

GREEN BUILDINGS

Dr. REBECCA JOHN

*Maharani Cluster University, Smt. VHD Central Institute,
School of Home Science, Bengaluru, Karnataka.*

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***About the Author: Dr. Rebecca John**, Associate Professor in Resource Management is currently working at Maharani Cluster University, Smt. VHD Central Institute, School of Home Science, Bengaluru. She also teaches Interior Design and Decoration at both the undergraduate and postgraduate levels and guides post-graduate research students both in Resource Management and Interior Design and Decoration. She also has various research publications, both in National and International journals to her credit.*

Sustainable buildings minimize energy and water consumption and are a key part of sustainable urban development that seeks to combat climate change. From large skyscrapers to novel museums, below we review some of the green buildings that pave the way to more responsible urban planning.

13.1 INTRODUCTION TO GREEN BUILDINGS

The construction industry, by its very nature, is a big user of natural resources. However, with growing concerns over climate change and the finite nature of these resources, there is increasing pressure on construction firms to reduce their environmental impact. Revisions to the building regulations are changing the boundaries for the minimum expected for construction today. Advances in technology are also offering new possibilities in terms of embodied energy use and building energy needs. While there are challenges involved in adopting sustainable construction methods, there are also great benefits too.

In India, buying a home is a dream for most. But then one has to also consider the low Air Quality Index (AQI), especially in metros like the Delhi National Capital Region (NCR), which reaches severe levels because of high pollution, especially in winter.

13.1.1 Characteristics of a Green Building

A 'green building' involves the practice of using processes and technologies that are environmentally friendly and energy-efficient throughout the building's lifecycle, starting from design, construction, operation, maintenance, and renovation. According to data shared by Anarock (2021), green buildings can reduce energy consumption by 20-30 percent and water usage by 30-50 percent, and significantly reduce waste generation through extensive recycling. Apart from the obvious protection of the ecosystem and biodiversity, the use of green building practices leads to better air quality; enhanced daylight, leading to lower electricity consumption; superior health and overall well-being, and enhanced productivity in the case of commercial buildings.

13.2 SUSTAINABLE CONSTRUCTION

13.2.1 Objectives of Sustainable Construction

The objective of sustainable construction is to reduce the industry's impact on the environment. Sustainable construction methods include:

- using renewable and recyclable materials
- reducing the embodied energy in building materials
- reducing the energy consumption of the finished building
- reducing on-site waste
- protecting the natural habitats during and after the construction phase.

13.2.2 Importance of Sustainable Construction

From energy usage to emissions, the construction industry has a huge impact on the environment. Aside from the loss of wild habitats from the development of green field sites, energy is used on-site during the construction phase. Heavy plants used in construction still lean heavily on fossil fuels. The construction industry is also responsible for the embodied energy within the building materials as well as the legacy of the building's energy needs when in use.

Informed choices at every stage of a new build project have an environmental impact. The construction industry accounts for an incredible 36% of worldwide energy usage and 40% of carbon dioxide emissions.

The fabrication and shipping of materials can have a great impact on carbon emissions. Mining for raw materials can result in the pollution of water courses. The manufacture of cement currently resulted in global annual emissions of 2.8bn tonnes of carbon dioxide; and if the current rates of urbanization continue, this could rise to over 4bn tonnes every year.

13.2.3 Challenges of Sustainable Construction

Adopting sustainable construction methods is not an overnight process. The clients' attitudes and available budget will be the most significant constraint or enabling factor. The selection of architects for the project will drive the work of all of the subsequent trades on the project. The Continuous Professional Development required by the Royal Institute of British Architects (RIBA) is a driving force in improving the architectural standards for the industry. Most architects will be familiar with the latest thinking on the following:

- Net Zero Operational Carbon
- Net Zero Embodied Carbon
- Sustainable Water Cycle
- Sustainable Connectivity And Transport
- Sustainable Land Use And Biodiversity
- Good Health And Wellbeing
- Sustainable Communities And Social Value
- Sustainable Life Cycle Cost.

There will always be pressure on contractors to reduce costs where possible, but there are still concerns that sustainable construction methods will cost an organization more.

But there is a light at the end of the sustainable tunnel: the perceived value of green buildings. Owners of a green building feel they are worth 7% more than a traditional one, which is likely due to the reduced operating costs that result from building energy-efficient structures. This greater perceived value can be cited in tenders and can help offset any additional costs that might result from sustainable construction.

13.2.4 Benefits of Sustainable Construction

Naturally, adopting sustainable construction methods will reduce the owner's or housing organization's impact on the environment. This will depend on the client's specifications which in turn will have a big impact on the construction specifications of the project and the long-term building running costs.

The quality of the design and its sustainability can have long-term reputational and corporate social responsibility benefits. The contractors, structural engineers, and architects must have an understanding of new materials and construction techniques required to be part of the most lucrative and innovative projects. The truth of the matter is that green buildings do come with lower operating costs. Research suggests that the use of the latest sustainable technologies in construction processes could potentially deliver a remarkable decrease in savings on global energy spending.

There are also direct savings available like waste reduction for your building organizers, as well as saving on transportation of waste. By adopting more efficient vehicles, fuel is also saved. One final benefit is the huge impact on the builders' company; sustainable construction can help them achieve a good reputation by demonstrating their sense of corporate social responsibility.

13.2.5 Corporate Social Responsibility (CSR)

Awareness and interest in CSR, the idea that businesses should support good causes, is greater than ever. There is no question that CSR results in positive public relations, but it can also influence buyer behaviour; when prices are similar, a larger number of consumers are likely to switch over to a different company if it's associated with a good cause. CSR can be shared amongst the supply chain, as it also reduces the carbon footprint which again is positive CSR.

13.3 MATERIALS USED IN SUSTAINABLE CONSTRUCTION

There are endless ways in which construction companies can improve sustainability and reduce their carbon footprint, such as:

- Using renewable energy
- Using on-site water treatment plants to minimize waste
- Recycling and building with renewable or waste materials, e.g. old wood and bricks.

Other materials used in sustainable construction are:

- **Wood:** Wood is a great material as it doesn't require a lot of energy to become a building material. Properly managed forests not only supply renewable material but also provide a biodiverse habitat for wildlife preservation.
- **Recycled Metals:** Plastic is fast becoming a sustainable construction material which is relatively easy to obtain thanks to an abundance of it existing in most societies. In some places, plastic and other rubbish are turned into concrete replacements, reducing greenhouse gasses and helping to stop landfills from becoming overrun with materials.
- **Sustainable Concrete:** Concrete is a widely used synthetic material, but also one of the most environmentally unfriendly. Its manufacture alone is responsible for about 5% of global carbon dioxide (CO₂) emissions. Fortunately, many companies are now exploring ways to reduce emissions by creating alternatives with plastic and other recyclables, which can reduce carbon dioxide production by almost 50%.
- **Mud bricks and Wool bricks:** Bricks use kiln-fires to increase their strength resulting in pollution through greenhouse gases, but in 2010 researchers from the Schools of Architecture at the University of Seville, Spain, and the University of Strathclyde in Glasgow, UK found new and greener ways to produce bricks just as strong, with untreated clay or wool as part of their composition.
- **Straw Bales:** Bales can be used in place of concrete or plaster for insulation. Straw is not only sustainable but affordable too, which helps keep the costs of building materials down.

13.3.1 Scenario of Green Buildings in India and their Requirements

With 146 certified buildings and spaces, or almost 2.8 million gross square metres, India was placed third in the world for Leadership in Energy and Environmental Design (LEED) of green buildings in 2021, according to the US Green Building Council's annual report.

With more than 14 million gross sq. mt, China came in first, and Canada certified more than 3.2 million gross sq. mt. The green construction rating system LEED is the most popular worldwide. Green Business Certification Inc. (GBCI), which has been aiming to hasten the implementation of green buildings throughout India, oversees LEED in India.

Across different countries, several programs and agencies define, categorize, and certify green buildings, such as LEED (the US), BREEAM (the UK), DGNB (Germany), and CASBEF (Japan). In India, the Indian Green Building Council (IGBC) and GRIHA are at the forefront of promoting green building programs and certifications.

13.3.2 Ground Reality of Green Buildings in India

According to a survey by Knight Frank India, LEED-certified buildings across seven cities were recorded at 39.59 million sq. ft. during the January-October 2022 period. Delhi-NCR recorded 9.85 million sq. ft. of the gross floor area of LEED-certified buildings, the highest among the top 7 Indian cities during the same period. The Mumbai Metropolitan Region (MMR) recorded 4.88 million sq. ft. of the gross floor area of LEED-certified buildings.

India recorded 82 platinum-certified buildings, 49 gold-certified buildings, and four silver-certified buildings across the top 7 leading markets in the Jan-Oct 2022 period. NCR registered the highest platinum-certified buildings accounting for 22 buildings.

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, provides fast-track environmental clearance for green building projects that are pre-certified and/or provisionally certified by IGBC.

Some state governments, like Punjab, Uttar Pradesh, West Bengal, Haryana, and Maharashtra, offer additional floor area ratios). Some state governments are also providing subsidies on fixed capital investment. Some states are also offering discounts on property tax

13.4 LEED CERTIFICATION - LEED CERTIFIED GREEN BUILDINGS

Leadership in Energy and Environmental Design (LEED) is the world's most widely used green building rating system. LEED certification provides a framework for healthy, highly efficient, and cost-saving green buildings, which offer environmental, social, and governance benefits. LEED certification is a globally recognized symbol of sustainability achievement, and it is backed by an entire industry of committed organizations and individuals paving the way for market transformation. Leadership in Energy and Environmental Design (LEED) was developed by the non-profit United States Green Building Council (USGBC). It includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods, which aims to help building owners and operators be environmentally responsible and use resources efficiently.

By 2015, there were over 80,000 LEED-certified buildings and over 100,000 LEED-accredited professionals. Most LEED-certified buildings are located in major U.S. metropolises. LEED Canada has developed a separate rating system adapted to the Canadian climate and regulations. Some U.S. federal agencies and state and local governments require or reward LEED certification. This can include tax credits, zoning allowances, reduced fees, and expedited permitting. Studies have found that for-rent LEED office spaces generally have higher rent occupancy rates and lower capitalization rates.

LEED is a design tool rather than a performance-measurement tool and focuses on energy modeling rather than actual energy consumption. It lacks climate specificity and has been criticized for a point system that can encourage inappropriate design choices and make energy conservation the weakest part of the evaluation. It has also been criticized for the phenomenon of "LEED brain" in which the public relations value of LEED certification drives the development of buildings.

13.5 ECO BUILDINGS AND GREEN INFRASTRUCTURE

A building that has been made in a way that does not harm the environment, for example, because it is made with sustainable materials (ones that will continue to be available and not all be used up) and uses natural energy for heat, etc.: Eco-buildings come in many different forms. It is also called a Green building or sustainable building.

13.5.1 Green Infrastructure

Green infrastructure or Blue-green infrastructure refers to a network that provides the "ingredients" for solving urban and climatic challenges by building with nature. The main components of this approach include stormwater management, climate adaptation, the reduction of heat stress, increasing biodiversity, food production, better air quality, sustainable energy production, clean water, and healthy soils, as well as more anthropocentric functions, such as increased quality of life through recreation and the provision of shade and shelter in and around towns and cities.

Runoff from stormwater continues to be a major cause of water pollution in urban areas. It carries trash, bacteria, heavy metals, and other pollutants through storm sewers into local waterways. Heavy rainstorms can cause flooding that damages property and infrastructure.

Historically, communities have used gray infrastructure—systems of gutters, pipes, and tunnels—to move stormwater away from where people live to either the treatment plants or straight to local water bodies. The gray infrastructure in many areas is aging, and its existing capacity to manage large volumes of stormwater is decreasing in areas across the country. To meet this challenge, many communities are installing green infrastructure systems to bolster their capacity to manage stormwater. By doing so, communities are becoming more resilient and achieving environmental, social, and economic benefits.

Green infrastructure filters and absorbs stormwater where it falls. Green infrastructure elements can be woven into a community at several scales. Examples at the urban scale could include a rain barrel up against a house, a row of trees along a major city street, or greening a pathway. Neighbourhood scale green infrastructure could include acres of open park space outside a city center, planting rain gardens, or constructing a wetland near a residential housing

complex. At the landscape or watershed scale, examples could include protecting large open natural spaces, riparian areas, wetlands, or greening steep hillsides. When green infrastructure systems are installed throughout a community, city, or across a regional watershed, they can provide cleaner air and water as well as significant value for the community with flood protection, diverse habitats, and beautiful green spaces.

Some common examples include:

- i. **Downspout Disconnection:** This simple practice reroutes rooftop drainage pipes from draining rainwater into the storm sewer to draining it into rain barrels, cisterns, or permeable areas. You can use it to store stormwater and/or allow stormwater to infiltrate into the soil. Downspout disconnection could be especially beneficial to cities with combined sewer systems.
- ii. **Rainwater Harvesting:** Rainwater harvesting systems reduce stormwater pollution by slowing runoff and collecting rainfall for later use. The variety of systems ranges from the backyard rain barrel and the commercial building cistern to ground-level pits, aquifers, and even nets that capture dew and fog. These types of systems have been implemented worldwide.
- iii. **Rain Gardens:** A rain garden can be beautiful as well as functional. Rain gardens are small, shallow, sunken areas of plantings that collect stormwater runoff from roofs, streets, and sidewalks. Also known as 'bioretention cells', they are designed to mimic the natural ways water flows over and absorbs into the land to reduce stormwater pollution.
- iv. **Planter Boxes:** Planter boxes are an attractive tool for filtering stormwater as well as reducing the runoff that goes into a sewer system. Planter boxes are urban rain gardens with vertical walls and either open or closed bottoms. Usually found in downtown areas, they collect and absorb runoff from streets, sidewalks, and parking lots. Ideal for areas with limited space, planter boxes can be a useful way to beautify city streets.
- v. **Bioswales:** Bioswales are essentially rain gardens placed in long narrow spaces such as the space between the sidewalk and the curb. Bioswales, often found along curbs and in parking lots, use vegetation or mulch to slow and filter stormwater flows.
- vi. **Permeable Pavements:** Permeable pavement is a good example of a practice that catches water where it falls. Permeable pavements infiltrate, treat, and/or store rainwater where it falls. They can be made of pervious concrete, porous asphalt, or permeable interlocking pavers. This practice could be particularly cost-effective where land values are high and flooding or icing is a problem.
- vii. **Green Streets and Alleys:** Green streets combine more than one feature to capture and treat stormwater. Green streets and alleys are created by integrating green infrastructure elements into their design to store and filter stormwater. Permeable pavement, bioswales, planter boxes, and trees are among the elements that can be woven into street or alley design.
- viii. **Green Roofs:** A green roof system atop a building helps manage stormwater and reduce energy costs for cooling. Green roofs are covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water. They are particularly cost-effective in dense urban areas where land values are high and in large industrial or office buildings where stormwater management costs are likely to be high.
- ix. **Urban Tree Canopy:** City trees, or tree canopy, soak up stormwater, provide cooling shade, and help to slow traffic. Trees absorb stormwater in their leaves and branches. Many cities have set tree canopy goals to

restore the benefits of trees lost when the areas were developed. Homeowners, businesses, and community groups can participate in planting and maintaining trees throughout the urban environment.

- x. **Land Conservation:** Land conservation is another good tool for communities to use for reducing the risks of stormwater runoff and sewer overflows. The water quality and flooding impacts of urban stormwater also can be addressed by protecting open spaces and sensitive natural areas within and adjacent to a city while providing recreational opportunities for city residents. Natural areas that should be a focus of this effort include riparian areas, wetlands, and steep hillsides.

13.5.2 Benefits of Green Infrastructure

1. Environmental Benefits:

- **Habitat and Biodiversity:** Green streetscapes enhance urban biodiversity as native species provide habitats for birds, insects, and other species. Native vegetation is better suited to the rainfall of the local area. Enhancement of biodiversity in cities can increase environmental awareness among urban residents.
- **Water Quality:** Green infrastructure improves stormwater quality by reducing the load of sediment, unwanted minerals, and other contaminants that are carried with runoff from impermeable surfaces.
- **Flow Management:** Retaining runoff in landscaped areas and slowing the rate of flow from the catchment area reduces the risk of erosion of the soil bed. Slower flow rates reduce stress on downstream waterways as well.
- **Natural Hydrology:** Where local soils are suitable, rain gardens are used to treat stormwater before it permeates the groundwater.
- **Passive Irrigation:** Directing stormwater to irrigate the planting reduces the need for manual watering and increases soil moisture.

2. Social Benefits:

- **Amenity and Landscape Design:** Landscape design contributes to a city's character and identity. Planting complements the built environment, softens the appearance of hard surfaces, and provides a visual screen.
- **Urban Cooling:** Trees and green infrastructure provide significant reductions in urban temperatures. Large trees with good soil moisture can reduce local temperatures through shading and evapotranspiration. Trees can reduce air temperatures in parks and green areas by as much as 2–8° C, and they have been linked to the prevention of unnecessary loss of life during heatwaves.
- **Encourage Outdoor Activity:** The green cover encourages outdoor activity, including walking, cycling, and other recreation.
- **Air Quality:** Vegetation improves air quality and reduces greenhouse gases. Trees remove carbon dioxide, nitrous oxides, sulphur dioxide, carbon monoxide, and ozone from the atmosphere. The most effective species in trapping pollutants are those with large leaf surface areas and high transpiration rates.

3. Economic Benefits:

- **Energy:** By reducing local temperatures and shading building surfaces, green infrastructure reduces the cooling demand of buildings, thus cutting energy needs.
- **Lifespan of Infrastructure:** Green infrastructure complements grey infrastructure such as catch basins and drainage pipes, and lengthens the lifespan of grey infrastructure.
- **Water Systems:** The impacts on drainage systems and the cost of managing erosion in waterways can be significant. Streets with green infrastructure slow the rate of runoff, reducing the pressure on these systems and lowering maintenance costs.
- **Property Values and Marketability:** Street trees and green infrastructure enhance aesthetic qualities and provide a significant neighborhood amenity. Properties on tree-lined streets are valued at up to 30% more than those on streets.

13.6 COOL ROOF

A cool roof is designed to reflect more sunlight than a conventional roof, absorbing less solar energy. This lowers the temperature of the building just as wearing light-colored clothing keeps you cool on a sunny day. Conventional roofs can reach temperatures of 150°F or more on a sunny summer afternoon, Sun. Under the same conditions, a reflective roof could stay more than 50°F (28 °C) cooler. This can save energy and money in buildings with air conditioning, or improve comfort and safety in buildings without air conditioning, by reducing heat flow from the roof into the occupied space. Most cool roofs have high “thermal emittance”—the ability to shed heat by giving off “thermal infrared” radiation. Nearly any type of building can benefit from a cool roof, but consider the climate and other factors before deciding to install one.

13.6.1 Benefits of Cool Roof

A cool roof can benefit a building and its occupants by:

- Reducing energy bills by decreasing air conditioning needs
- Helping older inefficient (or undersized) air conditioners provide enough cooling for today’s hotter summers
- Qualifying for money-saving rebates from utilities or government programs
- Making it possible to downsize new or replacement air conditioning equipment, saving money and potentially increasing cooling efficiency
- Improving indoor comfort and safety for spaces that are not air-conditioned
- Decreasing roof temperature, which may extend the roof service life

Cool roofs can also incur a winter heating penalty. That is, absorbing less sunlight on the roof reduces heat conduction into the building, increasing the need for mechanical heating in winter. Beyond the building itself,

cool roofs can also benefit the environment, especially when many buildings in a community have them. Cool roofs can:

- Lower local outside air temperatures, thereby lessening the urban heat island effect
- Slow the formation of smog from air pollutants, which are temperature-dependent, by cooling the outside air
- Reduce peak electricity demand, which can help prevent power outages
- Decrease power plant emissions by reducing the demand for energy to cool buildings.
- Help offset global warming by reflecting more sunlight into outer space

13.6.2 Types of Steep Roofs

- **Asphalt shingles** are composed of a fiberglass web coated with filled asphalt, or filled modified asphalt, which has been surfaced with colored ceramic-coated rock. Successive rows of shingles are overlapped. This helps the roof shed water while permitting the shingles to “breathe” (release underlying moisture). Choose an asphalt shingle that is surfaced with light-colored or (if a darker color is preferred) cool-coloured granules. Field-coating previously installed asphalt shingle roofs to make them cool can create moisture retention issues, may void the shingle manufacturer’s warranty, and is not recommended.
- **Wood shingles** (machine sawn) and wood shakes (hand split) are pieces of wood that are overlapped to cover the roof types. Wood shingles and shakes are naturally “cool coloured” materials.
- **Polymer shingles** (also known as synthetic or composite shingles) are formed of polymer shaped to resemble asphalt shingles, wood shingles, wood shakes, slate, clay tiles, or concrete tiles. They are overlapped to cover the roof. Choose a polymer shingle that is factory-coloured with light- or cool-colored pigments.
- **Clay tiles** can be unglazed (terra cotta), or glazed to increase water resistance and provide a choice of colour. Choose a terra cotta clay tile (typically a natural cool color) or a clay tile with a factory-fired light- or cool-colored glaze. Glazed clay tiles can also be retrofitted with a field-applied light- or cool-colored polymer coating that is applied when the tiles are installed.
- **Concrete tiles** are typically formed from gray-cement concrete. They can be integrally colored with pigments, or surface colored with a slurry coating (pigment + white cement) or with a pigmented polymer coating. Choose a concrete tile with a factory-applied light or cool-coloured slurry or polymer coating. Concrete tiles can also be retrofitted with a field-applied light- or cool-colored polymer coating.
- **Slate tiles** are split from slate (metamorphic rock) and overlapped to cover the roof. Slate tiles are not usually cool.
- **Metal shingles or tiles** are metal pieces, often shaped to resemble asphalt shingles, clay tiles, wood shingles, or concrete tiles, that are overlapped to cover the roof. They can be unpainted, factory painted, or factory

surfaced with mineral granules. Choose a metal shingle or tile that is factory-coated with light- or cool-colored paint, or factory-surfaced with reflective mineral granules. Unpainted metals are typically good solar reflectors but poor thermal emitters, and get hotter in the sun than painted metals of comparable solar reflectance; they are not the best choice. Metal shingles or tiles can be retrofitted with field-applied paint, but oven-baked factory-applied paint is more durable and economical than field-applied paint.

13.7 ZERO ENERGY BUILDINGS

Most buildings today use a lot of energy -- to keep the lights on, cool the air, heat water, and power personal devices. Even installing solar systems will not significantly counter the heavy energy load. There are, however, some buildings that strike a balance; or even tip the scales by decreasing power consumption. These are called 'zero energy building'.

Zero-energy buildings are designed and built to consume as little energy as possible. When a renewable source of energy is added to these buildings, they are capable of producing enough energy to meet or exceed their requirements to run. Zero-energy buildings use a combination of energy efficiency and renewable energy to produce as much energy as they use over the course of a year. By creating their renewable energy, zero energy buildings lower operating and maintenance costs, help the environment and increase resiliency during power outages.

Zero-energy buildings offer a variety of benefits, including:

- Reduced energy costs
- Increased comfort for occupants
- Positive environmental impact
- Reliable and affordable operations
- Improved energy security

13.8 ENERGY CONSERVATION TECHNIQUES IN BUILDINGS

The value of reducing energy consumption in buildings has increased worldwide. This is because the consumption of fossil fuels for the full-fledged operations of a building is as high as it is in other industries. Therefore, the adoption of energy efficiency techniques during the construction and operation of buildings would play a crucial role in the creation of sustainable cities in the future.

Energy efficiency is the use of less energy in a building to perform the same operation as buildings that consume energy inefficiently. It should be considered during the design stage, selection of construction materials, construction process, and operation of the building. Adopting passive solar house design strategies at the design stage is the first step toward an energy-efficient structure.

Low-energy building materials and less energy-consuming construction equipment must be used during the construction process. As far as building operation is concerned, utilities for renewable energy systems have to be integrated into the building for water heating, photovoltaic electrification, and energy conservation.

Efficient energy consumption in buildings is one of the most affordable ways to lessen the detrimental effects of climate change and health-related problems. It reduces household expenses and decreases carbon dioxide emissions. There was a special emphasis on reducing CO₂ emissions by the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow held on 31 October – 13 November 2021.

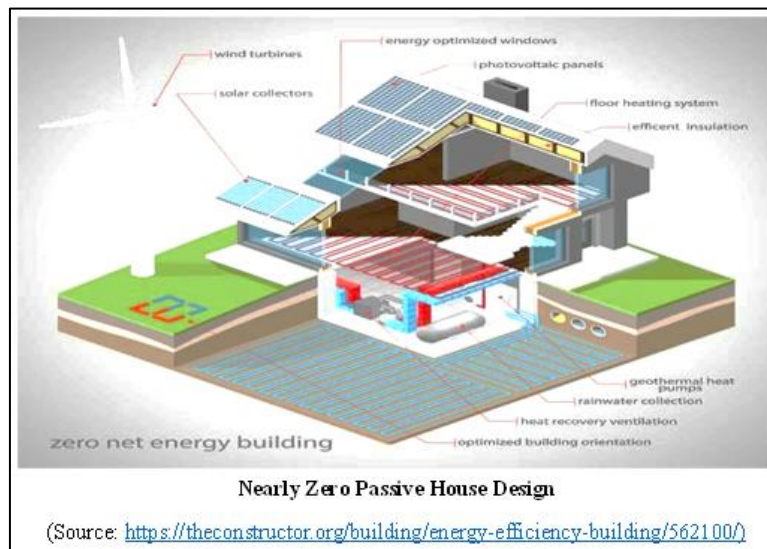
Moreover, energy-efficient buildings decrease indoor air pollution as they provide cleaner combustion and better ventilation than conventional buildings. As a result, the possibility of air pollution-related diseases such as asthma and lung cancer will be reduced. It saves lives, reduces medical treatment's financial and social costs, and increases the value of buildings.

13.8.1 Nearly Zero-Energy Passive Building Design

The design of a nearly zero-energy passive building involves adopting all solar passive strategies at the design stage before actual construction begins. For instance, passive solar heating/cooling, building daylighting, and provision for rainwater harvesting.

The passive building does not need complex design but requires a knowledge of solar geometry, local climate, and window technology. The passive solar design strategies should be selected based on the climatic condition of the project site.

In a hot and dry climate, passive cooling designs, such as wall and roof cooling, solar refrigeration, and earth water heat exchangers should be integrated into the building. In cold zones, passive heating designs should be adopted, such as air handling units, sunspace, and Trombe walls.



13.8.2 Utilization of Low Embodied Energy Building Materials

The usage of low embodied energy materials for building construction is important for reducing the impact of global warming and making the building energy-efficient. The embodied energy is the energy used by all processes related to the construction material's mining, manufacturing, transporting, and administering.

Some examples of low embodied energy construction materials are fly ash bricks, fiber-reinforced bricks, woods, stabilized adobe blocks, and cement-replacement materials such as silica fume, slag, and fly ash which are mostly by-products in factories. These materials are constantly becoming popular and widely used by contractors worldwide, especially in the Middle East, Europe, the USA, the UK, and India.

13.8.3 Usage of Energy-Efficient Equipment

This involves using energy-efficient equipment in a building that requires the lowest possible energy, such as LED lights, fans, air-conditioners, and refrigerators. Energy Star-approved fluorescent bulbs are highly desirable because they are more durable, and their maintenance cost is 75% less than conventional bulbs.

Moreover, using a lighting control mechanism improves energy efficiency because it automatically turns off lights and eliminates waste of energy. Finally, use a thermostat to regulate heating water and room temperature.

13.8.4 Integration of Renewable Energy Technologies in Different Applications

Integrating renewable energy technologies in the building is another way to reduce energy consumption and reduce carbon footprint.

Solar water heaters, small wind turbines to generate electricity, and solar photovoltaic electricity generation are examples of renewable energy technologies installed in a building to reduce operational energy consumption.

Other renewable energy sources like hydroelectricity, biomass, and biofuels can also be used. Roofs and facades of buildings are suitable for the placement of solar thermal collectors and photovoltaic panels.

Renewable energy offers great advantages, such as cost-effectiveness, sustainability, and security of energy supply, in addition to increased employment, and long life for energy systems. It also replaces the highly expensive and imported conventional energies such as oil, gas, coal, and nuclear fuel for certain countries.

13.8.5 Renewable Energy Technologies

LED Lighting & Daylighting: Over the years, LED lighting has replaced commonly used incandescent bulbs or halogen lamps. The main motivation for the shift towards LED lighting is its ability to produce roughly the same amount of lighting while consuming one-fifth of the energy in comparison to its predecessors. Thus, their reduced energy consumption cuts down on monthly electricity bills.

Additionally, the LED bulbs last much longer than other lights. This means that they need to be replaced less frequently and require less maintenance. LED lighting may initially be a more pricey investment, but lower energy and maintenance costs make the initial capital worthwhile in the long term.

The concept of daylighting is often implemented in conjunction with LED efficiencies to minimize the electricity usage of the building. This construction approach aims to optimize the use of natural light as much as possible. This will reduce the need for artificial light during the day. To achieve this, builders prioritize windows and glass elements throughout the building to let more natural light in. The glass can be single, double, or triple-pane depending on the specific needs of the structure.

13.9 MICROGRID TECHNOLOGY

More and more people are becoming concerned with resiliency and reliance on power. When there is a power cut, planned or unplanned, and the grid goes dark; what can be done? The solution to this problem is microgrids, in partnership with renewable energy such as solar energy.

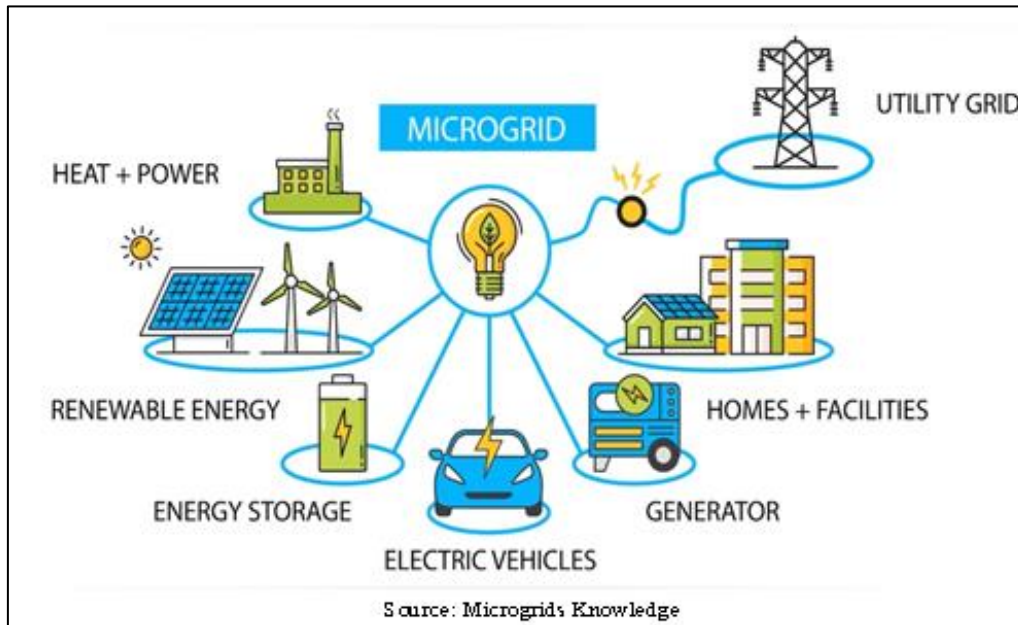
A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity concerning the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.

To meet the electricity demands of its users, a microgrid must have a generation source. Given that microgrids are an older concept, the electricity supplied to microgrids has historically been from “behind the meter” fossil fuel generators – gas-powered generators, for example. However, with the falling cost of solar, not to mention the environmental benefits of switching from fossil fuel generation to solar power, many of the microgrids being designed today supply electricity with a combination of solar and battery storage. The National Renewable Energy Laboratory (NREL) has been involved in the modelling, development, testing, and deployment of microgrids since 2001. It is located in Golden, Colorado, which is the United States' primary laboratory for renewable energy and energy efficiency research and development.

Advantages of Microgrids

- i. There are more than several benefits of microgrids:
- ii. Provide efficient, low-cost, clean energy
- iii. Improve the operation and stability of the regional electric grid
- iv. Critical infrastructure that increases reliability and resilience
- v. Reduce grid congestion and peak loads
- vi. Enable highly efficient Combined heat and power (CHP), reducing fuel use, line losses, and carbon footprint
- vii. Integrate CHP, renewable energy sources, thermal and electric storage, and advanced system and building controls
- viii. Support places of refuge in regional crises and first responders
- ix. Use local energy resources and jobs
- x. Diversified risk rather than concentrated risk

- xi. When properly designed, a regional power grid that combines both large central plants and distributed microgrids can be built with less total capital cost, less installed generation, higher capacity factor on all assets, and higher reliability.



Use of Microgrids

The grid connects homes, businesses, and other buildings to central power sources, which allow us to use appliances, heating/cooling systems, and electronics. But this interconnectedness means that when part of the grid needs to be repaired, everyone is affected. This is where a microgrid can help. A microgrid generally operates while connected to the grid, but importantly, it can break off and operate on its own using local energy generation in times of crisis like storms or power outages, or for other reasons.

A microgrid can be powered by distributed generators, batteries, and/or renewable resources like solar panels. Depending on how it's fueled and how its requirements are managed, a microgrid might run indefinitely. A microgrid not only provides backup for the grid in case of emergencies but can also be used to cut costs or connect to a local resource that is too small or unreliable for traditional grid use. A microgrid allows communities to be more energy-independent and, in some cases, more environmentally friendly. Microgrids are capable of becoming electrically isolated from the grid in the event of an outage. When the grid goes down due to anything from a severe weather event to a knocked-over telephone pole, you need to be disconnected from the grid—or “islanded”—to continue to produce and use electricity. As such, one key feature of a microgrid is its ability to continue operating even when the larger grid goes out.

For many people, a microgrid would be a solution to their power problem by being able to produce their power via solar panels and storing this energy for use in emergencies. These households could disconnect from the main grid and be self-sufficient until the main grid is back online.

End of Chapter Exercise

1. Discuss the objectives and characteristics of a Green Building.
2. Write about LEED Certification.
3. Explain about Eco buildings and green infrastructure.
4. Enumerate ten examples of green infrastructure.
5. Discuss about benefits of cool roofs.
6. Analyse zero-energy buildings and their benefits.
7. Explain the energy conservation techniques in buildings today.
8. Discuss the significance of microgrid technology with its advantages.

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