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DEVELOPMENT OF AFFORDABLE GREEN BUILDINGS IN INDIA: OPPORTUNITIES AND CHALLENGES

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Abstract: With urbanization and expansion of cities, India witnesses a dramatic growth in its buildings sector. These conventional buildings are responsible for significant consumption of fossil fuel energy and rise of global warming. According to the U.S. Energy Information Administration (EIA), the largest building energy consumption will be in India by the year 2040. Thus, it becomes necessary to incorporate technological ameliorations like green buildings. Benefits of green buildings are not restricted to energy sector only, but they are known to have positive health impacts on its occupants. Various studies claim the higher productivity of workers inside green offices leads to higher benefits in the long run. Realizing the role of green buildings in sustainable development of a country, India has set up Indian Green Building Council (IGBC). Despite being environmentally benign, the construction of green buildings in developing nations like India comes with its own economic challenges. Due to involvement of upcoming sophisticated technologies, the construction cost involve is high. Rate of growth of green buildings in India is sluggish in comparison to other developed nations. Limited land area in India demands replacement of old conventional buildings with new green ones which is further surrounded by related issues. In this paper, we aim at to analyze the development of affordable green buildings, their growth and highlight various opportunities in this field along with the practical challenges at various levels involved with respect to Indian scenario. We also provide a comparative analysis of green buildings and conventional buildings and finally suggest appropriate measures for affordable and sustainable development of green buildings.

Keywords: Green buildings, urbanization, sustainable development

Introduction

Building sector is one of the fastest expanding sectors that contribute significantly to the growth of Gross Domestic Product (GDP) of a country. However, it mutilates our environment by large amounts of CO_2 emissions, emissions of other greenhouse gases such as halocarbons, chlorofluorocarbons etc. together with profligate energy consumption in electricity use, natural gas etc. Buildings constitute 40 percent of the total energy use globally (Zhang & Cooke, 2010). This creates urgency for green buildings which can mitigate harmful environmental impact. According to the World Green Building Council (WGBC), a green building is the one which reduces or eliminates environmental harm through its design, construction or operation, lessens the burden on natural resources and improves quality of life of its occupants (Worldgbc.org, n.d.). Moreover, it is sought to reduce carbon footprint by incorporating renewable energy technological innovations.

A report by UN Environment &International Energy Agency (IEA) (2017) reveals a continuous escalation in green building growth across the globe. Many countries including that of China, U.S., Germany, India etc., have formulated their policies and programs to mandate energy codes and standards for newly constructed buildings. Current trends reveal a higher growth in developing nations like Mexico and India etc., where commercial construction is on its rise. In India, the technology is relatively new and the potential of market expansion remains high (Benjamin, 2016). Due to various challenges such as handling of construction waste, limited land area, lack of monetary incentives etc., being faced by the builders and engineers in the construction of green

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buildings, its growth has been impeded. For promotion of this technology, addressing these challenges becomes vital. In this context, we explore to identify major challenges and opportunities in the construction of green buildings that if monitored along with appropriate interventions will accelerate the growth of construction of green buildings.

Green Buildings v/s Conventional Buildings

Extensive literature exists when it comes to comparing the green buildings and the conventional buildings considering three major aspects – the cost involved in the construction, operation and maintenance of the building, benefits incurred and occupant satisfaction. It has been widely recognized that green buildings are more energy efficient, have lesser negative impact on environment and are more cost-effective than the conventional buildings. In the view of economic benefits, reduced cost of operation and maintenance of the building, increased productivity of occupants, lesser energy and water consumption, lower emission cost etc., are some of the cost-saving aspects of green buildings. Usually criticisms revolve around the construction cost of the building which includes cost of equipment installed, modern technologies used etc. However, the capital cost involved in it is covered up by the reduced energy use in the long run. Also, it is credible to accept a downward trend in its cost in near future with market developments, technological advancements and increased experience in green designs and technologies. This argument has been supported by a study of Garg (2011) which reveals that the average premium cost of 7 green buildings in India was in the range of 2 to 12 percent. The reason for large variations in the costs of two buildings occur is the availability of material used in the construction and systems installed, which can be higher in both green and non-green buildings. Therefore, it will be profitable to invest in green buildings by considering the long-term benefits.

Unlike conventional buildings, green buildings utilize the space, water and energy more efficiently. On an average, they are 28 percent more efficient than the conventional buildings and generate the power from renewable resources, making them environment-friendly (Kats, 2011). It also reduces waste, conserves natural habitat and enhances aesthetic beauty at the site. Healthy indoor environment of the building reduces health hazards to occupants and increases their productivity. The benefits incurred in economic, environmental as well as social aspects increase the desirability of growth of green building.

Much of the debate stays on the difference between customer satisfaction of green and non-green buildings where some studies reveal that there is no difference at all. However, a recent survey on 25 green building projects across India conducted by Indian Green Building Council (IGBC) based on occupant well-being and satisfaction (CII-IGBC, 2017) with the green building show that more than 70 percent of the occupants are satisfied with thermal environment, lighting systems, acoustics, sanitation and hygiene of the green buildings. The study is useful in bringing out the significance of green buildings on health and well-being of occupants which ultimately would lead to their increased productivity and reduced absenteeism. Considering resource deficiency problem and degraded air quality in India, it is highly favorable to promote this green technology.

Growth of green buildings in India

Being one of the largest economies, having rapidly increasing population growth rate and continuous rural-urban migration, India witnesses a tremendous expansion of the building sector in its cities. This sector is responsible for huge amount of energy consumption which exacerbates the problem of energy deficiency. According to International Energy Outlook report of U.S. Energy Information Administration (EIA)(U.S. EIA, 2017), fastest energy consumption in the buildings sector is to be in India by the year 2040. Therefore, technology which can reduce dependency on non-renewable source is well-accepted by Government of India (GoI) as a part of environmental conservation measures. GoI recognizing the role of green buildings in mitigating environmental harm, has incorporated its promotion in its recent policies and programs.

With the establishment of Confederation of Indian Industry (CII) - Sohrabji Godrej Green business Centre in the year 2004, green building movement gained momentum in India. One of the measures of CII was to give rise to Indian Green Building Council (IGBC) which was responsible for augmentation of this technology and develop a new green building rating system which can be adopted in Indian scenario. Well-known green building rating systems include IGBC rating system for both existing and new ones, GRIHA inaugurated by The Energy and Resource Institute (TERI) with the support from the Ministry of New and Renewable Energy (MNRE) and Bureau of Energy Efficiency (BEE).

Indian Green Building Council (IGBC) rating system

IGBC rating systems (Igbc.in, n.d.) are voluntary, consensus based and market driven building program which aims to mitigate environmental harm caused by the buildings. These include different rating systems for different types of buildings. To qualify for certification, projects should fulfill certain criteria set by IGBC on various environmental aspects like water conservation, waste management, energy efficiency etc. Based on the mandatory requirements for the buildings to fulfill, IGBC rating system evaluates the credit points for allotment of certification level.

Leadership in Energy and Environmental Design (LEED- India) (IGBC.in, n.d.) is a globally recognized certification system for the buildings, an effort from U.S. Green building Council. It aims at sustainable development of a country through green buildings which are both economical and eco- friendly. LEED-India is a private initiative of IGBC of introducing certification standards for green buildings which after 2014 is being handled byGreen Business Certification Inc.(GBCI). India ranking among the top ten countries in LEED has registered 650 projects under this certification system (Holowka, 2017).

Green Rating for Integrated Habitat Assessment (GRIHA)

GRIHA rating system (Grihaindia.org, n.d.) was founded by TERI with the support of MNRE; it is an independent rating system which is one of the most commonly adopted rating system in India developed for commercial, residential and institutional buildings. The rating system undergoes periodical technical revisions and the latest version of GRIHA i.e. GRIHA version 2015 consists of 31 points criteria which have to be fulfilled under various sections like site planning, sustainable building materials, innovation etc. It evaluates a building based on its performance and allots points out of 100 which then determine the certification level of the building from one star to five stars. All buildings of area more than 2500 m^2 are eligible for this certification. Recognizing the role of small green buildings in Indian scenario, an extension of GRIHA i.e. Small Versatile Affordable (SVA) GRIHA has been introduced which registers the buildings with an area of less than 2500 m^2. It is not only for responsible for certification, but also for providing consultants and experts for advising the various engineers and builders on planning and construction of the buildings. Currently, there are 1,175 green building projects registered under this rating system.

Bureau of Energy Efficiency (BEE)

GoI under the act of Energy Conservation in the year 2002 launched BEE (Beeindia.gov.in, n.d.). It aims to promote the energy efficient buildings by providing minimum energy standards for commercial buildings with a connected load of 100 KW and above through its Energy Conservation Building Code (ECBC) program. The program realizes the role of both supply and demand side pull to achieve the above objective and thus aims at ameliorating the market for green buildings. Further, it rates the buildings based on its energy specific usage in kWh/sq. m/year on a 1 to 5 star scale where the 5 star scales is the most efficient building and 1 star being the least efficient. Currently, there are 184 buildings which have been star rated in various categories under this rating system.

India witnesses continuous augmentation of green building growth including both commercial and residential buildings. Over the years, increasing governmental initiatives, stakeholder's contributions, international cooperation and similar factors have affected the growth of green buildings in India. For its promotion, the Ministry of Environment, Forest and Climate Change (MoEFCC), GoI provides faster environmental clearance on green building projects. Recent government initiatives include mandatory compliance of newly constructed building and retrofitting of existing buildings to fulfill certain criteria of a green building and additional Floor Area Ratio (FAR) being awarded for similar projects in some states of the country (Grihaindia.org, n.d.). According to the IGBC Annual Service Plan Report 2016-17 (2017), India ranks second in the world in terms of largest registered green building footprint. Figure-1 shows the trend in the growth of green building footprint in recent years. After the year 2014-15, a sharp increase is noted with the formulation of effective policies and programs leading to high expectations of future growth.

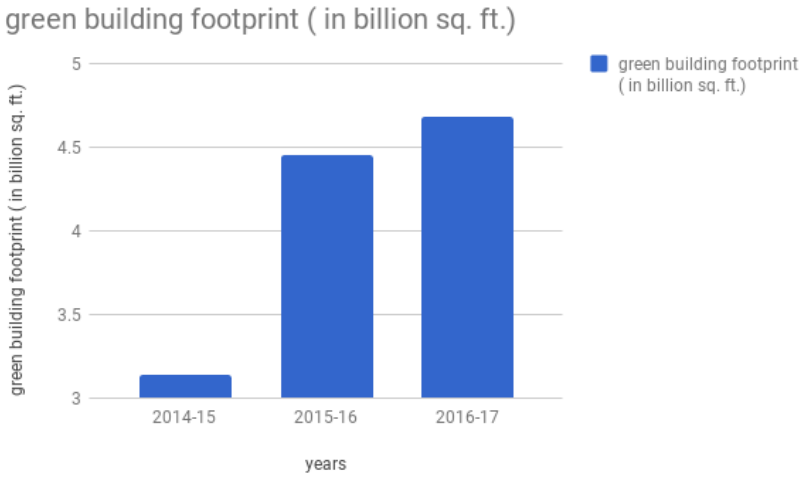

Figure 1:Growth trend of green building footprint in India (Cii.in, n.d.).

However, large potential for the market expansion of green buildings still exists which has not been exploited sufficiently. Realizing lack of awareness and shortage of professionals in this field as a key factor for its sluggish growth in developing countries, Ministry of New and Renewable Energy (MNRE) under its scheme "Energy Efficient Solar/Green Buildings" aims at promoting construction of energy efficient buildings in India by improving human capital through various capacity building programs, workshops, training programs etc. Moreover, Rs. 0.36 crores have been sanctioned under this program for these promotional activities for year 2017-18. Currently, there are 11 such buildings which have obtained GRIHA ratings and this number is yet to increase in the coming years (MNRE Annual report, 2018).

Challenges and Opportunities in development of green buildings

Despite such continuous efforts made by the GoI for promotion of green buildings in their smart cities programs, progress made is low as compared to countries like United States, China and Canada. According to a study conducted by Dodge Data & Analytics (2016), main factors contributing to the sluggish growth of green buildings in India are lack of public awareness and public incentives. In addition, there have been limited number of promotional activities on the part of government and educational institutions in order to provide training or capacity building programs that will facilitate effective growth of green buildings.

In this study, we consider the case of a 5-star GRIHA rated building located in Indian Institute of Technology (IIT) in the city of Kanpur, India namely Centre for Environmental Science and Engineering (CESE) (Iitk.ac.in, n.d.). Inaugurated in the year 2008, the two-storied building has effectively optimized its energy use and has been an inspiration for GRIHA itself. Superintendent Engineer of this building project, Mr. Rajeev Garg in his

interview threw light upon the challenges which the engineers and design planners came across while constructing this green building in India. Figure 2 shows the plan of this building. We mention some of the major challenges being faced during each stage of the construction along with various opportunities. The nature of issues faced in the construction of this building can be generalized to construction of similar projects in India.

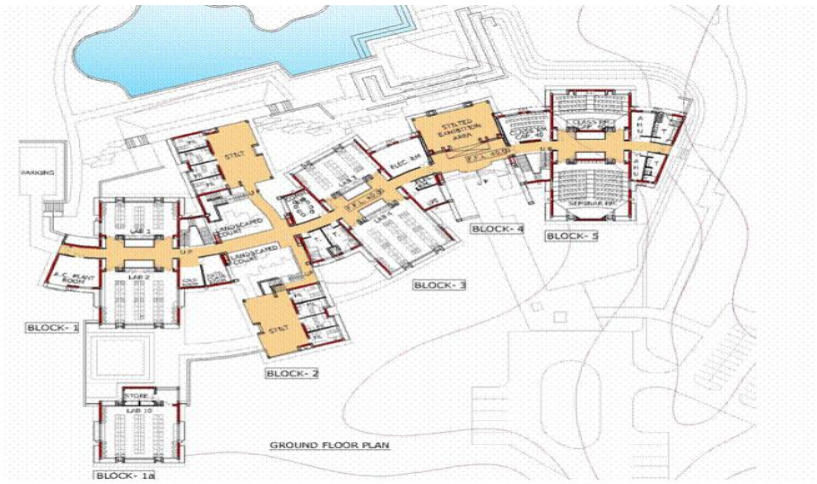

Figure 2: Plan of CESE building at IIT Kanpur (Iitk.ac.in, n.d.).

Following are the stages of construction of green buildings which can be further classified on the basis of challenges and opportunities Indian scenario poses.

Site selection and construction planning

For selecting a sustainable site, builders have to assess the location, natural habitat and similar factors which should comply with green standards. A sustainable site reduces development footprint, preserves natural habitat surrounding the building and has the facility of urban greenways. Few of the major characteristics included are:

- Location of site should be closed to basic amenities of the cities like restaurants, banks, shops in order to minimize polluting motorized transport. This will certainly be economical with the minimization of the travel cost.
- Brownfield sites are mostly preferred which will avoid burden imposed by building on land.
- Conservation of natural habitat enhances the aesthetic beauty of area surrounding the building.
- Maximize open space

Selection of design team

The first stage is followed by another crucial stage of forming a designing team constituting of experienced and well-trained professionals (architects, engineers, interior designers etc.) in the field of green building designs, who are responsible for building energy and cost effective buildings given all the constraints. A well-experienced staff is likely to accomplish the task in a relatively lesser time along with a greater efficiency. A study by Elforgani & Rahmat (2010) reveals that design team attributes are the key factors for success of green buildings establishment. Moreover, proper policies and governing system have highly influence on their efficiencies. India is currently a young country with a high number of engineering graduates in the country which gives India an edge at this stage of development of green buildings in India. Following discussion briefly mentions the government efforts being made in this respect.

Building Design

The stage of site selection and construction planning is broadly concerned with pre-building and extra building factors like preservation of natural habitat and minimizing the loss which construction of building will have on the surrounding. In the stage of building design we majorly focus on the building itself. According to the suggestions by Whole Building Design Guide (WBDG)(Wbdg.org, n.d.):

- Sustainable site design should incorporate minimal utilization or exploitation of water resources and which reuse or recycle waste water. Further, features like pervious land are preferred for enhancing water storage.

- The design should be so formulated so as to achieve energy efficiency with zero emissions from the building. Harnessing renewable sources like wind, sun, water, biomass for electricity generation in the building should be attained for fossil fuel conservation.

- Utilization of materials in building process should be in a way so as to optimally utilize available resources in the most productive and sustainable manner. This enhances air quality reducing pollution and toxicity.

- The site design should incorporate appropriate ventilation system, natural lighting system using solar energy and moisture control systems. This increases health and hence productivity of occupants by improving inner environment of the building.

- The site design should reduce operation and maintenance cost, and increase efficiency of operating systems embedded in the building.

Interior finishes and appliances

Next stage is the appliance selection which should be energy efficient and cost effective. Further, waste generated should be recycled or reused through built-in recycling facilities. Also, indoor finish materials should be pollution-free and should be certified as "green". The basic objective is to provide healthy indoor environment. Several energy audit studies show that end uses in lighting, heating, cooling etc., in the buildings have the potential of saving 40 percent of energy when used efficiently. Therefore, energy efficiency of buildings leads to economic benefits.

Specifications

Collection of data about the real time performance and working of the building is of extreme importance as it helps other builders to analyze the design of their own building so as to assess if the green building will be able to meet the requirements. Hence, maintaining a record of specifications of the buildings allows the builders to continue construction given in the sustainable criteria. The building specifications broadly include data about green products, energy equipment, ventilation systems, etc., installed in the building. While engineers focus on the design and construction planning of the building, this stage is equally important as it will ensure that the space constructed is in accordance with the high-performance design intent (Hui, 2001).

Operations and maintenance

The sustainability of a green building is maintained with optimization of its operation and maintenance. Its effective working largely depends on occupant actions and regular monitoring of installed systems. This calls for professional team that can assess the equipment and their proper functioning, pre-detectable failure, data on

installations and repair history etc. Also, the facility manager should look over building commissioning. Low operation and maintenance cost of green buildings pays off high capital cost involved in it.

Table 1 Categorization of different stages in green building construction and maintenance.

Stages	Challenge	Opportunity
Site selection and construction planning	✓	
Selection of design team		✓
Building design	✓	✓
Interior finishes and appliances	✓	
Specifications	✓	
Operation and maintenance	✓	

Challenges

Following are the challenges faced by builders and engineers at each stage of construction of the green building in India.

Site selection and construction planning

Limited land area- India faces huge shortage of land area in cities with its high population growth and rapid urbanization. Size of land allotted to the building project is usually insufficient. In the case of CESE building project, only 17,000 m^2 of land area was allotted(Iitk.ac.in, n.d.). This constraint can also be found in commercial building projects as they are usually situated in densely populated cities. Limited land area becomes a challenge when it comes to employing technologies like Earth Air Heat Exchangers (EAHE). EAHE broadly depends on the length of pipes and other factors for effective heat exchange between the air and the surrounding soil. Hence, installation of such technologies is impeded by land constraint.

During the construction planning, soil erosion has to be checked which otherwise would pollute the waterways. To retain the richness of topsoil, it is stacked to other place on the construction site and then planted back which becomes burdensome if there is limited space to hoard it. When it is stacked back, preservation of the soil for next 2 to 3 years becomes a challenge. Limited space at construction site results in increased transportation cost of construction material, hence adding to total cost of the project.

Choice of materials with less embodied energy- The total energy consumed in the production and transportation of construction materials is known as embodied energy. Choosing materials with less embodied energy becomes a great challenge for designers and contractors. In India, a large amount of energy is consumed in production of construction materials which accounts to nearly 20-25 percent of total energy demand (Praseeda*et.al.*,2015). Absence of stringent laws to reduce embodied energy during production exacerbates the problem. Pollution and Greenhouse Gases (GHG) emissions during production lessen the 'effective greenness' of a building.

Polluted water in rainwater harvesting systems- Water efficiency in green building can be achieved through rainwater harvesting. This method is regarded as sustainable and efficient to conserve water. However, in India, presence of heavy metals and trace organic compounds in the harvested rainwater makes it inappropriate for direct use. A study reveals that the quality of water which is being harvested through the rooftop rainwater harvesting system do not meet the drinking water guidelines (Meera & Ahammed, 2006). Moreover,

groundwater in the majority of states is polluted containing contaminants like arsenic, fluoride, nitrate and iron. Therefore, problem for the builders in India is not in the method of collection of rainwater, but in its treatment.

Lack of monetary incentives- In the view of financial aspect, availability of proper funding resources will facilitate green building growth. Being one of the fastest growing economies enables India to focus on its environmental projects and finance them. However, there has been lack of monetary incentives from policy provisions for green building projects which adds to sluggish growth of green building projects. Taking the case of CESE building, there were no subsidies provided for taking up this project.

Building design

Inappropriate sunlight in winters- Cavity walls, insulation of roof and surface finishing were some of the measures adopted in CESE green building in order to reflect back heat waves in summers. However, this turns out to be inappropriate for winters when the building does not let in the sunlight resulting into discomfort of the occupants.

Interior finishes and appliances

Security and privacy issues in the automated lighting systems and post-occupancy challenges- Automated lighting systems are advantageous in proliferating occupant's convenience and energy-saving in smart buildings. However, there are some issues which bring discomfort to users including time lag in turning lights on with the movement, complete darkness in unoccupied rooms which hampers security and privacy etc. Furthermore, one cannot install a single lighting system uniformly throughout the building for different section and users have different levels of lighting requirement based on the quality of work and personal preferences. The fact that it is hard to decide the exact nature in which different sections of the building are going to be used at the planning stage adds up to the challenges faced. Taking the case of CESE, the building was to become a center of environmental research which included laboratories demanding air conditioning which sufficiently increased energy demand of the building. Hence, it becomes a challenge for building designers to maintain the 'greenness' of the building if they comply with all the needs of occupants.

Specifications

In India, sample specifications are not developed appropriately and hence lead to environmental harm from building. In the case of CESE building, specifications have not been properly followed due to some changes in the planning which is the case in most of the green building in India. Challenge is to follow the specifications and release reliable data of the installed equipment.

Operation and maintenance

Several factors play a role in hindering the operation and maintenance of green buildings, mostly in the developing nations which leads to reduction in demand for them. According to GRIHA, benefits of going green in India are not realized as data on savings on operation and maintenance costs are not properly evaluated [25]. Further, depreciation cost of the green equipment such as solar panels, solar heater etc., are some of the factors of decrease in its demand.

Opportunities in green buildings

Apart from posing various challenges as mentioned above, Indian scenario also proves to be advantageous at certain stages of construction and maintenance of a green building. Following discussion identifies certain opportunities in some of the stages discussed which if harnessed can improve the performance of green buildings.

Selection of design team

Easy availability of consultants and engineers- MNRE, GoI through its HRD scheme aims at to support research and educational institutions by providing them with financial support. Further, many fellowships are awarded to well qualified students for joining the masters programs in green sectors or various training programs in this field (Mnre.gov.in, n.d.). IGBC initiated many training programs across India and nearly 21,000 professionals were trained with green building concepts (Igbc.in, n.d.). TERI on the other hand has also contributed by providing professional Heating Ventilation and Air-conditioning (HVAC) consultants, design consultants and others to the green building projects including that of CESE building. Increase in number of such consultants is an opportunity for promoting faster growth in green buildings.

Building design

Abundance of renewable sources-India has a vast opportunity in harnessing its renewable sources for electricity generation which can be utilized in the green buildings. It is fourth largest wind power producer in the world. With a vast coastline area with the Indian continent, buildings located in these on-shore areas have the potential to generate household electricity with the technologies available in the country. States like Tamil Nadu, Gujarat and Karnataka etc. have an immense potential in this field.

Further, India is a tropical country which receives solar radiations equivalent to 5000 trillion Kilowatt-hours annually which can be harnessed for electricity generation in cities (Indianpowersector.com, n.d.).According to MNRE annual report 2017-18, India has a potential of 750 GW_P solar powers (MNRE Annual report, 2018). The electricity generated from solar power can be used in solar heaters, solar lamps, solar cookers etc., thus reducing pressure on non-renewable resources.

Sustainable building materials like bamboo, cotton, natural rubbers, straw etc. can be utilized in the green buildings in the form of carpets, floors etc. For instance, in CESE building, bamboo trellis is used for reducing external solar heat gains from the roof. Abundance of such materials in India lessens the cost of building and hence becomes an opportunity.

Suggestions

In this section we provide certain suggestion based on our analysis on Indian scenario in the view of development of green buildings in India. The prospective measures we suggest can be broadly classified into three categories:

Government policy

- Preference should be given to the brownfield development which will lessen the burden on land and natural resources. Governmental incentives should be provided to the green building projects on brownfield land.
- Standard specifications should be devised for the green buildings and proper data collection methods should be adopted so as to assess the fulfillment of the specification set for the green building.
- Employing skilled and experienced staff for operation and maintenance of green buildings can significantly reduce its cost. Governmental initiatives such as subsidies or reduced fees for various training programs will attract professionals to attain proficiency in green designs.

Financial support

- Unavailability of financial assistance hampers the growth of green buildings. Monetary incentives such as subsidies or tax cuts (Ex. Property taxes) are a pertinent solution for boost in the growth of green buildings.

Technological inventions/methods

- Polluted rainwater harvesting systems can lead to health hazards. Technical interventions such as water treatment systems can significantly reduce this risk. Further, efficient roof materials and roof designs can be another solution for reducing the harm.

- For promoting renewable energy technologies which can be incorporated in green buildings, investments in research and development in this field should be stimulated which can further reduce non-renewable energy consumption.

- An assessment on the 'greenness' of the building should include both the energy consumption during operation as well as building product embodied energy. Designing a sustainable building requires an appropriate choice of building materials with less embodied energy. Some of the measures to reduce embodied energy include substitution of materials with high embodied energy with low embodied energy (Ex. use of natural bio-based material like timber in construction wherever possible), use of recycled or reused material, use of LED lightings which are more energy-efficient etc.

- Technological advancements should be made in the automated lighting systems which are customized according to the occupant's desire which will enhance the quality of indoor experience.

Conclusion

Despite contributing significantly to the economic growth of a country, the construction industry markedly adds to the environmental impairment by harmful emissions and energy consumption. In order to mitigate this harm and improve health and productivity of occupants, green building seems to be a viable option. Green buildings are known to be energy-efficient, cost-effective and emission-free green technology. Recent environmental policies and programs of both developed and developing nations have incorporated the promotion of this technology by mandating energy standards and codes for both new and existing buildings. In India, there has been continuous escalation in the number of registered green building projects. However, the presence of few challenges in the construction stages pose as a hurdle for market expansion of this technology. To identify these challenges, the superintendent engineer of a 5 star-rated CESE green building was interviewed. The study reveals few of the major challenges faced by builders and engineers including limited land area, handling of construction waste, lack of monetary incentives and lack of data on savings in operation and maintenance of the building. This study recommends few of the suggestions which can be adopted to overcome these challenges and harness various opportunities for promotion of green buildings.

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