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An integrated design process to reduce energy demand and maximize efficiency

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The built environment has a huge impact on our economy, environment, health and productivity. Construction activity is one of the largest activities driving the economy in any country that has significant impact on the environment. Negative impacts of the environment are reduced if green design measures are implemented in buildings as an integrated part of the design and construction process. Recent studies have also shown that green buildings can reduce operational cost of a building significantly in addition to an increase in employee productivity and health.

'Green' building design is an integrated approach to building design that minimizes the negative impacts of the building on our fragile environment. Rather than isolated, independent components, buildings are integrated systems that interact with their environments. Through efficient use of resources, the buildings can levy minimal environmental impact, while enhancing users' comfort and productivity. *A green building may be defined as a building, which depletes the natural resources to the minimum during construction and operation. It maximizes use of efficient building materials and construction practices, optimizes use of onsite sources and sinks by bio-climatic architectural practices, uses minimum energy to power itself, uses efficient equipment to meet its lighting, air conditioning and other needs, maximizes use of renewable sources of energy and uses efficient waste and water management practices and provides comfortable and hygienic indoor working conditions*. It is evolved through a design process that requires all the concerned persons i.e. the architect, landscape designer, the air conditioning, electrical and plumbing consultants, the energy consultants, to work in a team to look into all aspects of building and system planning, design, construction and operation, critically evaluate the impacts of each design decision on the environment and arrive at viable design solutions to minimize the negative impacts and enhance the positive positive impacts on the environment. To sum up, the following aspects of the building design are looked into in an integrated way in a green building:

- Site planning
- Building envelope design
- Building system design (HVAC, lighting, electrical and water heating)
- Integration of renewable energy sources to generate energy onsite.
- Water and waste management in a building
- Selection of ecologically sustainable materials (materials with high recycled content, rapidly renewable materials, materials with low emission potential etc)
- Indoor environmental quality (maintain indoor thermal and visual comfort and air quality)

The scope of green design is vast and this article talks of an efficient building envelope and system design, which forms a primary component of any green design.

Energy Efficiency in a Green Building

One of the primary requirements of a green building is that it should have optimum energy performance and yet provide the desirable thermal and visual comfort.

The three fundamental strategies adopted to optimize energy performance in a proposed building can be broadly classified as:

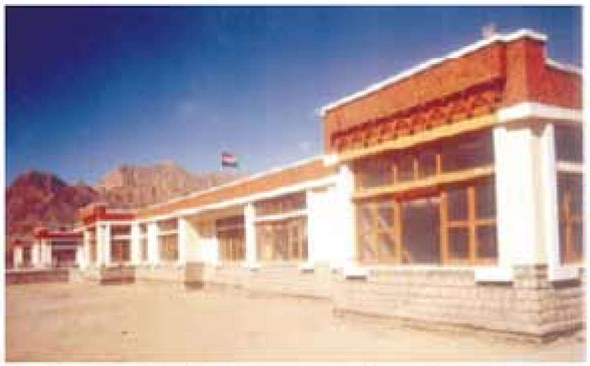
• Reduction in energy demand
• Use of onsite sources and sinks
• Maximize system efficiency

Reduction in Energy Demand. The primary function of the building envelope is to protect its occupants from heat of sun, rains, and provide a comfortable environment for work and leisure. In order to do so it is almost always essential to provide energy consuming space conditioning and lighting devices. Reduction in energy demand entails adoption of design measures to reduce space conditioning, lighting and service water heating loads.

The first step to reduce energy demand is to design for the macro and micro climate of the site by adoption of suitable bio-climatic design principles. As suggested by the name itself, bio-climate design varies from one climate zone to other. India has six climatic zones ranging from extreme cold conditions in the cold desert of Leh and Ladakh to extreme hot and dry conditions in Rajasthan. A building in a cold climatic zone has to adopt measures to harness the sun to the maximum extent by adoption of measures like maximum exposure to south, windows to capture heat, dark colored surfaces, high thermal mass and insulation to retain the captured warmth of the sun, or use of design elements such as trombe wall, sun spaces etc. On the other hand, a building designed for a hot climate would have measures to reduce solar gain like, smaller window sizes, shaded walls, minimum exposure to west and east, external wall and roof insulation or use of design elements like solar chimneys, wind towers, etc to maximize ventilation. The humidity levels of a climatic zone govern the use of water-based measures for cooling a building. While measures like water bodies, fountains, roof gardens are conducive for a hotdry climate, these should be used with caution in a humid climatic zone.

Onsite Sources and Sinks. Use of onsite sources and sinks offers wide opportunities for energy savings in building. Site microclimate is an important aspect that makes building designs in the same climatic zone, distinct from one another. Each building site will have distinct topography, vegetation, wind flow pattern, solar and daylight access – and the design response should be able to address the site requirement. Thus, two buildings located in the same climatic zone may have different design features due to varying microclimate. For example, in an unconditioned building, design and placement of windows according to site wind regime can reduce energy requirement for mechanical ventilation. Strategies such as daylight integration with artificial lighting, use of geothermal exchange to extract heat from the ground are some forms of use of onsite sources and sinks.

Maximise System Efficiency. Maximising system efficiency offers further opportunity for energy savings. Use of efficient lighting, air conditioning and service water heating systems can reduce energy use in a building by 30-40%.



Large south-facing windows for solar gain in cold climate of Leh.

GBC building showing wind towers and solar PV system.

Design of CII - Godrej GBC

Steps to reduce energy demand and use onsite sources and sinks. The CII-Godrej Green Business Centre (GBC) building is an initiative in green design that has received the prestigious Platinum rating under the LEED Green building rating system of the United States Green Building Council adopted in USA.

The LEED (Leadership in Energy and Environmental Design) Green Building Rating System™ is a voluntary, consensus-based US national standard for developing high-performance, sustainable buildings. It provides a framework for assessing building performance and meeting sustainability goals.

The design of the building and its system posed a challenge to the designers as the building was aiming to get the highest award under the rating system and energy optimization of a building has a high weightage under the point system offered in the LEED rating system. Yet the designers took up the challenge and fulfilled all criteria to receive the Platinum rating.

As energy consultants to the project TERI was responsible for ensuring maximum energy efficiency in the building through an appropriate building envelope and system interventions.

The GBC building comprising of a technology demonstration centre, meeting rooms and conference areas, digital library with information centre and office area with ancillary facilities is located in Hyderabad, which has a predominantly hot and dry climate.

This required the building to keep away the heat of the sun round the year. Also, the building being a dayuse one required maximum natural lighting to be provided.

Several steps were taken to reduce energy demand and to use onsite sources and sinks effectively. A design was evolved based on response to site conditions, users' functional requirements and the form conceived by the architects which was circular with the spaces orientated in all cardinal directions.

TThis meant that east and west orientation of some facades of the building could not be avoided. However, appropriate positioning of windows and use of shading devices overcame the negative impact of the form. The strategies adopted to reduce energy demand in the building and to utilize site energy to the maximum are:

- Maximizing north and south exposure and minimizing east and west exposure within the given boundaries of the building form made solar path analysis and solar orientation.
- The building depth was fixed to harvest maximum daylight.
- The fenestration was maximized on the north orientation to minimize heat gains from windows and for facilitating simple solar control and to maximize day lighting.
- The fenestration sizes were determined based on the daylight requirement.
- Energy-efficient glazing systems with desirable insulating and light transmission properties were applied to all fenestration.
- Exterior shading systems were devised and incorporated.
- Aerated concrete blocks, which provide adequate insulation, were used as the basic walling material. The proposed building has mass wall (above grade) made of 10-inch thick aerated concrete blocks plastered on inside and has a stone facing on the exterior. The U-value of the wall assembly is 0.1 Btu/hr-ft^2°F.
- Roof insulation (with R-15 polyurethane foam) was applied to reduce heat gain from the roof. The U-value of the roof assembly is 0.052 Btu/hr-ft^2°F.
- Shading of west walls was incorporated by tradition jali work. The east and west were further protected putting buffer spaces like AHU rooms, electrical rooms along these facades.
- Roof garden on 50% of the roof of the building was incorporated.

- Wind catchers designed as evaporative coolers were designed for pre-cooling of fresh air input into the air handling units of the HVAC system.

Energy optimization achieved in a building has to be quantified under the LEED Rating system. The quantification is done through a method set by the ASHRAE 90.1-1999- Energy standard for buildings except low-rise residential. The method is called the Energy Cost Budget (ECB) method. Under this method the energy performance of the proposed building is compared with that of a baseline building. The baseline building is a hypothetical building, which has same configuration and usage pattern as the proposed building. The building envelope properties (thermal conductivity of wall, roof, floor and windows, solar heat gain coefficient of glazed windows, doors and skylights) and system properties (performance standards for air conditioning equipment, lighting power density and performance standard of lighting equipment, electrical equipment and service water heating equipment) in the baseline building are set as per minimum allowable under ASHRAE 90.1. The proposed building has to adopt improved levels of efficiency in each of the above to have better energy performance than the baseline building.

Points are awarded to a building that would perform better than the baseline building. The energy performance of the proposed and the baseline building are predicted by using building simulation software. The proposed building's energy cost (cost of total energy consumption in the building) is then compared with that of a baseline building. Energy cost budget (ECB) method as defined by ASHRAE 90.1-1999 is followed in making this comparison. A total of 10 points out of 69 points under the LEED rating system are achievable for optimized energy performance in a building. Two points are achievable if the building’s energy cost (for regulated energy components -i.e. energy cost of lighting, air conditioning and service water heating) is 20% less than the base building. Likewise 4, 6, 8, & 10 are achievable if the energy cost is 30, 40, 50, or 60% less than the base building.

Design measures like proper orientation placement and sizing of fenestration, does not get any credit under ECB protocol of quantifying energy performance although these measures substantially reduce energy consumption in a building.

Building envelope measures that get credit under ECB are improved insulation of walls, roof and windows, appropriate shading devices and reflective roof.

Envelope efficiency measures contributed to 12% energy savings over the base building in the GBC building. The ECB qualified envelope improvement measures that were adopted in the GBC building are autoclaved aerated concrete blocks for walls, roof insulation, double glazed windows with low-emissive coatings, shading devices for walls, windows and roof, and roof garden.

Design of CII-Godrej GBC

Steps to improve efficiency of installed systems. The prime goal of green design is to promote integrated approach to building design. The energy performance of a building does not solely depend on improved thermo-physical properties of walls, roof or windows, but it is the combined effect of improved envelope efficiency and system efficiency that gives maximum benefit.

Daylit spaces in the GBC building.

Efficient lighting and HVAC system design in GBC building enabled further energy savings over baseline building. The lighting power density of the proposed building was reduced by use of efficient lamps (compact fluorescent lamps, highefficacy tube lights), luminaries, and ballasts. Further, the building being fully day lit, huge savings is effected by use of day linking strategies.

Day light cum occupancy sensors are used in perimeter zones of offices, meeting rooms and permanent technology center (exhibition space). The lights in these zones have dimmable ballasts. The sensors sense lux level in the space, and dim the lights based on lux levels that keep varying with changing outdoor illumination levels. Adequate glare control strategies have also been adopted to get maximum savings by day lighting. Lighting energy consumption in the proposed building is 86% lower than that in base building. The contribution of lighting energy savings in the overall improved energy performance of GBC building was 15%.

Improved HVAC system efficiency contributed to another 18% energy savings. Energy conservation measures in HVAC system included use of efficient water-cooled chillers with high COP, variable air volume system, efficient cooling towers, primary/ secondary chilled water pumping system and suitable control strategies. The basic differences between the baseline and proposed building are shown in **Table 1**.

Table 1 : Basic differences between baseline and proposed building.

PARAMETER	BASELINE CASE	PROPOSED CASE
Building envelope		
Wall U-Value	0.58 Btu/hr ft²°F	0.1 Btu/hr ft²°F
Heat capacity	13.6	13.6
Roof U-Value	0.063 Btu/hr ft²°F, with R-15 insulation	0.052 Btu/hr ft²°F, with R-15 insulation
Heat capacity	9.5	9.5 (without roof garden)
Heat capacity		13.0 (with roof garden)
Vertical fenestration assembly		
North U assembly-Value	1.22 Btu/hr ft²°F	0.3 Btu/hr ft²°F (U glass) in thermally unbroken AL section
SHGC	0.61	0.61
Other directions		
U-assembly Value	1.22 Btu/hr ft²°F	0.3 Btu/hr ft²°F(U glass) in thermally unbroken AL section
SHGC/SC	0.19	0.4 (with fixed shading device to give an equivalent SHGC of 0.19)
Window shading	No	Yes
Exterior shading	No	Yes (corridor roof and PV roof)
Systems		
Lighting System	As per ASHRAE/IESNA 90.1-1999	Energy efficient lighting

Daylight control	No	Yes
HVAC system		
Air handling units	Variable air volume system	Variable air volume system with indirect evaporative pre-cool for outside air.
Chilled water plant	Air cooled electric reciprocating compressor with condenser, with COP of 2.80	Water-cooled electric scroll compressor with COP of 4.23
Chilled water pumping	Primary only	Variable flow with primary secondary pumping
Heat rejection unit	None	Open medium efficiency, Variable speed fan
Passive systems	No shading of external walls and windows No evaporative pre cooler	Shading with lattice walls, window shading Evaporative pre coolers used selectively for specified areas with fixed overhangs

Design of CII-Godrej GBC

Use of renewable energy sources. The next step to achieve energy-efficiency is to use renewable energy technologies for meeting part of the energy requirement in a building. Renewable energy options also will vary from site to site based on availability of the energy source. High temperature solar, geothermal, wind and biomass are some explore able options for onsite generation of energy. 23kWp roof integrated solar photovoltaic system is used in the GBC building to generate 29,000 kWh of power. The system is interfaced with the grid and a net metering scheme has been adopted.

23kWp Solar PV system in GBC building.

The photovoltaic system along with the energyefficiency measures adopted in the building reduced its energy cost by nearly 55% as compared to the baseline building. The GBC building has been awarded 9 points out of 10 points under the energy category for having achieved such a high level of improved energy performance as compared to the base building.

Conclusion

Energy savings of upto 60% is achievable, if buildings are designed using green design principles. The final selection of the design measures should be done after doing a cost benefit analysis of the same. Typically, the measures described have a payback period between 1-3 years. In the current perspective of increasing energy demand for powering the energy intensive systems in a building, the time has come when, green design should not be an isolated effort by an inspired individual, but a standard design process which is adopted in all our future buildings.