SUSTAINABLE

CIVIL INFRASTRUCTURE DEVELOPMENT:

CASE STUDIES

(Second Edition)

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Sustainable Civil Infrastructure Development: Case Studies

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Second Edition

Title of the Book: Sustainable Civil Infrastructure Development: Case Studies

Second Edition: 2024, IIP Series

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ISBN: 978-93-6252-138-5

MRP: 1,710/-

Publisher, Printer & Distributor:
Selfypage Developers Pvt. Ltd.,
Pushpagiri Complex,
Beside SBI Housing Board,
K.M. Road Chikkamagaluru, Karnataka.
Tel.: +91-8861518868
E-mail: info@iipseries.org

IMPRINT: IIP Iterative International Publishers

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ISBN: 978-93-6252-138-5

Chapter 18

Green Building and its Environmental Impact

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ISBN: 978-93-6252-138-5

Abstract

One of the biggest risks of the twenty-first century is climate change, which is brought on by the emissions of greenhouse gases (mostly carbon dioxide) into the atmosphere as well as other environmental residential and industrial pollutants. India's population expansion, rapid urbanisation, and rapid growth in the IT and allied industries have all contributed to an increase in energy consumption. In modern cities, buildings account for up to 40% of total energy usage. In general, green building is regarded as an environmental component because green building materials are produced using locally available eco-sources, or environmentally friendly materials. Green buildings minimise resource use (energy and water) throughout their lifespan, lessen negative environmental effects, and offer better inside environments. High levels of engineering, economic, and environmental performance are possible with green buildings. The key subjects of this study include about the green buildings, their impact on the environment, energy use, interior air quality and ventilation. The current study also looks into green technology, green roofs, and green construction materials like bio-cement, eco-cement, and green concrete. Green building designs are significant because they employ sustainable materials and require less energy, which has a positive impact on the environment.

Keywords: Green Building Practices, Environmental Impact, Sustainable Construction, Water Efficiency, Green Infrastructure

I. Introduction

The process of conserving energy, water, and materials, as well as minimizing the effects of a building's construction on the environment and public health, is known as green building, or sustainable architecture. Beyond just the structure itself, green building concepts also take into account land-use planning, community development, and site planning. The whole-systems approach of green construction is used to design and build more pleasant, safe, and healthy buildings while conserving energy, water, and other resources. The term "green building" usually conjures images of solar panels. In actuality, energy consumption is only one aspect of environmentally friendly building. Utilizing landfills for construction waste and building materials can have negative impacts on volunteers, homeowners, and the environment.

Buildings that are designed, built, and operated according to environmentally conscious and resource-efficient principles are referred to as green buildings, often known as sustainable or eco-friendly construction. Reducing a structure's adverse effects on the environment and public health over its whole life is the aim of green building. Important elements and factors to consider when developing green building includes place and mode of transportation, sustainable sites, energy and the environment, resources and materials, indoor air quality, innovative design and local priority.

II. Objective of Present Study

The study of green building has multiple purposes, all of which support the main objective of developing more ecologically friendly and sustainable buildings. The following are some main goals of researching green buildings:

1. Environmental Conservation
2. Energy Efficiency
3. Resource Efficiency
4. Human Health and Well-being
5. Cost Savings
6. Regulatory Compliance
7. Innovation and Technology
8. Resilience to Climate Change
9. Occupant Education
10. Certification and Recognition

The goal of studying green building is to change the construction industry, encourage responsible building practices, and make the built environment more resilient and sustainable by pursuing these goals.

III. Literature Review

A recommendation is obtained about Indian society through a survey and a detailed examination of the most significant green building regulations in the world serve as the foundation for the implementation strategy (Potbhare *et al.*, 2008). Parashar and Parashar (2012) investigated a review on the creation of environmentally friendly structures. They proposed the effect of an inclined green roof on the interior temperature of any building in the climate of Chhattisgarh. Gupta *et al.* (2014) conducted a review of green building pedagogy. They concentrated on the historical, modern, and future approaches to teaching green building in India. The use of accessories in the structure, such as glasses and Aluminum Composite Panel (ACP), is included in the current green building pedagogy. Future Pedagogy discusses the use of sensors and nanotechnology in the construction industry. Tathagat and Dod (2015) reviewed the function of green buildings in environmentally friendly building practices. It was suggested that the technical essay address how energy efficiency in green buildings in India helps to lower greenhouse gas emissions, which in turn lowers energy consumption and environmental deterioration. Parikh (2016) reviewed a study of India's progress in creating the concept of green building. According to her, the goals of green building design are to optimize the use of renewable resources through recycling, reuse, and other techniques, minimize the demand for non-renewable resources, and improve their performance while in use. Kotkar and Salunkhe (2017) examined a review pertaining to green building. They proposed that green building technology has emerged as one of the most well-liked global topics in an effort to mitigate the construction industry's significant detrimental consequences on the environment, society, and economy. Significant changes in the climate are being brought about by the observed global increase in Green House Gases (GHGs). Laeeq *et al.* (2017) conducted a review on the concepts and awareness of green building. To determine the most effective implementation strategies, they stated the degree of acceptability of green building principles in commercial buildings and the primary problems arising from their adoption. Mane (2017) reviewed Green Buildings and Sustainable Construction. They proposed that there is a rising awareness of the detrimental effects of construction-related activities and the need to address them. The Indian government has already made great strides to advance the concept of green building for better environmental and social protection. Manna and Banerjee (2019) studied a review on green building movement in India. They suggested the principles behind green building design in order to prevent environmental deterioration. They discussed about the Green Building rating system and its certification procedure. Pamu and Mahesh (2019) conducted a review of a comparative study on India's green building rating system in terms of energy and water. They proposed comparing India's two green building rating schemes for existing structures in terms of energy and water consumption.

IV. Importance of Green Building

The Green building incorporates concepts such as sustainable development and sustainability. Through improved design, construction, operation, maintenance, and removal, green building minimizes a building's negative effects on human health and the environment while promoting the efficiency of buildings with regard to the use of water, energy, and materials. India places a high value on green building because it reduces waste streams, preserves and replenishes natural resources, improves air and water quality, and enhances and protects biodiversity and ecosystems. Energy efficiency, the production of renewable energy, and water efficiency are some of the more prevalent characteristics of green buildings.

Green building can result in

1. Lowering operating costs through increased productivity and the use of less energy and water
2. Better public and occupant health as a result of better indoor air quality
3. Reduced environmental impacts, such as storm water runoff and heating

Achieving both ecological and aesthetic balance between a building and its surrounding natural and built environment is a common goal for green building practitioners. Comparable to their less sustainable counterparts, sustainable homes and buildings can have nearly the same appearance and feel.

V. Overview of Sustainable Design

Recyclable and renewable building materials are used in sustainable construction projects and waste and energy production are kept to a minimum. Reducing carbon emissions, constructing cities that can withstand shocks to the environment, economy, or society, and opening up new growth prospects for cities are all advantages of sustainable design. Basic components of sustainable architecture include eco-friendly materials, better air quality, and efficient use of water and energy both inside and outside the building. The main distinction between sustainable and green design is that the former is a broad ideology that considers performance, social, environmental, and financial implications. The environmental aspects are given more attention in green design. Building sustainably entails using recyclable and renewable resources and building materials. It is important to take precautions during construction projects to preserve the surrounding natural environment and minimize waste and energy usage. By generating long-term solutions, sustainable design assists societies in guaranteeing the welfare of their citizens and environmental balance for future generations. Designers create products that are compostable, recyclable, and best of all, infinitely reusable in order to reduce waste. In addition to maximizing natural day lighting, ventilation, and insulation, green buildings also avoid materials with high volatile organic compound (VOC) emissions and have excellent acoustic performance. At every stage of a building's lifecycle, green buildings integrate a range of approaches to practices, technologies, and materials. The combination of actions taken in response to a building's particular circumstances is tailored to minimize the building's negative effects on the environment and on people.

VI. Energy Efficiency

A key component of green buildings is energy efficiency, which aims to minimize energy use, lessen environmental effect, and improve sustainability

ISBN: 978-93-6252-138-5

overall. Energy efficiency in green buildings can be achieved through a variety of tactics and technological advancements (Table 18.1). Reduced heat transmission and a decreased need for heating and cooling are two benefits of having well-insulated walls, roofs, and floors. There is a greater use of LED lighting since it lasts longer and uses less energy than conventional lighting. This employs day lighting techniques to increase natural light and decrease dependency on artificial lights by installing heating, ventilation, and air conditioning (HVAC) systems that use less energy. To guarantee peak performance and energy savings, regular maintenance and tuning are required. Utilizing occupancy sensors and zoning to control temperature in response to use. Apply integration of clean, sustainable power generation from on-site renewable energy sources, such as solar and wind turbines. Green energy credits or power purchase agreements (PPAs) are used to obtain renewable energy from outside suppliers. Building management systems (BMS) enable real-time modifications based on occupancy and environmental conditions by providing centralized control and monitoring of many systems. Energy management programs and smart thermostats can maximize HVAC performance. Installation of equipment and appliances with an ENERGY STAR rating, use electronics, office equipment, and other gadgets that use less energy, installation of heat pump and highly efficient water heaters and incorporating solar water heating devices to heat water using sustainable energy sources can be applied. Installing high-performance windows with numerous glazing layers and low-emissivity coatings will improve insulation and lessen heat transfer.

Table 18.1: Energy Savings from Green Building

Building	Sq. ft	Normal Building (kWh)	Actual Building (kWh)	% Reduction	Annual Energy Savings (Rs in lakhs)
Wipro, Gurgaon	1,75,000	48,00,000	31,00,000	40%	102
ITC, Gurgaon	1,70,000	35,00,000	20,00,000	45%	90
CII Godrej Hyderabad	20,000	3,50,000	1,30,000	63%	9

VII. Importance of Water Conservation in Green Building

In order to promote resource efficiency, environmental sustainability, and general good stewardship, water conservation is an essential component of green building design and construction. Growing urbanization and population

ISBN: 978-93-6252-138-5

growth around the world are increasing the demand for water, which could cause shortages in some areas. Freshwater resources are limited, and issues like excessive groundwater extraction and surface water depletion plague many regions. Overuse of water can have a detrimental effect on aquatic ecosystems and biodiversity by causing natural water bodies to disappear. The distribution and treatment of water require energy. Green buildings help to reduce associated carbon emissions and save energy indirectly by conserving water. Rainfall in certain places is becoming more intense and unpredictable due to changes in precipitation patterns brought about by climate change. Water-efficient features in green buildings make them more capable of adjusting to these changes. Water conservation minimizes the amount of wastewater produced, which eases the strain on sewage treatment plants and lessens the effect treated effluent discharge has on the environment. Energy and water are related. Energy is needed to transport and treat water, and water is needed to produce energy. Reducing greenhouse gas emissions and energy consumption are indirectly impacted by water conservation in green buildings. Stricter water regulations are being implemented in many regions in response to environmental concerns and water scarcity. Green buildings with an emphasis on water conservation are better positioned to abide by existing and upcoming rules. Lower water consumption from the installation of water-efficient fixtures and technologies saves building owners and occupant’s money on operating expenses. Drought-resistant green buildings with water-efficient features are more resilient, lowering the need for water use restrictions and assisting in ensuring occupants has a consistent water supply.

By prioritizing water conservation in green building practices, stakeholders contribute to the sustainability of the built environment, minimize environmental impact, and help address broader water-related challenges on a local and global scale. The integration of water-efficient technologies, landscaping practices, and occupant education fosters a more resilient and responsible approach to water use in the construction and operation of buildings.

VIII. Sustainable Materials and Resources

Throughout a building's existence, green building—also referred to as sustainable or eco-friendly building—focuses on utilizing resource- and environmentally-conscious methods. Choosing sustainable resources and materials is part of this. By using recycled steel, the environmental effect of steel manufacturing is minimized and the need for new raw materials is decreased. Recycled concrete aggregates are used in construction, which lessens

ISBN: 978-93-6252-138-5

the requirement for landfill space and the environmental impact of producing concrete. By using recycled glass in countertops and tiles, glass waste can be kept out of landfills and less energy is used in the production of new glass. By lowering the need for heating and cooling, high-performance windows with low-emissivity coatings and insulated frames improve energy efficiency. Selecting insulation with recycled content or natural materials, such cellulose or recycled denim, improves energy efficiency. Building designs that use solar photovoltaic (PV) systems aid in the on-site production of clean, renewable energy. Small-scale wind turbines can be installed in some places to capture wind energy and help with the building's power requirements. Water conservation can be achieved by installing dual-flush toilets, showerheads, and low-flow faucets. Reducing dependency on conventional water sources can be achieved by gathering and utilizing rainwater for irrigation or non-potable water requirements. Air quality is enhanced, stormwater runoff is decreased, insulation is provided, and green roofs are covered in plants. Lowering interior temperatures and reducing the urban heat island effect are made possible by reflective roofing materials or coatings. When it comes to flooring, bamboo is a quickly renewable resource that is less harmful to the environment than conventional hardwoods. Cork is a sustainable flooring material that is extracted from the bark of cork oak trees without causing any damage to the tree. Indoor air pollution can be attributed in part to volatile organic compounds, or VOCs. A low- or zero-VOC paint or finish can help preserve the quality of the air within buildings. By using low- or non-toxic adhesives and sealants, indoor air pollution can be reduced and healthier living conditions can be encouraged. Optimizing energy use and improving overall building performance can be achieved by integrating energy-efficient lighting, HVAC (heating, ventilation, and air conditioning) systems, and other smart technologies. By evaluating the environmental impact of building materials and components at every stage of their life cycle—from extraction to disposal—life cycle assessments help decision-makers minimize the building's overall environmental footprint.

IX. Indoor Environmental Quality (IEQ)

The easiest way to define Indoor Environmental Quality (IEQ) is the state of the building interior. In addition to access to daylight and views, comfortable acoustics, and occupant control over lighting and thermal comfort, it also includes air quality. It might also cover the practical features of the space, like how well people and tools are arranged for easy access when needed and whether there is enough room for everyone to live in. Instead of concentrating just on temperature or air quality, building managers and operators can improve tenant satisfaction by taking into account all aspects of IEQ. Giving indoor air enough ventilation and filtration is one of the key tactics for enhancing indoor environmental quality (IEQ). Whereas filtration involves removing impurities and pollutants from the air, ventilation involves bringing in fresh outdoor air and expelling stale indoor air. In terms of Indoor Environmental Quality (IEQ), thermal comfort is a significant factor. Relative humidity, air temperature, air speed, clothing level, metabolic rate, and radiant temperature can all have an impact on how comfortable one is with the temperature and humidity inside. Building occupants' mood, productivity, and well-being can all be significantly impacted by thermal comfort. IEQ is greatly influenced by lighting and views, which affect building occupants' circadian rhythm, mood, alertness, and productivity. They can also improve the interior environment's aesthetics and spatial aspects. Acoustics and noise, or the level and quality of sound in an indoor space, is a fourth factor that affects IEQ. This may have an impact on focus, dialogue, comfort, and even how the room is perceived. Acoustic panels, tiles, carpets, and curtains can be used to improve speech intelligibility by reducing reverberation and echo. In order to reduce unwanted noise from the outside or from nearby areas, sound-absorbing elements can also be installed, such as double-glazed windows and walls.

X. Economic and Environmental Benefits of Green Construction

There are several financial and environmental advantages to green construction, commonly referred to as sustainable or eco-friendly construction. These benefits lead to lower long-term costs, more effective use of resources, and a smaller environmental impact.

Economic Benefits

Energy-efficient systems and technologies are often used in green buildings, which eventually results in lower energy consumption and lower utility costs. Installing water-efficient fixtures and systems contributes to a reduction in water usage, which lowers building owners' water bills. Long-term savings are often achieved through the use of sustainable building materials and techniques, which produce structures that are more resilient and require less upkeep. A better overall economic performance can be achieved by making informed decisions based on the life cycle costs of materials and systems (Table 18.2). Tax breaks, rebates, and grants are frequently offered by governments to incentivize the construction of green buildings, which benefits owners and developers monetarily. Green buildings are frequently in great demand and draw buyers and tenants who care about the environment, which can raise the value of the property. Structures certified by LEED programs, for example,

ISBN: 978-93-6252-138-5

might be valued higher in the real estate market. Jobs in the fields of sustainable building, renewable energy, and energy efficiency are produced by the development and upkeep of green buildings. Future changes to building codes and environmental legislation can be lessened by adhering to green building standards and regulations.

Table 18.2: Cost-benefit analyses

2-12%	Construction cost premium
25-30%	Savings in Energy Consumption
20-30%	Savings in water consumption
50%	Less waste generation
35%	Reduced carbon emission
1.9% to 2%	Rental Premium achieved in commercial buildings
30%	Reduction in building operating expense
40%	Increase in office space utilization

Environmental Benefits

The environmental benefits of green building include the following:
1. Decrease in the use of natural resources
2. Decrease in running expenses
3. Everyone's safety, comfort, and well-being
4. Energy efficiency and lowering of energy usage
5. A rise in occupant productivity
6. Improved indoor air quality (the health effects of IAQ are enormous)
7. Green building encourages businesses to make a great first impression on clients, staff, partners in business, and shareholders while also reaping the benefits of a green corporate image

XI. Green Building Certifications and Standards

The National Building Code, the Energy Conservation Building Code (ECBC), the standards established by rating programs like Leadership in Energy and Environmental Design-India (LEED-India), the guidelines and standards established for the residential sector by the Indian Green Building Council (IGBC), TERI-GRIHA and other similar certifications, and the Bureau of Energy Efficiency (BEE) are all combined to form the Green Building Code in India. The National Building Code (NBC) contains basic and general principles for energy efficiency, although these are only guidelines (Table 18.3).

Table 18.3: Green Building Performance in India

Name of the Project	Location	Built up Area (sq ft)	Rating Achieved	Increase in Cost(%)	Payback Period (years)
CII-Sorabji Godrej GBC	Hyderabad	20,000	Platinum	18	7
ITC Green Centre	Gurgaon	170,000	Platinum	15	6
Wipro	Gurgaon	175,000	Platinum	8	5
Technopolis	Kolkata	72,000	Gold	6	3
Spectral Services Consultants Office	Noida	15,000	Platinum	8	4
Hitam	Hyderabad	78,000	Silver	2	3
Grundfos Pump	Chennai	40,000	Gold	6	3

a. **LEED/ IGBC (Indian Green Building Council) Green Ratings:** The Confederation of Indian Industry (CII) launched the Green Building Movement in 2001. They established the Indian Green Building Council (IGBC) in the same year, but the green building movement in India really took off in 2003 after the Sohrabji Godrej Green Business Centre Building in Hyderabad, which was named the world's greenest building in 2003, became the country's first green building and received the highly coveted LEED (Leadership in Energy and Environmental Design) Platinum rating from the US Green Building Council (USGBS). India does not currently have a complete and functional green building code, in contrast to the United States Green Building Council (USGBC), which created LEED (Leadership in Energy and Environmental Design). A building utilizing tactics meant to improve performance in measures, like resource use, reduced CO2 emissions, and improved indoor environmental quality, can receive third-party verification through the globally known LEED green building certification system.

b. **GRIHA (Green Rating for Integrated Habitat Assessment) by TERI (The Energy and Resources Institute):** The Government of India adopted the Green Rating for Integrated Habitat Assessment in 2007 as the national rating system for green buildings. It was developed in collaboration with the Ministry of New and Renewable Energy and was initially conceived by TERI (The Energy and Resources Institute). The system provides basic requirements for buildings based on predefined parameters (Table 18.4).

Table 18.4: Incentives to Developers and Occupants for adopting GRIHA

GRIHA Rating	Discount in premium (for developers)	Discount in property tax (for occupants)
5 Star	50%	10%
4 Star	40%	8%
3 Star	30%	5%
2 Star	20%	--
1 star	10%	--

c. **IEP (Integrated Energy Policy:** The Government of India (GoI) developed the Integrated Energy Policy (IEP) in January 2016, which serves as a guide for expanding the use of renewable energy sources and creating alternatives for energy supply. Additionally, in January 2016, the government modified the power national tariff policy in order to promote renewable energy.

d. **BEE Star Rating:** BEE created a voluntary Star Rating Program for commercial buildings, which was introduced by the Ministry of Power in 2009, to attract customers to energy-efficient buildings. The program is based on a building's actual performance as measured by its area's energy usage, expressed in kWh/sq. Significant advantages are gained by India's Energy Star-rated buildings over non-green ones; specifically, they have 40% more energy efficiency and far lower operating costs than conventional structures. Industry statistics show that, in order to be certified Energy-Star, over 85% of buildings with an Energy Star rating have an energy management control system, and 50% have motion sensors installed in their lighting systems.

e. **GEM (Green & Eco-friendly Movement):** To encourage environmentally friendly green building design and construction, ASSOCHAM introduced the "GEM Sustainability (Green) Certification Program" in 2017. NBC 2016 and BEE ECBC 2017 serve as the foundation for the GEM Sustainability Certification Rating Program. The objective is to tackle the sustainability of a particular development from the planning stage all the way through to the building and operating stages (Table 18.5).

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Table 18.5: Policy Initiative for Green building in India

2000	Energy Conservation Act (ECA)
2001	Establishment of India Green Building Council
2002	Formation of Bureau of Energy Efficiency under ECA 2001
2005	Bureau of India standards published the National building Code
2006	Issuance of Energy policy draft Ministry of Environment and Forests makes Environment Impact Assessment necessary for all building with built area of 20,000 sq kms.
2007	Green rating for integrated habitat assessment was adopted as the national rating system for green buildings in India
2008	National action plan on Climate Change was launched, integrated energy policy 2008 approved by the cabinet
2014	Announcement of smart cities program
2015	India signs first Union climate change Paris agreement
2016	First 20 Smart Cities announced States of AP and Telangana adopting mandatory compliance measuresfor building efficiency

A framework for sustainable building practices is provided by these certifications and standards, which help architects, developers, and legislators design resource- and environmentally-conscious buildings. A stakeholder's choice of certification program will depend on a number of factors, including project goals, building types, and regional priorities.

XII.Future Trends and the Role of Innovation

Green building will probably change in the future due to continuous technological advancements, changing sustainability objectives, and increased public awareness of the need for more ecologically friendly building methods. These trends will be largely driven by innovation, which will result in more resilient, sustainable, and efficient buildings. It is anticipated that more and more Internet of Things (IoT) devices and smart building technologies will be integrated. IoT devices and sensors can monitor indoor environmental quality, optimize energy use, and improve the overall performance of buildings. As smart building technologies advance, more building systems will be able to be automated and controlled more effectively. More energy-efficient buildings that generate and store their own clean energy will be made possible by developments in building-integrated solar technologies, energy storage solutions, and smart grid integration. Researchers are looking into materials

ISBN: 978-93-6252-138-5

with better durability, better insulation, and less of an impact on the environment. Engineered wood products, high-tech insulators, and less carbon-intensive cement substitutes are examples of innovations. Building material reuse and recycling will be made easier by advancements in deconstruction methods, modular construction, and material recycling technologies, which will support the construction industry's shift to a more circular approach. Improvements in indoor gardens, green walls, and natural lighting are examples of modern architectural and design strategies that bring people closer to nature and enhance well-being and productivity. Buildings will use less water thanks to advanced water management systems like intelligent irrigation, greywater recycling, and energy-efficient plumbing fixtures. With the use of digital twin models, a building's performance can be tracked and analyzed in real time, facilitating data-driven choices that improve sustainability, occupant comfort, and energy efficiency. Building material, design, and construction technique innovations will help create structures that are more resilient to extreme weather, enhance disaster resilience, and adjust to shifting environmental conditions.

In conclusion, a combination of technological innovation, sustainable design principles, and an all-encompassing approach to the well-being of the environment and people will probably define the future of green building. Buildings that are more resilient, sustainable, and supportive of the planet's and its inhabitants' general well-being will be made possible by the continuous dedication to research, development, and the incorporation of creative solutions.

XIII. Conclusion

One of the biggest threats of the twenty-first century is climate change, which is brought on by the atmosphere's accumulation of greenhouse gases, primarily carbon dioxide, as well as various industrial and domestic pollutants. Up to 40% of the energy used in modern cities is consumed by buildings. Improving efficiency can significantly reduce their consumption, which is a useful way to reduce greenhouse gas emissions and slow the depletion of non-renewable energy sources. The building industry is thought to have over 50% of savings potential, making it a viable sector to address climate change and global energy issues. Since environmentally friendly materials derived from local sources are used to create eco-constructions that ensure the preservation of natural resources while providing a healthy habitat, green buildings are typically seen as environmental components. This is because the construction of green buildings is based on the preservation of cultural and architectural heritage. This makes sure that, after a predetermined building lifetime, the building components and materials are disassembled to recyclable or repurposed environmentally friendly materials. The purpose of this study is to define green buildings and explain how they relate to energy, the environment, indoor air quality, ventilation, and building planning. Additionally, green designs, green roofs, green technologies, and green building materials are all discussed in this study. The current study also discusses the economics of green buildings, rating systems for green buildings, and implementation challenges. Green building techniques aim to create buildings that are environmentally conscious, energy-efficient, and offer healthier living and working environments. Green buildings add to a more resilient and sustainable built environment by using sustainable resources and materials. Employing green building practices is increasingly acknowledged as a prudent business decision that also satisfies social and environmental requirements. The future of green building will likely be shaped by a confluence of innovative technology, sustainable design principles, and a comprehensive approach to the welfare of people and the environment. Research, development, and the integration of innovative solutions will be the means by which buildings become more resilient, sustainable, and conducive to the overall well-being of the planet and its inhabitants.

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ISBN: 978-93-6252-138-5

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ISBN: 978-93-6252-138-5

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