capable of significantly decreasing building energy consumption and carbon emissions. In residential building design, solar photovoltaic power generation systems should be tailored according to the building's energy requirements and climatic attributes to optimize energy utilization efficiency.

#### (1) Introduction to Solar Photovoltaic Systems

Solar photovoltaic systems harness solar radiation to directly convert it into electrical energy. They principally comprise solar panels, inverters, battery storage systems, power, and loads. Solar panels serve as the fundamental components, with inverters converting DC power into AC power, while battery storage systems facilitate energy storage.

#### (2) Design of Solar Photovoltaic Systems

When devising solar photovoltaic systems, appropriate selection of solar panels, inverters, and battery storage systems should be based on the building's energy demands and climatic features. Considerations such as conversion efficiency, durability, and light absorption pertain to solar panels, while charge and discharge efficiency, cycle life, and safety relate to battery storage systems, aiming to optimize solar radiation utilization [11].

## 5. Case Analysis of Sustainable Building Design in Civil Architecture

### 5.1. Case Overview

The Government Headquarters Building of the Hong Kong Special Administrative Region (HKSAR), as shown in Fig. 1, stands as a significant government office edifice located in Central, Hong Kong, reaching completion in 2011. Incorporating diverse principles and technologies of Sustainable Building design, the structure achieves heightened benchmarks in energy efficiency, water resource management, and environmental stewardship.



(a) Central Government Offices



(b) LegCo Complex Low Block Entrance

**Fig. 1** The Government Headquarters Building of HKSAR [11]

### 5.2. Measurement Applied in the Building

HKSAR Government Headquarters demonstrates a passionate commitment to embrace a cleaner future, with emphasis on sustainable design contributing to a concerted effort to bring back the blue sky. Disposition of the blocks allows the prevailing wind to penetrate the inner-city providing ventilation through the Open Door passage, it also allows solar access to the site from the south, while the stepped heights of the buildings allow airflow mixing and recirculation, channeling wind from higher elevations to enhance air ventilation at pedestrian level. Besides, innovative façade design systems are adopted to achieve sustainability for the development. Drawing upon the building data of the Government Headquarters Building of HKSAR, the discernible impacts of its sustainable building design scheme are as shown in Table 1.

**Table 1.** Key initiatives in green building design applied to the government headquarters building of HKSAR

Key Measurements	Application Area	Effect
A. Solar Panels	Rooftop	An expanse of 1,000m <sup>2</sup> solar panels, which facilitate electricity generation and illumination provision.
B. Rainwater Harvesting System	At the bottom of the building.	Gather and utilize rainwater for garden irrigation and toilet flushing.
C. High-Efficiency Insulation Material	Within walls and roofs.	Reduce the energy consumption in air-conditioning system.
D. Efficient Ventilation and Natural Lighting System	Indoor	Reduce the energy consumption in both air-conditioning and lighting system.

### 5.3. Analysis of Energy Usage

Upon scrutinizing the data delineated in Table 2, it becomes evident that electricity stands as the predominant source of energy consumption for the Government Headquarters Building of HKSAR, constituting 76% of the total energy consumption. This is succeeded by oil, gas, and water pumps. Although there hasn't been a significant decrease in the overall total energy consumption subsequent to the implementation of sustainable building design technologies and measures, a noteworthy realignment in the distribution of energy usage proportions has transpired, resulting in energy savings.

**Table 2.** Energy usage for the HKSAR [12]

Types of Usage	Annual Consumption (MWh)	Proportions of Total Consumption
Electricity	12900	76.00%
Oil and Gas,	1800	11.00%
Water Pumps	1500	9.00%
Chillers	900	5.00%

### 5.4. Analysis of Water Resource Usage

**Table 3.** Water Usage in the HKSAR [12]

Usage	Proportions
Cooling Systems	49.00%
Toilets and Sinks	34.00%
Irrigation and Cleaning,	15.00%
Drinking Water	2.00%

The data presented in Table 3 illuminates that the Government Headquarters Building of HKSAR has embraced myriad sustainable building design measures pertaining to water usage, culminating in substantial water-saving outcomes.

#### 5.4.1 Collection and utilization of water resources

Endowed with a rainwater harvesting system at its base, the Government Headquarters Building effectively harvests rainwater for garden irrigation and toilet flushing. Furthermore, solar panels spanning an area of 1,000m<sup>3</sup> embellish the building's rooftop, furnishing heating and pressurization for a portion of the water usage. These endeavors serve to curtail the building's water consumption while augmenting the efficiency of water resource utilization [13].

### 5.4.2 High proportion of water usage in toilets

The data underscores that water usage in the Government Headquarters Building is predominantly allocated to toilets and garden irrigation, with toilets constituting a substantial portion of water usage. This trend is attributed to the adoption of advanced toilet water-saving technology and sewage discharge systems, which have significantly reduced toilet water usage to nominal levels, necessitating only a modest amount of water for flushing [14].

## 6. Conclusion

This paper investigates the application of sustainable building design principles in residential building design. Then, a specific residential building is utilized as a case study, and the following conclusions are presented.

(1) It is important to integrate the principles of sustainable building design into the field of architecture. The comprehensive application of these principles to site selection, site design, building layout, building facilities, wall energy-saving design, etc., can achieve sustainable development, reduce energy consumption, improve residents' comfort, protect the environment and other goals.

(2) In the residential building design scheme, the effective implementation of the basic principles of sustainable building design can not only ensure the quality and efficiency of the design scheme, but also reduce the energy consumption and pollution generated during the construction process. Architects should adopt appropriate methods to manage and solve problems related to energy consumption, water, lighting, ventilation, etc., thereby demonstrating the personalized attributes of green design and ensuring that all aspects of building design emphasize the concept of low-energy eco-design.

(3) The prospects for the advancement of sustainable buildings are as follows:

a. Health-centric evolution of sustainable buildings: With the rapid proliferation of sustainable buildings, the need for the development of health-conscious buildings is gradually surfacing. Healthy buildings represent a deeper progression of sustainable buildings in terms of health considerations, stemming from sustainable buildings while surpassing their limitations.

b. Intelligent progression of sustainable buildings: Distinct from mere upgrades of intelligent buildings or simplistic notions of environmentally friendly structures, intelligent sustainable buildings amalgamate smart city concepts with cutting-edge Internet technologies (such as big data, the Internet of Things, cloud computing).

c. Industrialized evolution of sustainable buildings: The fusion of sustainable buildings with industrialization fosters reciprocal advancement. Future sustainable buildings will adopt the EPC model, embracing standardized design, factory production, assembly construction, and information management, thus facilitating resource consolidation, technological harmonization, and optimization of benefits throughout the construction process, thereby propelling the evolution of sustainable building production methodologies.

## References

- [1] An Shunjie. Analysis of the Application of Sustainable building design in Civil Architectural Design. *Ceramics*, 2023, (1): 3.
- [2] Gao Jiayan. Reflections on Sustainable building design in Civil Architectural Design *Ceramics*, 2022, (09): 108-110.
- [3] Yao Qing. Discussion on the Application of Sustainable building design in High-rise Civil Architectural Design. *China Residential Facilities*, 2022, (07): 160-162.
- [4] Jiang Ying. Analysis of the Application of Sustainable building design in High-rise Civil Architectural Design. *Housing*, 2022, (02): 124-126.
- [5] Du Juan. Application of Green Building Design in Civil Building Design. *Residential & Real Estate*, 2021, (12): 104-105.

- [6] Zhu Wei, Lin Wangcheng. Exploring the Application of Green Building Design in Civil Buildings. *Shi Hezi Tech*, 2023, (12): 56-58.
- [7] Gao Feng. Application of Sustainable building design in Civil Architectural Design. *Green Environmental Building Materials*, 2018, (3): 1.
- [8] Shen Jiali. Application of Sustainable building design Concept in Civil Architectural Design. *Sichuan Building Materials*, 2021, 47(05): 49+56.
- [9] Zhang Xianjun, Sun Jian. Discussion on the Application of Sustainable building design in High-rise Civil Architectural Design. *Tomorrow's Fashion*, 2019, (7): 49.
- [10] Mu Haoming. Foreign Case Studies on Energy Conservation Renovation of Existing Buildings - Exterior Thermal Insulation Renovation of a Theater in the United States. *Construction Science and Technology*, 2011, 15: 66-67.
- [11] Archiposition Official Website. Architectural Story in Hong Kong: Are there memories of you in this multi-faceted city. July 4, 2022. Retrieved on March 22, 2024. Retrieved from: <https://www.archiposition.com/items/9798901663>
- [12] Quan Shihai. Current Situation and Prospect of Green Building Development in China. *Chongqing Architecture*, 2020, (12): 14-16.
- [13] Zheng Zhidan. Discussion on the Application of Sustainable building design in High-rise Civil Architectural Design. *Doors and Windows*, 2019, (12): 25.
- [14] Zhang Zhiwen. On the Application of Sustainable building design in High-rise Civil Architectural Design. *Green Environmental Building Materials*, 2020, (5): 82+85.