Chapter 26
Green Buildings: Eco-friendly Technique for Modern Cities

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Abstract Buildings are a major energy consuming sector in the economy. About 35–40% of total energy is used by buildings during construction. The major consumption of Energy in buildings is during construction and later in lighting or air conditioning systems. This consumption must be minimized. Buildings affect land use, energy use, communities and the indoor and outdoor environment. In today's scenario, one of the tools in creating Smart city is Green Building or Sustainable building. Green building is the practice of designing, constructing, operating, maintaining, renovating and demolishing buildings in ways that conserve natural resources, reduce pollution and are environmentally responsible. Green building concept is expanding around the world. Use of sustainable principles in buildings can reduce these impacts and also improve working conditions and productivity, increase energy, water, and material efficiency and reduce costs and risks. Sustainable buildings can be showcases to educate people about environmental issues, possible solutions, partnerships, creativity and opportunities for reducing environmental impacts in our everyday lives. Successful green buildings leave lighter footprints on the environment through conservation of resources. In other words, green building design involves finding the delicate balance between homebuilding and a sustainable environment. In the developing countries like India, poverty alleviation can be effectively achieved by conservation of energy and creation of employment opportunities.

Keywords Building design · Environmental impacts · Carbon footprints · Green building · Vegitecture · Energy efficiency

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Acronyms

BREEAM	Building research establishment environmental assessment method
CASBEE	Comprehensive assessment system for building environmental efficiency
EPA	Environmental Protection Agency
GRIHA	Green rating for integrated habitat assessment
HVAC	Heating, ventilation and air conditioning
IAQ	Indoor air quality
IEQ	Indoor environmental quality
IGBC	Indian Green Building Council
LEED	Leadership in energy and environmental design
MoEF	Ministry of Environment and Forests
NABERS	National Australian Built Environment Rating System
NSW	New South Wales
O&M	Operations and maintenance
TERI	The Energy and Research Institute
USGBC	United States Green Building Council
VOC's	Volatile organic compounds

26.1 Introduction

Smart Cities are those which have smart (intelligent) physical, social, institutional and economic infrastructure. Smart City offers decent living options to every resident. This would mean that it will have to provide a very high quality of life, i.e. good quality but affordable housing, cost efficient physical infrastructure such as 24 × 7 water supply, sanitation, 24 × 7 electric supply, clean air, quality education, health care, security, entertainment, sports, robust and high-speed interconnectivity, fast and efficient urban mobility, etc.

Energy concerns are also a key feature of "Smart Cities". In today's world of climate change and high energy prices, it is critical that buildings use as few fossil fuels (including coal generated electricity) as possible. One of the good areas to focus energy efficiency measures would be the green building materials.

"A green building is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building".

Green building (also known as green construction or sustainable building) is the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability and comfort (EPA 2009).

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation (Hopkins 2002)
- Depending upon project-specific goals, an assessment of green materials may involve an evaluation of one or more of the above-mentioned parameters.

26.2 Concept of Green Building

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and the environment pollution concern in the 1970s (Hegazy 2002; Pushkar et al. 2005). The green building movement in the US originated from the need and desire for more energy efficient and environmentally friendly construction practices. However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of an existing structure. Also known as sustainable design, this approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy amongst the practices used. Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of new buildings on the environment and human health.

While the practices, or technologies, employed in green building are constantly evolving and may differ from region to region, there are fundamental principles that persist from which the method is derived: siting and structure design efficiency, materials efficiency, energy efficiency, water efficiency, indoor environmental quality enhancement, operations and maintenance optimization and waste and toxics reduction (Simpson 2002; CIWMB 2009). The essence of green building is an optimization of one or more of these principles. Also, with the proper synergistic design, individual green building technologies may work together to produce a greater cumulative effect.

26.2.1 Siting and Structure Design Efficiency

The foundation of any construction project is rooted in the concept and design stages. The concept stage, in fact, is one of the major steps in a project life-cycle, as it has the largest impact on cost and performance (EPA 2014). However, building as a process is not as streamlined as an industrial process, and varies from one building to the other, never repeating itself identically. In addition, buildings are much more complex products, composed of a multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable may affect the environment during all the building's relevant life-cycle stages.

Building a green building is not just a matter of assembling a collection of the latest green technologies or materials. Rather, it is a process in which every element of the design is first optimized and then the impact and interrelationship of various different elements and systems within the building and site are re-evaluated, integrated, and optimized as part of a whole building solution. For example, interrelationships between the building site, site features, the path of the sun and the location and orientation of the building and elements such as windows and external shading devices have a significant impact on the quality and effectiveness of natural daylighting. These elements also affect direct solar loads and overall energy performance for the life of the building. Without considering these issues early in the design process, the design is not fully optimized and the result is likely to be a very inefficient building. This same emphasis on integrated and optimized design is inherent in nearly every aspect of the building.

If all Buildings in urban areas were made to adopt green Building concepts, India could save more than 8400 MW of power which is enough to light half of Delhi or 5.5 lakh homes a year according to estimates by TERI. Architects and planners should start thinking green in the planning of Buildings. Integrating living and vegetation with architecture is fast gaining popularity around the world and now a new term "Vegitecture" has been coined for it and it is becoming common. Thus, the Architect may think to bring concrete jungles to green jungles through "Vegitecture". Simple inclusion of plants here and there in architecture, pocket parks, on roofs and on the street, make the concrete jungle a more friendly place for people to call a city home. Vegitecture helps to reduce effects of heat island and smog, boosts shading, food production and so on. There are four defining elements in vegitecture:

- Using vegetation as a primary component of the building skin and roof systems.
- Creating usable site area in urban development by implementing landscaping on structure.
- Blurring the lines between interior and exterior spaces through design.
- Use of these strategies for environmental and social benefits.

26.2.2 Building Materials Efficiency

The guiding principle in attaining building material efficiency is to minimize the use of non-renewable construction materials and other resources, such as energy and water through efficient engineering, design, planning and construction and effective recycling of construction debris. By maximizing the use of recycled content materials, modern resource efficient engineered materials and resource efficient composite type structural systems wherever possible. Maximize the use of reusable, renewable, sustainably managed, bio-based materials.

Building materials typically considered to be 'green' include rapidly renewable plant materials like bamboo (because bamboo grows quickly) and straw, lumber from forests certified to be sustainably managed, ecology blocks, dimension stone, recycled stone, recycled metal, and other products that are non-toxic, reusable, renewable and/or recyclable for example trass, linoleum, sheep wool, panels made from paper flakes, compressed earth blocks, baked earth, rammed earth, clay, vermiculite, flax linen, sisal, seagrass, cork, expanded clay grains, coconut, wood fibre plates, calcium sand stone, high performance concrete, roman self-healing concrete (Kennedy 1999). For example, hollow fly ash bricks can be used in walls during construction. This will also provide good insulating properties apart from using waste materials. The Environmental Protection Agency (EPA) also suggests using recycled industrial goods, such as coal combustion products, foundry sand and demolition debris in construction projects (Spiegel and Meadows 1999). The use of bio-based materials and finishes such as various types of agriboard (sheathing and or insulation board made from agricultural waste and byproducts, including straw, wheat, barley, soy, sunflower shells, peanut shells and other materials) can also be explored. Some structural insulated panels are now made from bio-based materials. Use lumber and wood products from certified forests where the forest is managed and lumber is harvested using sustainable practices (Buchanan and Levine 1999). Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation.

26.2.3 Energy Efficiency

Green buildings often include measures to reduce energy use. In order to minimize adverse impacts of buildings on the environment (air, water, land, natural resources) aggressive use of energy conservation measures has to be done. By optimizing passive solar orientation and use of external shading devices such that the design of the building minimizes undesirable solar gains during the summer months while maximizing desirable solar gains during winter months. For example, designers orient windows and walls and place awnings, porches and trees to shade windows and roofs during the summer while maximizing solar gain in the winter. By optimizing building orientation, shape, design, interior colours and finishes maximizes the use of controlled natural day lighting which significantly reduces artificial lighting energy use thereby reducing the buildings internal cooling load and energy use. Another strategy, passive solar building design, is often implemented in low-energy homes. Use Energy Star certified energy efficient appliances, office equipment, lighting and HVAC systems also reduce energy use. In addition, solar water heating further reduces energy loads (WB 2001).

By incorporating sensors and controls and designing circuits so that lighting along perimeter zones and offices can be switched off independently from other interior lights when daylighting is sufficient in perimeter areas.

26.2.4 Water Efficiency and Waste Reduction

Reducing water consumption and protecting water quality are key objectives in sustainable building. This can be achieved by preserving the existing natural water cycle and designing site and building improvements such that they closely emulate the site's natural "pre-development" hydrological systems. Emphasis should be placed onsite infiltration and ground water recharge using methods that closely emulate natural systems. Thorough site assessment should be done and building should be strategically located so as to preserve key natural hydrological features. Existing forest and mature vegetation should be preserved which play a vital role in the natural water cycle by absorbing and disbursing up to 30% of a site's rainwater through evapotranspiration.

By optimized use of low-impact storm water technologies, such as bio-retention, rain gardens, open grassy swales, pervious bituminous paving, pervious concrete paving and walkways, constructed wetlands, living/vegetated roofs and other technologies that support on-site retention and ground water recharge or evapotranspiration. Stormwater that leaves the site should be filtered and processed naturally or mechanically to remove trash and debris, oil, grit and suspended solids.

One critical issue of water consumption is that in many areas, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified and reused onsite. The protection and conservation of water throughout the life of a building may be accomplished by using low-flow plumbing fixtures and toilets and waterless urinals. Use onsite treatment systems that enable use of rainwater for hand washing, greywater for toilet flushing, rain and storm water for site irrigation, cooling tower make-up and other uses. The use of non-sewage and greywater for onsite use such as site irrigation will minimize demands on the local aquifer (Barry 2007).

Green architecture also seeks to reduce waste of energy, water and materials used during construction. For example, in California nearly 60% of the state's waste comes from commercial buildings. During the construction phase, one goal should be to reduce the amount of material going to landfills. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing onsite solutions such as compost bins to reduce matter going to landfills.

By collecting human waste at the source and running it to a semi-centralized biogas plant with other biological waste, liquid fertilizer can be produced. Practices like these provide soil with organic nutrients and create carbon sinks that remove carbon dioxide from the atmosphere, offsetting greenhouse gas emissions.

Producing artificial fertilizer is also more costly in energy than this process (Lange 1997).

26.2.5 Cost Efficient

The most criticized issue about constructing environmentally friendly buildings is the price. At first glance, the additional work and alternative materials needed to build green may seem like a burdensome cost, but closer attention reveals this perception to be misleading. If sustainability is viewed as an expensive add-on to a building, we would mistake efforts to reduce energy costs or improve indoor environmental quality as comparable to specifying a better grade of countertop or a more impressive front door. Most green buildings cost a premium of less than 2%, but yield 10 times as much over the entire life of the building (Kats 2003).

Green buildings have been observed to have tangible and intangible benefits. The tangible benefits such as the economical advantages are not immediately visible. However, the lifetime payback is much higher compared with that of conventional buildings, which mainly accrue from operational cost savings, reduced carbon emission credits and potentially higher rental or capital values. The intangible benefits such as social advantages are due to the positive impact of green buildings in the neighbourhood environment. Moreover, due to better working conditions, the productivity of occupant increase and health problems decreases. The performance of green buildings in India, indicates that platinum-rated buildings have a higher payback period of 5–7 years, while gold-rated and silver-rated buildings have a payback period of 3–4 years.

26.2.6 Indoor Environmental Quality Enhancement

The building should provide a healthy, comfortable and productive indoor environment for building occupants and visitors. It should also provide a building design, which affords the best possible conditions in terms of indoor air quality, ventilation, thermal comfort, access to natural ventilation and daylighting and effective control of the acoustical environment.

Indoor air quality seeks to reduce volatile organic compounds (VOC's), and other air impurities, such as microbial contaminants. Buildings rely on a properly designed HVAC system to provide adequate ventilation and air filtration as well as isolate operations (kitchens, dry cleaners, etc.) from other occupancies. During the design and construction process choosing construction materials and interior finish products with zero or low emissions will improve IAQ. Many building materials and cleaning/maintenance products emit toxic gases, such as VOC's and formaldehyde. These gases can have a detrimental impact on occupants' health and productivity as well. Avoiding these products will increase a building's IEQ and there will be reduction in the active energy consumption.

26.2.7 Operations and Maintenance Optimization

No matter how sustainable a building may have been in its design and construction, it can only remain so if it is operated responsibly and maintained properly. Ensuring operations and maintenance (O&M) personnel are part of the project's planning and development process will help retain the green criteria designed at the onset of the project. Every aspect of green building is integrated into the O&M phase of a building's life. The addition of new green technologies also falls on the O&M staff. Although the goal of waste reduction may be applied during the design, construction and demolition phases of a building's life-cycle, it is in the O&M phase that green practices, such as recycling and air quality enhancement take place.

26.3 Green Rating Systems in World

The green building movement has led to the emergence of various green rating systems. The predominant ones are:

BREEAM—Building Research Establishment Environmental Assessment Method, which is widely used in the UK;
LEED—Leadership in Energy and Environmental Design, which was developed by the US Green Building Council (USGBC) and used in the US;
Green Star—Developed by the Green Building Council of Australia and used in Australia.
The New Zealand Green Building Council has also developed their own version of the Green Star tool;
CASBEE—Comprehensive Assessment System for Building Environmental Efficiency, which was developed by Japan Sustainable Building Consortium and is used in Japan;
Green Mark—used in Singapore and mandated by the Building & Construction Authority for all new development and retrofit works;
NABERS—National Australian Built Environment Rating System managed by the NSW (New South Wales) Department of Environment and Climate Change. The only rating system to measure ongoing operational performance.

26.4 Green Building Movement in India

India is witnessing tremendous growth in infrastructure and construction development. The construction industry in India is one of the largest economic activities and is growing at an average rate of 9.5% as compared to the global average of 5%. As the sector is growing rapidly, preserving the environment poses lot of challenges and at the same time presents opportunities. The construction sector therefore needs to play its role and contribute towards environmental responsibility. The Green Building movement in India is a step in this direction – to minimize the negative impact of construction activity on the environment.

The green building movement in India was started in 2003 and received a major impetus when, CII—Sohrabji Godrej Green Business Centre Building in Hyderabad became the first green building in India which was awarded with the prestigious and the much covered Leadership in Energy and Environmental Design (LEED) Platinum rating by the US Green Building Council (USGBS) and also became the world's greenest Building in 2003 (Shrinivas 2005; Ramesh and Khan 2013).

This building is one of the world's best examples of passive architectural design. The building does not discharge any waste water and recycles all the used water. The building design comprises of two air conditioning towers where the incoming air is cooled 7–8 °C by spraying water thereby reducing the load on air conditioning energy consumption. The roof is covered with roof garden as well as solar photovoltaic thereby reducing the energy consumption by almost 60% against a comparable conventional building.

This establishment provided momentum to develop green building competence and capability in the country.

26.5 Green Rating System in India

The green rating systems followed in India are: LEED India—administered by the Indian Green Building Council (IGBC); GRIHA -Green Rating for Integrated Habitat Assessment developed by The Energy and Research Institute (TERI). These tools are relatively new and have not fully evolved. There is no doubt that more and more developers are resorting to these systems to get their buildings certified. Rating systems provide a tool to enable comparison of buildings on their sustainability credentials. Many occupiers and investors are using these tools as a guide to selecting properties for lease or acquisition. Meanwhile, these systems are also being constantly improved. Therefore, the entire green building ecosystem is getting in place. Among all these rating systems, LEED has emerged as the most popular and is followed across 24 countries across the globe, including India. It is an internationally accepted benchmark for the design, construction and operation of high performance green building. LEED certified buildings utilize less toxic

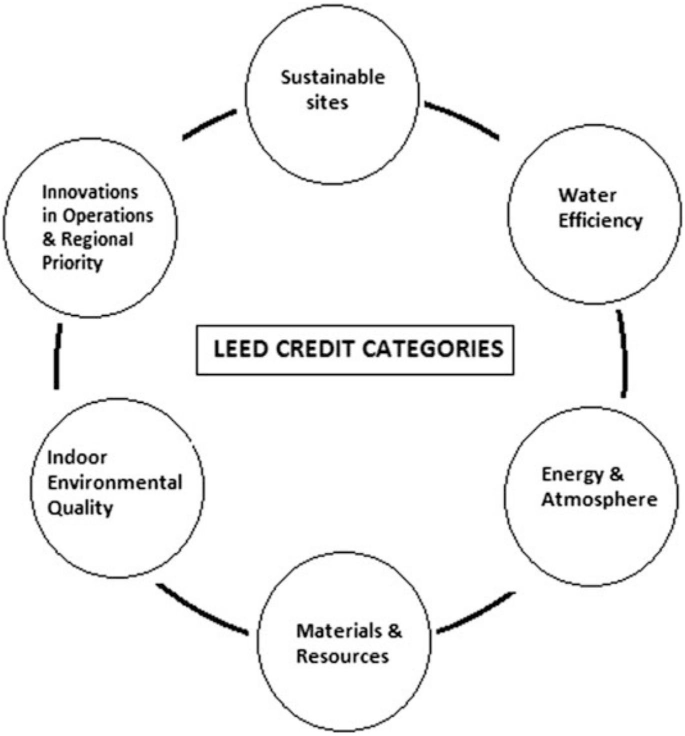

Fig. 26.1 LEED credit categories. *Source* Compiled by Authors

materials, low-emitting adhesives and sealants, paints, carpets, and composite woods, and indoor chemical and pollutant source control. The LEED rating system broadly encompasses five environmental categories—sustainable sites, water efficiency, energy and atmosphere, materials and resources and indoor environmental quality (IEQ) (Fig. 26.1).

Additionally, it emphasizes the innovation and design process to address sustainable building expertise and other design measures that are not already covered in the five environmental categories. The system is designed to be comprehensive in scope and simple in operation. There are credits for each criterion under the broad categories. These criteria credits are earned by addressing the specific environmental impact in design and construction. Different levels of green building certification are awarded based on the total credits earned. A total of up to 61 credits can be earned.

TERI- GRIHA Rating System TERI's green building rating system Green Rating for Integrated Habitat Assessment (GRIHA) has been developed as an instrumental tool to evaluate and rate the environmental performance of a building. The rating can be applied to new and existing buildings of various uses. The rating system is based on national and international energy and environmental principles.

The guidelines or criteria appraisal will be revised every 3 years to take into account the latest scientific developments during this period. GRIHA has derived inputs from the codes and guidelines developed by the Bureau of Energy Efficiency, the Ministry of Non-Conventional Energy Sources, MoEF (Ministry of Environment and Forests), Government of India and the Bureau of Indian Standards. The rating system aims to achieve efficient resource utilization, enhanced resource efficiency, and better quality of life in the buildings.

26.6 Top Energy Efficient Green Buildings in India

According to an estimate by 2030, the Indian building stock is expected to reach 100 billion square feet compared to the existing 25 billion square feet. Much to the credit of our infrastructure industry, India has over 2380 registered green building projects and over 60 LEED platinum certified constructions (the highest certification for energy efficient green construction). India is amongst the few countries spearheading the green building movement worldwide.

Methodology I
As per the literature survey, following seven broad parameters have been chosen for our study to provide rating to the selected green buildings in India.

1. Siting and structure design efficiency
2. Building Materials efficiency
3. Energy efficiency
4. Water efficiency and Waste reduction
5. Cost Efficiency
6. Indoor environmental quality enhancement
7. Operations and maintenance optimization.

Result and Discussion I
The sustainable approaches adopted by the selected buildings were mapped with the selected seven parameters and rating was done on the basis of the results obtained by mapping analysis. Results of the analysis have been given in Table 26.1.

Under our study, Centre for Environmental Sciences and Engineering Building, IIT, Kanpur and ITC Hotels have been rated as the best green buildings since they are adopting all seven selected parameters in an efficient way. Turbo Energy Limited, Chennai has got the least rating among the selected parameters since it is utilizing only one of the selected parameter for green efficiency. Remaining buildings were rated moderately in the range of 28–85%.

Our study suggested that if these parameters can be implemented from the beginning of the design stage, more green buildings can be developed having long term cost efficiency and least environmental degradation. Proper awareness should be created among the people to make them understand the importance of green

Table 26.1 Top energy efficient green buildings of India and comparative sustainable energy parameters

S. No.	Name of green building	Sustainable parameters adopted	Percentage rating as per the selected parameters (%)
1.	Druk White Lotus School, Ladakh • The school was awarded for being the best educational building In 2002 • joint winner of the best green building award	• Exploits the ample sunlight using photovoltaic panels for energy and is self- sufficient • All the water needed for the school is made available on the school premises itself with dedicated boreholes and solar pumps supplying them • The school used and continues to use only materials, culled from the local area, making the whole structure fit organically with the environment • The roof of the school is made completely from locally available poplar and willow, and is also a local technique, is very effective against the harsh exterior conditions and cold winds	71
2.	Centre for Environmental Sciences and Engineering Building, IIT, Kanpur	• Fully compliant with the energy conservation building code • Sustainable site planning has been integrated to maintain favourable microclimate • Architectural design has been optimized as per sun path analysis and climate • Has energy efficient artificial lighting design and daylight integration • Orientation of building: North-South • It has energy efficient air conditioning design with controls integrated to reduce annual energy consumption • Passive strategies such as an earth air tunnel have been incorporated in the HVAC design to reduce the cooling load	100
3.	CII-Sohrabji Godrej Green Business Centre, Hyderabad	• One of the best examples of passive architectural design • Does not discharge any waste water and recycles all the used water • Design comprises of two air conditioning towers where the incoming air is cooled 7–8 °C by spraying water thereby reducing the load on air conditioning energy consumption • The roof is covered with roof garden as well as solar photovoltaic thereby reducing the energy consumption by almost 60% against a comparable conventional building	85
4.	CRISIL House, Hiranandani Gardens, Mumbai (greenest commercial complex in India)	• Provides energy efficiency through a mix of innovation and cutting edge technology • 70% of the work area does not require any artificial lighting during the day, which is very rare for commercial building in India • All the interiors are made up of recycled construction material • An atrium at the centre of the building allows natural light to seep in even the interior parts of the building • Only energy efficient artificial lighting is used in the building that ensures reduced carbon footprint	28

(continued)

Table 26.1 (continued)

S. No.	Name of green building	Sustainable parameters adopted	Percentage rating as per the selected parameters (%)
5.	ITC Hotels (ITC Grand Chola in Chennai, ITC Maurya in Delhi, ITC Maratha in Mumbai, ITC Sonar in Kolkata, ITC Grand Central in Mumbai, ITC Windsor & ITC Gardenia in Bengaluru, ITC Kakatiya in Hyderabad and ITC Mughal in Agra and ITC Rajputana in Jaipur)	• ITC Hotels the greenest luxury hotel chain in the world with all its ten premium luxury hotels LEED Platinum certified	100
6.	Infosys Limited, Mysore	• The overall water consumption of the building is 58% less as compared to other buildings of similar capacity • Most of the waste water is recycled and used for irrigation • Design comprises of an efficient building envelope, which includes insulated walls and roof, along with spectrally selective double glazed windows which are appropriately shaded • Efficient equipment and smart automation is used across the building that leads to a 40% reduction in energy costs • Almost 90% of the work spaces inside the building harvests natural light; the design of the building includes light shelves that ensure that natural light travels as deep as possible inside the building • Almost 100% of the building's energy consumption is met with green power • Manufacturing of most of the building material is done locally to ensure reduced pollution due to transport	85
7.	Suzlon One Earth, Pune	• 100% powered by onsite and offsite renewable sources • The campus has 18 hybrid wind turbines that fulfil 7% of the total energy consumption; the rest of energy demand is met from offsite wind turbines • 90% of the occupied spaces in the campus have daylight exposure; all the lighting used is also LED that reduces the overall consumption • Daylight sensors and occupancy sensors are installed across the building that automatically controls the artificial lighting in presence of daylight and turn off the lights when no one is around • More than 70% of the building material used has a reduced carbon footprint • Jet fans are installed in the basements that push out stale air and bring in fresh air from time to time which consumes 50% less energy as compared to conventional ducted basement ventilation system • Pavements and roads within the campus are designed to enable water percolation and thereby control storm water runoff and contribute towards an increased water table level	85

(continued)

Table 26.1 (continued)

S. No.	Name of green building	Sustainable parameters adopted	Percentage rating as per the selected parameters (%)
8.	Infinity Benchmark, Salt Lake City, Kolkata (seventh in the world to receive a LEED Platinum rating)	• The building design reduces the overall energy costs by 30% • Equipped with Carbon dioxide monitoring sensors, intelligent humidification controls, rainwater harvesting and waste water recycling systems	57
9.	Great Lakes Institute of Management, Chennai	• The institute is of the few LEED Platinum certified educational institutions in the world. Spread over 27 acres it certainly is the most energy efficient academic centre in India	28
10.	TCS technopark and Grundfos Pumps, Chennai	• After installing thermal storage, they have experienced a huge reduction in peak load in the daytime. This is achieved with the thermal energy systems which collect energy and store it for later use, even months later • Uses the solar heat collected in the solar collectors and during summer it uses the cold air conditioning obtained from the winter air	28
11.	Patni Knowledge Center, Noida	• One of India's largest LEED Platinum certified office space • The building design utilizes passive (architectural) and active (mechanical/electrical) strategies to minimize energy consumption • The building depth has been optimally designed to capture daylight for more than 75% of the occupied interiors • Almost 50% of the land cover is green area and the building does not discharge any waste recycling all its sewage water	42
12.	Turbo Energy Limited, Chennai	• Uses solar power to condition or control the air in the building by passive solar, solar thermal energy conversion and photovoltaic conversion in which sunlight is converted to electricity	14

Source Compiled by Author

buildings and its significant role in visualizing the dream of smart city in our country.

Methodology II

On the basis of above information and knowledge, first survey was conducted in ten academic institutes (JSS Academy of Technical Education, NOIDA; MGM Engineering College, NOIDA; Ajay Kumar Garg Engineering College, Ghaziabad; ABES Engineering College, Ghaziabad; Indraprastha Engineering College, Ghaziabad; Krishna Engineering College, Ghaziabad; Ideal Institute of Technology, Ghaziabad; IMS Engineering College, Ghaziabad; Raj Kumar Goel Institute of Technology, Ghaziabad and R. D. Engineering college, Ghaziabad) in

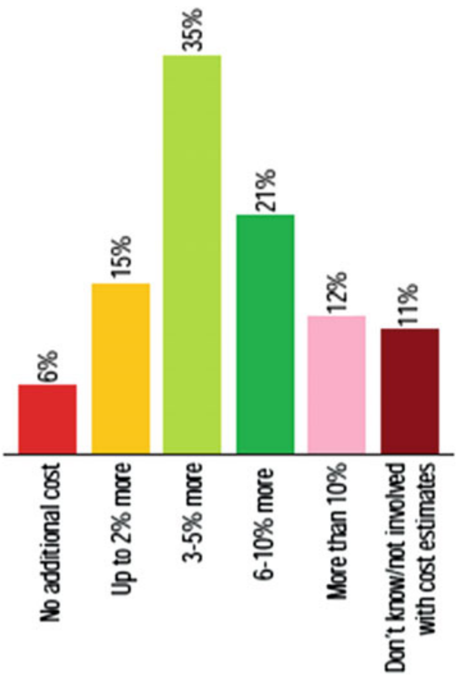

Fig. 26.2 Willingness to spend by academic institutes to make their buildings sustainable

NOIDA–Ghaziabad region to know that how much more they are ready to spend to make their institute green.

The results of the first survey are shown in Fig. 26.2.

Second survey and study was conducted at our institute level to evaluate the barriers to adopting green building principles during the period of 1st April to 30th April 2016. The results of second survey are shown in Fig. 26.3.

Result and Discussion II

Green building concept has to become an inevitable movement for sustainable development. Despite the relatively high level of optimism and activity, none of the institute was ready to go for a green makeover. Majority of them were ready to invest between 3 and 10%. Our institute is ready to spend 6–10% more to make it sustainable (Fig. 26.2).

From the second survey (Fig. 26.3), it was found that biggest barriers to adopt green building principles are related to financial issues specifically higher first cost and poor return on investment. There is lack of awareness and have an exaggerated perception of green building which cannot be removed at once.

The suggestions which our team provided to the institute are as follows and they are well received by them:

- Installation of more photovoltaic panels on the roof tops of all academic blocks (I, II, III, IV and V)
- Electricity generation from fuel cells

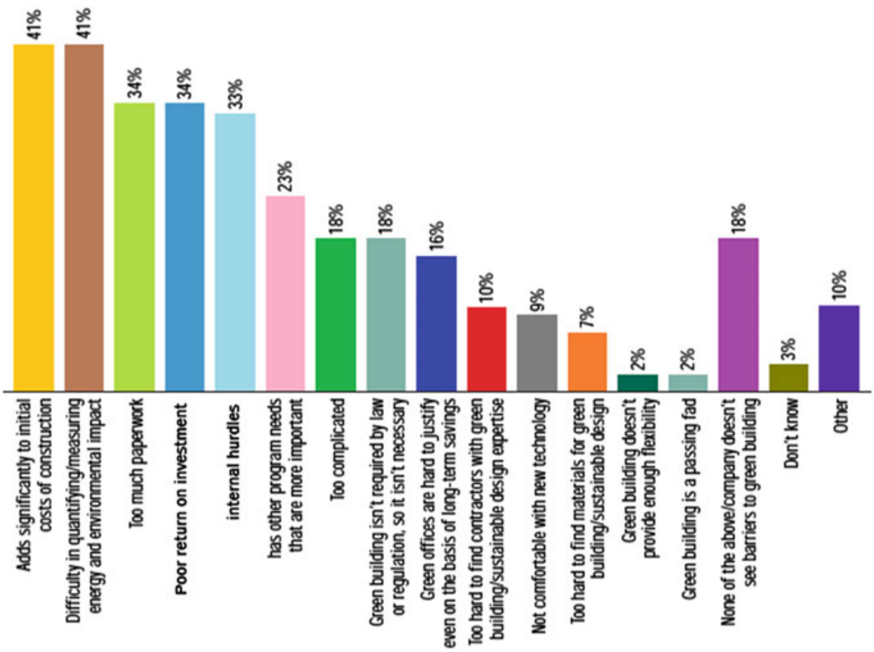

Fig. 26.3 Barriers to adopting green building principles at JSS Institute

- Suitable Mechanism of rainwater harvesting
- Waste water treatment plant within the complex
- Composting of Biodegradable waste
- Upgradation building's lighting to make sure it uses energy efficiently.
- To reduce building's electricity bill, use plug groups of appliances into a smart power strip that uses a timer mechanism to turn them all off at a certain time.
- Use of double glazed windows to enhance shading during summers to keep the room cool.
- To reduce the amount of water use for normal operations throughout the building leakages should be fixed and existing fixtures to be replaced with low-flow options and other water conserving fixtures which will minimize wastewater generation.

26.7 Conclusion

Buildings are perhaps the single greatest stress on the environment, accounting for 'one-sixth of the world's fresh water withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows'. Given threats to the biodiversity upon which human life depends, impending shortages of clean water and other materials, and the possibility of devastating climate change, the greening of buildings constitutes a collective imperative. In an environmentally stressed world, green buildings are moving from an exotic curiosity to a necessity. With the growing awareness on green buildings, the green building movement is well poised to reach greater heights. The penetration of green building concepts and the quantum jump in the green building footprints offers many challenges and at the same time presents tremendous opportunities. The stakeholders of the construction industry need to be well equipped to measure up to these opportunities.

Green buildings may be conceived of as a checklist of environmentally friendly elements, and such checklists are needed to authenticate that a given building is as environmentally friendly as it claims. Green architects, however, prefer to think of buildings as integrated wholes, visually pleasing against the surrounding environment, highly functional for daily uses, and environmentally friendly. One visionary believes that the true green city of the future will be a metropolis where designers are able to comfortably fuse elements considered to be 'real nature' with those thought of as 'man-made nature'. The barrier between natural and artificial, then, is likely to become fuzzy, as buildings move toward a harmony with natural processes. And, instead of being a great drain on energy and a disruptor of ecosystems, buildings are evolving towards being part of a healthy, managed environment. A strong awareness of the advantages of green buildings, a conscious effort to change, will speed this process along.

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