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Green Buildings: Eco-Efficient Infrastructure

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***Abstract*—The world's population has grown exponentially since the second world war, and there is currently pressure on available land and natural resources. As a society, we will eventually be faced with the depletion of our most widely used source of energy, the non-renewable fossil fuels. Scientists from whole world are coming to the conclusion that the present rate of energy consumption in the world will not be sustainable in the future. There are many ways in which scientists are taking steps to reduce consumption such as developing new types of vehicles, energy sources, recycled materials, and designing environmentally friendly buildings. These environmentally friendly buildings are also known as "green" buildings. We can reduce our dependence on fossil fuels and other resources by constructing buildings that use recycled materials in their construction, are more energy efficient, produce oxygen, purify pollutants, and generate energy on site using environmentally friendly means. One of the major benefits of green buildings is that they require less energy to operate. This has the effect of lowering energy costs and reducing dependence on the local utility. Some technologies may have a higher initial cost than the conventional alternatives, but the increased efficiency of a green building can offset this cost over the lifetime of the building.**

***Index Terms*—Energy Efficiency, Sustainability, Renewable Energy, Green House Gases(GHG).**

I. INTRODUCTION

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 is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. There are several key steps in designing sustainable buildings: specify 'green' building materials from local sources, reduce loads, optimize systems, and generate on-site renewable energy. Green building practices aim to reduce the environmental impact of new buildings. Buildings account for a large amount of land use, energy and water consumption, and air and atmosphere alteration. Considering the statistics, reducing the amount of natural resources buildings consume and the amount of pollution given off is seen as crucial for future sustainability, according to EPA the building sector alone accounts for 30-40 percent of global energy use.

Figure1. Technologies to achieve energy-neutral building (Source: WBCSD 2007)

A building that can achieve energy neutrality by adopting measures such as:

1. Earth duct - for fresh air intake conditioning
2. Heat recovery ventilation system
3. Geothermal heat pump
4. Ground heat exchanger
5. Hollow core concrete slab with air ducts to exploit thermal mass
6. Solar hot water system and photovoltaic cells for electricity production - space between façade and hollow core concrete slab open in summer to allow for ventilation
7. Hot water tank
8. Gravel-filtered rainwater tank and collection system
9. Non-potable rainwater distribution system for washing, gardening and toilets

10. Water basin to cool south facing facade in summer through evaporation

The terms "energy-efficient" and "high performance" buildings refer specifically to the energy efficiency whereas green buildings refer to the broader environmental consideration of a building, including the energy efficient aspects. Many countries in Asia and the Pacific region are vulnerable to energy price fluctuations and the adverse impacts of climate change. The primordial role of energy efficiency in green buildings cannot therefore be underestimated because it makes sense from both business and environmental perspectives.

Buildings are large entities and have huge impacts on the environment in various ways. With the present-day methods of design, construction, use and maintenance, large quantities of resources such as materials, energy and money are consumed. In the phases of construction, occupancy and demolition, large quantities of waste and potentially harmful atmospheric emissions are generated, resulting in adverse effects such as loss of amenity and biodiversity. A study carried out on the life cycle analysis of dwellings in Sweden concluded that 70-90 percent of the environmental impact occurs during the phase when the building is used (ISO14042, 2006). In addition to the greenhouse gases (GHG) emission, inefficient design and construction of buildings contributes largely to the generation of municipal solid waste and wastewater. In California, nearly 60 percent of the waste generated in the state comes from the commercial buildings. Local authorities in many cities spend a sizeable share of their budget to create the infrastructure, transport water from hinterland and treat it before supplying to buildings for human consumption. However, most buildings are not equipped to harvest rainwater or minimize water consumption by adopting measures such as the use of water-efficient faucets and showerheads, recycling of bathwater and washbasin water for flushing toilets and watering plants.

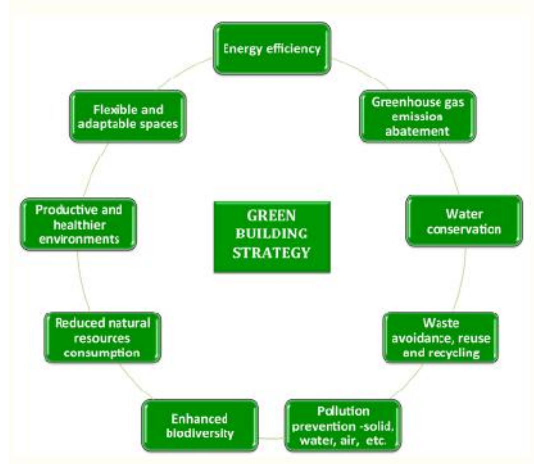


Figure2. The role of Green Building

The potentially negative health effects of poor indoor environment in buildings are of major concern as people spend 85-95 percent of their time indoors. People are exposed to problems such as high radon gas concentrations and suffer from allergies due to poor indoor air quality associated with inefficient and defective heating or cooling systems. In low-income countries, traditional fuels used for heating and cooking contribute to chronic obstructive pulmonary disease in adults and acute respiratory infections in young children. Paints, varnishes, solvents and preservatives commonly used in buildings generate volatile organic compounds (VOCs) that have been proven to be public health hazards. Furthermore, when structure of a building begins to deteriorate, there are possibilities of exposure to asbestos which may be an important risk factor for the chronic respiratory disease mesothelioma. These poor indoor qualities attributed to the buildings lead to the notion of Sick Building. Syndrome (SBS); occupants of affected buildings often describe a complex range of vague and often subjective health complaints. Other than health aspects, there is also the problem of urban warming, or the so-called "heat island effect". Roofing and walls used for construction of buildings capture and retain the solar heat and radiate to the surrounding. Air conditioners used to cool the building by evacuating heat from within the building reject it outside. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality. Relevant studies have demonstrated that greening approaches are the most inexpensive solutions to alleviate the urban heat island effect and to provide tangible benefits in terms of optimizing the energy use in buildings.

Benefits of Green Buildings:

Green building design is rooted in an understanding of natural systems and the behaviour of eco-systems, facilitating and preserving the interrelationship between nature and buildings. Green building practices strive for integral quality in a very broad way, including economic, social and environmental performance. Rational use of resources and appropriate management of building stocks contributes to saving scarce resources, reducing energy consumption and improving the environmental quality. While sustainable buildings can achieve cost reductions because of the lower need for lighting, ventilation, heating and cooling, they may incur slightly higher capital costs because of the additional features and systems incorporated in these buildings, such as on-site energy generation, rainwater harvesting or wastewater recycling, etc. However, the marginally higher investments guarantee the generation of several-fold higher life-cycle savings.

According to UNEP, greening of buildings can be part of the strategies to improve access to basic services, reduce vulnerability, and contribute to better living conditions of the poor residing in informal settlements or overcrowded housing estates that are associated with the lack of access to electricity, fresh water, health-care and effective waste management (UNEP 2011).

Based on the several thousands of green buildings designed, built and operated over the last couple of decades, there is increasing evidence around the world that while green buildings generally incur a small green premium above the cost of standard construction, they deliver a suite of economic, social and environmental benefits that conventional buildings do not. Buildings have the potential to reduce energy consumption by 75 percent, contributing to 20 percent reduction in the world's total energy needs, improving the quality of life, creating over a million jobs and reducing pressure on energy prices worth billions of Dollars (Rockwool Company,2010).

Benefits of green buildings for developers:

1. Capital cost savings: Green building design necessitates the adoption of a system's approach that helps in substantial cost saving. For example, architectural design that is well suited to the local climate can cut down the need for heating/cooling substantially, thus helping to downsize the heating, ventilation and air conditioning (HVAC) system. The TaiGeserviced apartments in Shenzen is the first LEED-certified commercial building in China, developed in 2004, which saves 75 percent of lighting power and 50 percent of air conditioning power consumption while providing the same visual and thermal comfort. Though the building cost more to build, it rents at a premium (Wen Hong et al 2007).

2. Operational cost savings: Bioclimatic architecture combined with judicious use of insulation, and high efficiency equipment and appliances will guarantee sizeable operational cost savings (e.g. typically 30 to 50 percent lower energy and water bill and waste disposal costs, along with reduced carbon footprint from energy savings). This is particularly relevant in the context of high fossil fuel prices which are unlikely to come down in the future. Developers can use this argument to market the building to their prospective clients or tenants.

Typical benefits for owners and facilities managers

1 Savings in energy and water costs
2 Lower maintenance costs and better performance
3 More competitive real estate holdings
4 Improved employee productivity
5 Healthier indoor environment and reduced absenteeism
6 Faster leasing and sales
7 Demonstration of commitment to sustainability and environmental stewardship

Several Asian countries in the process of development are vulnerable to grid failures in the form electricity brown-outs and black-outs or water shortages. It makes sense to incorporate green features such as day lighting and natural ventilation, solar power generation and rainwater harvesting to make buildings less reliant on external grids. A study conducted in California concluded that four of the green building design features that led to increased productivity are increased ventilation control, temperature control, lighting control and day lighting. For example, glare from windows decreased performance by 15-21 percent whereas an increase in ventilation was associated with 4-17 percent performance improvements, and from 9 to 50 percent reduction in sickness. Companies opting for green buildings could attract and retain a committed workforce (Heschong 2003).

Affordability of Green Buildings:

There is general perception that buildings designed to be sustainable are likely to be more expensive than the traditional ones and have to look different with technology-laden rooftops. This can be major hindrance for the mainstreaming of green building practices because of the general aversion to make additional investments in order to achieve lower energy costs. It is crucial to design buildings that are genuinely environment-friendly, accessible and do not require additional budget. For this, there has to be more emphasis on adopting the right building science and depending less on high-cost building technologies. A better scientific understanding of the way buildings work can help in avoiding high technological sophistication or the "technical fix". In short, the challenge is to do more with less. A report by the World Business Council for Sustainable Development pointed out that despite the increasing knowledge and understanding about green buildings, key decision makers still overestimate the cost. A 1,400- person survey found that the average guess for the additional cost of building green was 17 percent, when the actual amount is closer to 5 percent. A 2003 report by the U.S. Green Building Council put the increase at as little as 2 percent. Other more conservative estimates for the most energy-efficient buildings are around 10 percent. These additional costs, although sometimes initially high, are paid back over 2–7 years. After the initial payback period, they become a negative cost, as the savings over time are greater than the initial increase in investment (UNEP/ILO/IOE/ITUC 2008).

Similar study conducted by the Indian Green Building Council (IGBC) concluded that LEED rated green buildings in India consumed 30-50 per cent less energy compared to a conventional building at an incremental cost of 5-8 per cent that was paid back within 3 to 5 years, which is short compared to the typical life span of a building of at least 50 years. The incremental cost depends on the extent of eco-friendly features that have already been considered during the design process. Moreover, working in environment with access to daylight and views has a positive impact on human psychology. Studies have shown that people having access to daylight and view generally contribute to 12-15 per cent higher productivity.

Key Features of a Green Building:

Modern sustainability initiatives call for integrated and synergistic design for new construction and also in the retrofitting of existing buildings. Green buildings bring in a vast array of practices and technologies that can be combined to help reduce the need for natural resources, improve human comfort and health, and mitigate negative environmental impacts. Green buildings emphasize design practices that favour the usage of renewable resources, for example, the usage of sunlight for lighting through passive or active solar design. Green buildings are associated with some key features which give the architectural design unique characteristics that are missing in traditional construction. These include:

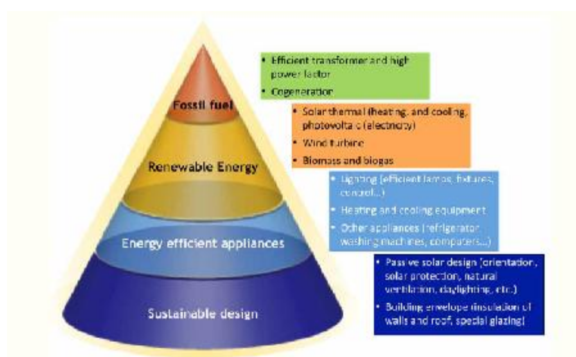
- Energy efficiency and environmental protection
- Water and waste management
- Materials and resources efficiency
- Indoor environmental quality enhancement

Energy Efficiency and Environmental Protection:

Energy conservation and environmental protection are essential to achieve sustainable development. One of the main aims of a green building is to have least impact on the environment through sustainable design, energy efficiency and renewable energy.

Figure 3. Strategy to design a building to minimize its dependence on non renewable energy

Step 1: Green buildings are conceived to match with the specificity of the site and the local climate. In cold climates, poor building envelope affects the thermal gains and losses in the building, and contributes to excess energy use. Green buildings are carefully designed to eliminate such problems. Insulating materials and similar techniques such as high reflective building material and optimized glazed area are used to treat cooling and heating load in an efficient manner. Placing the windows effectively, with optimal window to wall ratio and by using energy-efficient glazing, the lighting load in the building can be reduced too. Air infiltration from outdoor and air leakages that contribute to losses, are minimized. Passive solar designs and appropriate building envelope may lead to higher initial investment, but they can help to divide the building energy demand by a factor of four or more. As a result, the incremental cost of the building infrastructure can be justified by the cost savings associated with the downsizing of systems needed to ensure lighting and cooling/heating in the building



Step 2: Once the building design features have been optimized, one can then consider highly efficient mechanical and electrical systems and appliances. Green buildings possess high-efficiency of appliances, heating and cooling equipment and ventilation which are installed, calibrated and performed according to specifications. Artificial lighting is used only when required and it is provided using energy-efficient technologies. Well positioned and high quality skylights bring in natural light in dark areas and improve the energy performance. In order to reduce the dependence on fossil fuels, energy-efficient heating and cooling systems are selected and operated only when necessary and to the level required. Where relevant, waste energy is recovered, reused and recycled.

Step 3: The steps described above are capable of dividing the energy demand of the building by a factor of ten. At this stage, it becomes interesting to look for ways to replace the demand for energy deriving from fossil fuel. Depending on the location, it is possible to exploit various natural and renewable forms of energy such as solar, wind, wood and biomass, biogas, hydro and geothermal/ground source to meet the energy needs of the building in a decentralized manner, thus reducing the dependence on fossil fuels.

Step 4: The main sources of energy for traditional buildings are electricity, natural gas, liquefied petroleum gas (LPG) and sometimes heating oil, coke and coal. But by the time the building designing goes through the first 3 steps, its demand for fossil fuel would be zero or minimal. Further improvements can be incorporated by looking for supply-side efficiency options such as combined generation heat and power and development of district energy networks. Another possibility is the development ofsmart grid that optimizes the grid performance through the dynamic and real-time exchange of energy between the building and the power grid.

Water and Waste Management

Managing of water and the waste from the beginning of the construction period until demolition is an important feature of a green building. Green buildings reduce their water demand and wastewater and solid waste generation.

Figure 4. Strategy to manage water, wastewater and solid waste in green buildings

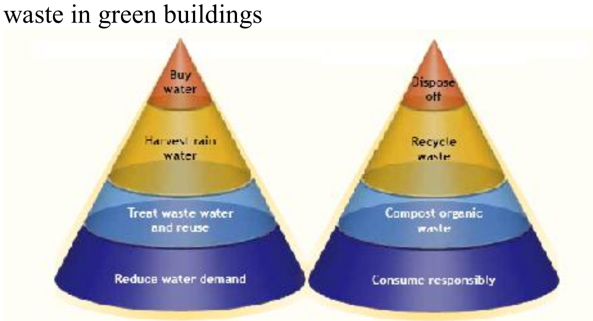


Figure 4 depicts the strategy adopted by green buildings to minimize their need for municipal water supply, and the amount of wastewater and solid waste to be disposed off responsibly. As far as water is concerned, the following steps are recommended:

Step 1: Green building designing process includes the use of technological options to minimize the need for water, such as low-flow water fixtures, faucets and shower-heads fitted with aerators, water-efficient washing machines and dish washers, waterless urinals, sensor-based faucets, urinals and flush-toilets. They also opt for landscape and native plants that are well suited to the local climate and are draught-resistant, allowing to reduce or eliminate the need for irrigation. Drip irrigation and sprinklers are employed to increase infiltration rate and uniform distribution. Most of these options are capital-intensive but divide the water demand by two or

more, thus helping to lower the water bill and the investment on water piping.

Step 2: Once the water demand is minimized, the next option is to look for treating lightly-contaminated grey water from wash basins, showers, etc. for its treatment on-site using natural systems such as constructed wetlands or biological nutrient removal systems, or high-efficiency mechanical filtration systems. The treated water can be used for flushing urinals and toilets, washing floors and cars, gardening or in cooling towers of air conditioning systems that are high water consumers.

Step 3: Rain water harvesting system and storage system are included in the building construction to reduce dependency on water from municipal connection, and surplus water after its use is sent to recharge groundwater and the aquifer.

Step 4: Lower water consumption also means lower demand for municipal water supply and reduced burden on municipal wastewater handling system. The municipal potable water use can thus be limited to cooking, drinking and hygiene, reducing the water bill and the minimizing the volume of water that needs to be treated. These measures serve the dual purpose of reducing the water demand by a factor of 5 to 8 and lower the cost of infrastructure needed to evacuate wastewater from the building. Even during the construction phase water use is minimized by using material such as pre-mixed concrete or by using recycled treated water.

The entire practice of solid waste management is founded upon the well-known 3R principles: waste reduction, reuse and recycling. Green building occupants are sensitized to purchase responsibly by opting for materials and products that are long-lasting and are more environment-friendly. Instead of purchasing a product on the basis of its initial cost alone, emphasis is given to life-cycle costing that considers all costs associated with its purchase, operation and disposal. Waste segregation at source is encouraged in order to extract maximum value from the waste and minimize the volume of waste that is ultimately sent to land-fills or for incineration. All organic waste is used as animal-feed or used on-site for producing either organic fertilizer by composting or producing biogas through anaerobic techniques of fermentation. All recyclable wastes such as metal, glass, paper and plastic are sent for recycling.

Material Efficiency:

Building construction is resource intensive. The building sector is responsible for more than a third of global resource consumption annually. The manufacturing of building materials consumes about 10 percent of the global energy supply. In green buildings, there is a preference for building materials that are less resource exhaustive, recycled to a great extent, and are non-toxic. Thanks to the greater awareness about the relevance of green production materials, the market is undergoing innovation and rapid transformation. Green construction materials (certified wood-based or rapidly renewable) and materials with high recycled-contents are now available in greater numbers and at costs that are very much competitive with their traditional counterparts. Green buildings opt for concrete that contains fly ash from coal-fired power plants or slag from the iron and steel industry. Similarly kiln-fired bricks are giving way to sun-dried compressed and stabilized earth blocks that require much less energy to manufacture, create greater employment opportunities in developing countries, and create no debris or pollution when buildings are demolished. Building green involves establishing construction waste management plan which starts with the adoption of design that minimizes construction debris. Standard-sized or modular construction techniques are adopted to generate less waste and lower disposal costs. Policies adopted to purchase building materials from local and regional markets within a radius of 300 – 500 km and to recycle materials on-site as much as possible help to lower the environmental impacts and transportation costs. The waste prevention and recycling options have the biggest positive impacts on the environment: reduced depletion of natural resources such as trees, oil and minerals, lower emissions from manufacturing and transportation, less demand for energy and water compared to virgin material manufacturing processes, and reduced greenhouse gas emissions due to lower demand for energy in manufacturing and transportation.

A study carried out in Sweden concludes that buildings constructed with recycled materials reduce the environmental impacts by 45 percent in comparison with those using all new materials (Thormark 2006). Other studies also show that if recycled materials are used for construction, between 12 and 40 percent of the energy used for material production can be saved (UNEP 2011).

Indoor Environment Quality:

Green buildings are designed to create a healthy, pleasant and productive work environment. The design and construction of the building especially focuses on the indoor air quality (IAQ), thermal and lighting comfort to ensure healthier indoor environment, improved comfort and well-being of the occupants, increased productivity and better marketability of the building. Provision is made for the occupants to control the level of lighting and ambient temperature in the space occupied by them. Architectural features allow occupants to operate windows in order have access to natural air, get rid of pollutants trapped within the building, and alter the temperature of the living or work space. Material selection is extremely important for maintaining a healthy non-toxic indoor environment. Building materials, furnishings and finishes are selected with close attention being paid to the toxic component in the product, such as formaldehyde. Materials with low chemical emissions are utilized like wool carpets and jute padding and paints that do not contain off-gas volatile organic compounds (VOCs) and that have chemical composition acceptable by the design team. Usage of adhesives is avoided. Highly efficient ventilation system with quality air filters assures good indoor air quality and also minimizes moisture intake. When necessary, more fresh and outdoor air is brought in the conditioned room but at the same time keeping an optimal level of air intake or adopting mechanism that allow heat transfer between the exhaust and fresh inlet air so that cooling or heating load is minimized. The moisture accumulation control in the building is treated with equal importance to the indoor air quality as it leads to mould growth and presence of bacteria and viruses as well as dust mites and other organisms which are of health concern. Well insulated and tightly sealed envelopes are constructed to reduce water condensation on cold surfaces on the interior part of the building that can enhance sustain microbial growth, but adequate ventilation is provided to eliminate moisture from indoor sources as well. This is done to create an environment that guarantees adequate thermal comfort to the occupant. Careful control of humidity and temperature not only provides comfort but also helps to achieve significant operation and maintenance savings over the life of the building. Furthermore, green architectures help to retain employees and occupants, thus raising property value and income. Design of lighting system is a major part in the improvement of the indoor environment quality. The human eye works better with the natural light but excess outdoor light creates glare. Green buildings enable the ability to control the amount and intensity of natural light entering the space so that it is suitable to the need of the occupant. Even when artificial lighting is utilized, appropriate colour rendering of the light is done to increase productivity of the occupant.

The acoustics of the building is another factor that has profound effect on the environmental quality of the building. Poor acoustical qualities in work places or school environments result in stress and fatigue and also hinder verbal communication. Background noise levels are carefully monitored and regulated with sound-dampening options such as sound absorption material and acoustics barriers, wherever necessary.

Conclusions:

In general people are becoming more aware of the potential dangers facing humans if resources are consumed and wasted at the rates they are today. As a result it is likely that there will be a move towards designing more efficient buildings and communities.

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