Green Buildings

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By

Debajit Palit
The Energy and Resources Institute (TERI)

North Eastern Regional Centre
503,Orion Tower,Dispur
GS Road,Guwahati-781005,India
Tel:91-361-2345395/2344363
Fax:91-361-2345395
email:debajitp@teri.res.in

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The importance of energy efficient buildings has assumed great urgency today. In light of fast depleting energy resources, energy scarcity and increasing environmental pollution, innovative ways to cut down energy consumption are necessary. The construction industry is one of the largest energy consuming sectors. In modern buildings significant amounts of energy are also consumed to keep the building environment comfortable. The residential, commercial and institutional building sector consumed 31 percent of global energy and emitted 1900 mega tons of carbon in 1990. By 2050, its share is expected to rise to 38 percent and 3800 mega tons respectively [IPCC 1996]. In India, estimates suggest that about 20 to 25 percent of the total energy demand is due to manufacturing materials required in the building sector, while another 15 percent goes into the running needs of the building. The Ministry of Power estimate indicates that about 20 to 25 percent of the total electricity consumed in government buildings in India is wasted because of inefficient design parameters of buildings, which results in an annual energy related financial loss of about 1.5 billion Rupees. (US $33 million)[1]

In developing countries like India, rising population, increasing standards of living and rapid urbanization result in an increase in building construction activities. This will demand a larger share of the energy available in an already strained energy supply scenario. As most of the required energy is currently derived from burning fossil fuels, the building sector has emerged as a major factor impacting on the environment. To achieve the collective objectives of energy security and environmental protection, eco-sensitive buildings or 'green buildings' that utilize their resources judiciously, minimize their emissions and have efficient waste management systems, should be considered and designed.

How do we create energy efficient buildings?

Energy efficient and environment conscious building design is essentially an integrated approach. The available options in architectural intervention, building materials and design methodologies need to be carefully evaluated to minimize energy usage, minimize the ecological degradation that may be caused by the construction of the building and provide cost effective solutions. The aim is to achieve the desired comfort with the least input of conventional energy. Though the rules are not very well defined, architects and designers accomplish the task through solar passive design, use of renewable energy technology systems, and/or natural building materials. While designing such buildings, not only new building stock can be targeted but also existing buildings can be retrofitted

[1] Correct as of June 1st, 2004.

with energy efficient and eco-friendly technologies, thereby substantially reducing energy consumption. In general, energy efficiency in new buildings can be achieved through:

- Bioclimatic architectural principles;
- Load minimization by the incorporation of solar passive techniques in building design;
- Design of energy efficient lighting and HVAC systems;
- Use of renewable energy systems to meet a part of the building load; and
- Use of low energy materials and energy efficient methods of construction.

Basic energy sources in an eco-friendly building complex

Sky	Sun	Air	Earth	Water
- day lighting **- heat sink**	**- heating** **- electricity generation** **- day lighting** **- greenhouse effect** **- solar chimneys**	**- ventilation** **- heat sink**	**- roof gardens** **- earth berms for insulation**	**- roof ponds** **- fountains for humidification** **- rainwater harvesting**

Source: TERI

Passive solar design interventions

The first stage of green building design is to incorporate solar passive design interventions and try to reduce the loads on conventional systems. Passive design elements are integral parts of any architectural components similar to walls, windows and roofs in a conventional structure. In any design, an architect can achieve energy efficiency and at the same time maximize comfort levels by studying the micro and macroclimate of the site and applying bioclimatic architectural concepts in terms of building orientation with respect to the sun, shading of windows, color, texture, landscaping etc. The solar passive design generally varies according to the climatic condition prevalent at the site. In cold climates, south-facing windows designed to let in the sun's heat while insulating against the cold are ideal. In hot and moderate climates, the strategy is to admit light while rejecting heat. Water bodies may be used in hot and dry climates for evaporative cooling as well as heat sinks for reducing the thermal heat gain. Useful daylight is harnessed through appropriate windows, skylights and light shelves. One of the passive solar cooling devices is the

thermal chimney, which can be designed like a smoke chimney to vent hot air from the house out through the roof. However, one has to resort to advanced techniques of passive conditioning such as roof ponds, trombe[2] walls, wind towers, etc in extreme climatic conditions.

Energy efficiency

Energy conservation is possible by judicious design of lighting and HVAC (heating, ventilation and air conditioning) systems, controls and operation strategies. Increasing insulation levels in conditioned buildings is regarded as the most cost-effective investment in energy efficiency. Thermal insulation of external walls, roofs and floors, and double-pane windows can reduce energy consumption for space heating by lowering heat losses through the envelope of the building. Energy consumption for cooling is also reduced because of lesser heat gains from outside through the envelope. Energy efficient windows with their high thermal insulating values and spectral selectivity can make air-conditioning systems work more effectively. This can lead to reduction in AC loads, lower consumption of electrical energy and reduction in peak load demand [Bandyopadhyay 2001]. The use of energy efficient glazing helps in minimizing unwanted solar gains in summer and heat losses in winter, while maximizing the amount of useful daylight in buildings. Lighting load constitutes about 10 to 15 percent of the total electrical load of a building, and so energy efficient lighting systems, such as compact fluorescent lamps and fluorescent tubes with electronic ballast, are generally recommended instead of conventional lighting fixtures to reduce the lighting load. Although the initial cost of such installation is high, they last longer and the running cost is also less. As electricity is efficiently converted to light in energy efficient lamps, the amount of heat generated is also less.

Use of renewable energy technologies

Renewable energy systems are installed for meeting a partial load of the building, thus considerably reducing the overall electrical and thermal load. Solar energy could be utilized for a variety of purposes and in a number of ways: generating electricity, providing hot water, and heating, cooling, and lighting buildings. Solar photovoltaics (PV) can provide electricity for lighting. Solar thermal systems may be used for heating water or space heating and transpired solar collectors can preheat air for the building's ventilation system. Solar water heaters generate hot water at 60 to 85^{0}C and can

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[2] A trombe wall is a thermal storage wall with vents provided at the top and bottom. It is made of concrete, masonry or composites of brick and sand and is generally located in the southern side (in the northern hemisphere) of a building to maximize solar gains.

conveniently be used for domestic use. The usefulness of a solar water heater can be ascertained from the fact that a standard 100 liter capacity system can be installed as an alternative to electric geyser[3] for residential use that can save 1500 units of electricity annually and could prevent emissions of 15 tons of carbon dioxide into the atmosphere every year [MNES 2001]. It is estimated in India that the use of 1000 solar water heater of a 100 liter capacity each can contribute to a peak load saving of 1 MW. In cold and sunny climates, solar air heaters can be used extensively to reduce demand for electricity and firewood for space heating.

Solar electricity can be generated by integrating solar cells in buildings, on roofs and facades, or by installing grid connected photovoltaic plants. It is an expensive proposition where grid connected electricity is available, but for locations where conventional electricity is not available or the grid is far away, it makes an ideal alternative. Further, 'building integrated PV' (BIPV) systems may be installed for the generation of electricity, and surplus electricity generated during non-working hours could be fed to the grid. Inclined roofs, if oriented in the right direction, are an ideal support structure for PV modules.

In moderate to high wind speed locations, roof top aero generators may be installed for the generation of electricity. A sunspace or solarium, which comprises of a combination of direct and indirect gain systems, may be used to heat up the living space by convection and conduction through the mass wall. Technologies have been commercialized to convert the solid and liquid waste generated in a building to productive use in the form of bio-fertilizer, gas for power generation, cooking etc. The long-term objective is thus to reduce building energy loads in a cost-effective manner such that renewable sources of energy can meet and exceed energy demand in the building.

Low energy materials and methods for building construction

The choice of building materials also substantially contributes towards reducing the energy load of buildings. The use of conventional energy can be minimized by use of low energy materials, efficient structural design and reduction in transportation energy. Thus when building an energy efficient structure, it is necessary to closely examine the issues of building materials and to make appropriate decisions according to local conditions. Bamboo which is called the poor man's timber in India is also getting recognized globally as a suitable building material because it is eco-friendly and highly suitable for energy efficient buildings.

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[3] Electric water heater generally used for heating water for bathing.

Energy efficient buildings in India

In India, the concern for energy scarcity and the environmental problems associated with the consumption of energy in the building sector has resulted in continued interest in energy efficient building design. The Ministry of Non-Conventional Energy Sources (MNES), of the Government of India has undertaken several initiatives to promote solar efficient building design in the country.

TERI (The Energy and Resources Institute) took a major step in the green building sector in India in 1997 by designing and constructing the RETREAT (Resource Efficient TERI Retreat for Environmental Awareness and Training) complex at Gurgaon (35 km from New Delhi). The RETREAT, built as a model training complex with a built-up area of 3000 sq meters, demonstrates efficient utilization of energy, sustainable and integrated use of both natural resources and clean energy technologies, and efficient waste management systems [TERI 2000; TERI 2001]. It has established that 'zero energy in - zero waste out' buildings could be created and run efficiently in the country. The building has been designed as south-facing for the winter heat gains. Deciduous trees have been planted on the southern side of the complex which protects the building from the summer sun, and in winter, by shedding their leaves, the trees brighten up the rooms and provide the required heating. The south side of the structure is partially sunk into the ground to reduce heat gains and losses. Instead of the conventional grid electricity, the complex has a PV-Gasifier hybrid power plant. The biomass gasifier generates 50 kW power by burning twigs, branches, straw and crop residue and a 10 kW roof integrated PV system generates power from solar energy. To avoid conventional air conditioning methods, an earth tunnel system has been constructed that collects atmospheric air, cools it under the earth, and then pumps it to the residential rooms to maintain a steady temperature. The air conditioning of the conference hall and other common facilities is achieved by using gas-fired ammonia absorption chillers, which consume 75 percent less electrical energy than a conventional system, as well as being cleaner and CFC (chlorofluorocarbon) free. Further, the use of 40mm thick expanded polystyrene insulation on the walls, and vermiculite concrete insulation on the roof, has brought down the space conditioning loads by about 15 percent. The lighting is provided by a combination of innovative day lighting techniques, such as skylights, the use of compact fluorescent lamps, high efficiency fluorescent lamps and lighting controls to reduce consumption. The building design and engineering has led to a reduced peak load of 96 kW, down from a conventional peak load of 280 kW, showing a saving of 184 kW. The efficient lighting system alone has resulted in a lighting load of only 9kW compared to the minimum requirement of 28kW in a similar conventional building. Solar hot water systems integrated into the parapet wall

meet the entire hot water requirement for the building. The 'Root Zone' facility recycles wastewater with the help of phragmites and the recycled water is used for gardening purposes. The annual energy savings by use of the passive design and efficient devices in the building is about 250 000 units of electricity and 2 100 LPG cylinders, valued at about 1.05 million Rupees per year.

Select list of energy efficient buildings in India

Cold and Cloudy

- State Bank of Patiala, Shimla
- Himurja building, Shimla
- HP state Cooperative Bank, Shimla
- Nirman Bhavan, Shimla
- MLA Hostel, Shimla
- 200 Bed Hospital, Khaneri
- HPWD Rest house, Kotgarh

Cold and Sunny

- Degree College and Hill Council Complex, Leh
- LEDeG Trainee's Hostel, Leh
- Sarai for Tabo Gompa, Spiti

Hot & Humid

- WBREDA Building, Kolkata
- WBPCB building, Kolkata
- CMC House, Mumbai
- Vikas Apartment, Auroville
- La Cuisine Solaire, Auroville

Mixed Climate

- RETREAT Building, TERI, Gurgaon
- Urja Bhavan, Bhopal
- Water and Land Management Institute, Bhopal
- School of Energy & Environmental Studies, DAV, Indore
- Solar Energy Centre, Gurgaon
- American Institute of Indian Studies, Gurgaon
- SOS Tibetan Children's Village, Dehradun
- Bidani House, Faridabad
- Transport Corporation of India building, Faridabad
- PEDA building, Chandigarh
- IREP Training Centre, Bakholi

Hot & Dry

- Solar Passive Hostel, Jodhpur
- Torrent Research Centre, Ahmedabad
- Indian Institute of Health Management Research, Jaipur

Moderate

- TERI SRC office building, Bangalore

Source: TERI 2001.

Limitations of solar passive building design

Though the benefit of solar passive building design is immense, there are also some limitations for construction of such buildings. The effort of the architect should be to design and build an energy efficient and eco-friendly structure without compromising the comfort of the occupants. Some of the limitations of solar passive building design are:

- It may be difficult in urban areas with limited site area to implement complicated solar passive ideas such as roof cooling systems or earth-air tunnels.
- Earth, stone and other natural building materials cannot be used to a great extent by architects for building design in urban areas.
- The idea of energy conservation is not always well accepted by users. No amount of careful planning and design will work unless the user is prepared to adapt.

Conclusion

With increasing degradation of the environment because of increased energy consumption, environment conscious building design has become urgent. The benefits of green design to society in general, and building owners and users in particular, are manifold. The construction of such buildings results in reduced destruction of natural habitats and bio-diversity, reduced air and water pollution, less water consumption, limited waste generation and increased user productivity. The cost differential between passive and conventional systems is hard to determine, as passive elements are an integral part of the building architecture. However, it is believed that passive design could prove to be a cost effective solution and should not cost more than 15 to 20 percent of the total building cost. What is needed now is to educate society about energy conserving concepts and motivate architects and builders to design and construct such buildings. The sector is a promising one and is expected to develop further at a faster rate with the active cooperation of architects, engineers, builders and policy makers.

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(The views expressed in this paper are those of the author in his individual capacity and do not necessarily reflect the views of the organisation he belongs to.)