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Approach to Sustainable Buildings

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Abstract:- *"GREEN" symbolizes environment friendly practices in all facets of human endeavor therefore it is the voluntary pursuit of any activity, which encompasses concern for energy efficiency, water conservation, use of recycled products & renewable energy. Green or Sustainable building is a whole system approach for designing and constructing buildings that conserve energy, water and material resources and are more healthy, safe and comfortable.*
Green building is the practices of increasing the efficiency with which buildings use resources, energy, water and materials. While reducing building impacts on human health and the environment through better sitting, design, construction, operation, maintenance, and removal – the complete building life cycle. A green building is similar to any other building in appearance. However the difference is in approach, which involves a concern for intending life span of natural resources, provide human comfort, safety & productivity. A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment.
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I. Introduction

India is witnessing tremendous growth in infrastructure and construction development. The construction industry in India is one of the largest economic activities and is growing at an average rate of 9.5% as compared to the global average of 5%. As the sector is growing rapidly, preserving the environment poses a host of challenges.

The concept of green buildings is not as nascent as we think it is. For example, our own ancestors worshipped the five elements of nature - Earth as 'Prithvi, Water as "Jal', Agni as 'Energy', Air as 'Vayu', and Sky as 'Akash'. Today through the Sustainable Designs/ Green Development, we are rediscovering the Indian ethos.

"chipko movement" was formed in the 70's, the people set up peaceful resistance to deforestation in a Gandhian manner and raised the slogan "Ecology is Permanent Economy". The movement was really effective to create awareness in the minds of average Indian to be more concerned about ecology & environmental aspects.

"Indian Green Building Council" is coordinating the establishment and evolution of national consensus to provide the construction industry with tools necessary to design, build and operate buildings that deliver high performance. The council is coordinating with other concerned agencies to promote green buildings & help faster greater economic vitality and environmental health at lower costs.

The Green Building Movement started in India by 2001; has gained tremendous momentum during the past 5 yrs. Ever since the Green Building center embarked on achieving the prestigious LEED (discussed in subsequent pages) rating for their own center at Hyderabad.

Building activities have undergone tremendous changes in terms of design, features, landscaping and aesthetics. The concerns for energy and environment coupled with the advent of new technologies have opened up new dimensions and approach in building design, all over the world. The new approach is to look at the building performance to blend with the overall philosophy of sustainable development.

During the past few decades or so, environment system has become more an integrated discipline that links the natural & social sciences. Environmental system as an integrated natural social has a tremendous application to human affairs since real world situations almost always involve a natural science component and social, economic, and political components. The two can not be dealt with separately to critical problems.

One of the critical socio natural problems related to environmental engineering is faster & unprecedented economic growth and haphazardly increasing urbanization and industrialization as well as expanding tourism in India. The construction industry/ real estate sector are booming and there is an ever lasting demand for building material.

II. The Concept Of "Green"

There are large amounts of materials used and energy consumed during the construction and operation of an average building. One of the growing areas of interest for many universities and colleges is the implementation of green technologies when constructing new facilities in order to produce buildings that are more energy efficient and have less impact on the natural environmentally during operation.

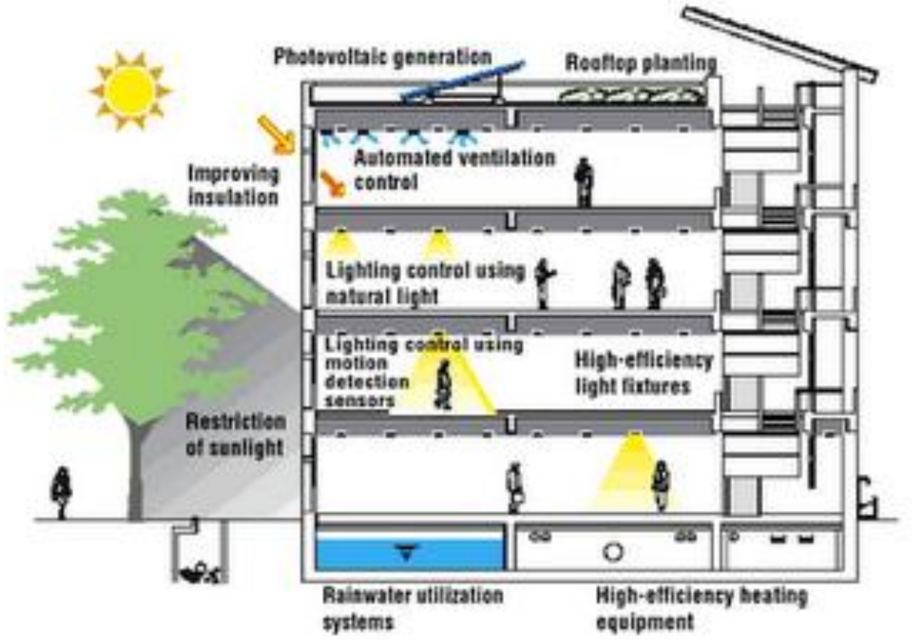
The world's population has grown exponentially since the second world war, and there is currently a huge pressure on available land and natural resources. As a society, we will eventually be faced with the depletion of our most widely used source of energy, the non-renewable fossil fuels. Many people and organizations are coming to the conclusion that the average person's daily energy consumption in World will not be sustainable in the future. There are many ways in which these organizations 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

The voluntary pursuit of any activity, which encompasses concern for energy efficiency, environment, water conservation and use of recycled products & renewable energy, can be defined as "Green".

'A Green building should create delight when entered, serenity and health when occupied and regret when departed' – Perhaps this is one of the most inspiring definitions of a Green building, articulated in the book 'Natural Capitalism'.

A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment.

In India, The Green building movement has gained tremendous momentum during the past 3-4 years, since the CII- Godrej GBC embarked on achieving the prestigious LEED rating for its own centre at Hyderabad. The Platinum rating awarded for this building sparked off considerable enthusiasm in the country.



III. Elements Of Green Buildings

Below is a sampling of green building practices.

A. Siting

- Start by selecting a site well suited to take advantage of mass transit.

- Protect and retain existing landscaping and natural features. Select plants that have low water and pesticide needs, and generate minimum plant trimmings.
- Use compost and mulches. This will save water and time. Recycled content paving materials, furnishings, and mulches help close the recycling loop.

B. Energy Efficiency

- Most buildings can reach energy efficiency levels far beyond California Title 24 standards, yet most only strive to meet the standard. It is reasonable to strive for 40 percent less energy than Title 24 standards. The following strategies contribute to this goal.
- Passive design strategies can dramatically affect building energy performance. These measures include building shape and orientation, passive solar design, and the use of natural lighting.
- Develop strategies to provide natural lighting. Studies have shown that it has a positive impact on productivity and well being.
- Install high-efficiency lighting systems with advanced lighting controls. Include motion sensors tied to dimmable lighting controls. Task lighting reduces general overhead light levels.
- Use a properly sized and energy-efficient heat/cooling system in conjunction with a thermally efficient building shell. Maximize light colors for roofing and wall finish materials; install high R-value wall and ceiling insulation; and use minimal glass on east and west exposures.
- Minimize the electric loads from lighting, equipment, and appliances.
- Consider alternative energy sources such as photovoltaics and fuel cells that are now available in new products and applications. Renewable energy sources provide a great symbol of emerging technologies for the future.
- Computer modeling is an extremely useful tool in optimizing design of electrical and mechanical systems and the building shell.

C. Materials Efficiency

- Select sustainable construction materials and products by evaluating several characteristics such as reused and recycled content, zero or low off gassing of harmful air emissions, zero or low toxicity, sustainably harvested materials, high recyclability, durability, longevity, and local production. Such products promote resource conservation and efficiency. Using recycled-content products also helps develop markets for recycled materials.
- Use dimensional planning and other material efficiency strategies. These strategies reduce the amount of building materials needed and cut construction costs. For example, design rooms on 4-foot multiples to conform to standard-sized wallboard and plywood sheets.
- Reuse and recycle construction and demolition materials. For example, using inert demolition materials as a base course for a parking lot keeps materials out of landfills and costs less.
- Require plans for managing materials through deconstruction, demolition, and construction.
- Design with adequate space to facilitate recycling collection and to incorporate a solid waste management program that prevents waste generation.

D. Water Efficiency

- Design for dual plumbing to use recycled water for toilet flushing or a gray water system that recovers rainwater or other non potable water for site irrigation.
- Minimize wastewater by using ultra low-flush toilets, low-flow shower heads, and other water conserving fixtures.
- Use recirculating systems for centralized hot water distribution.
- Install point-of-use hot water heating systems for more distant locations.
- Use a water budget approach that schedules irrigation using the Irrigation Management Information System data for landscaping.
- Meter the landscape separately from buildings. Use micro-irrigation (which excludes sprinklers and high-pressure sprayers) to supply water in nonturf areas.
- Use state-of-the-art irrigation controllers and self-closing nozzles on hoses.

E. Occupant Health and Safety

- Recent studies reveal that buildings with good overall environmental quality can reduce the rate of respiratory disease, allergy, asthma, sick building symptoms, and enhance worker performance. The potential financial benefits of improving indoor environments exceed costs by a factor of 8 and 14 (Fisk and Rosenfeld, 1998).
- Choose construction materials and interior finish products with zero or low emissions to improve indoor air quality. Many building materials and cleaning/maintenance products emit toxic gases, such as volatile

organic compounds (VOC) and formaldehyde. These gases can have a detrimental impact on occupants' health and productivity.

- Provide adequate ventilation and a high-efficiency, in-duct filtration system. Heating and cooling systems that ensure adequate ventilation and proper filtration can have a dramatic and positive impact on indoor air quality.
- Prevent indoor microbial contamination through selection of materials resistant to microbial growth, provide effective drainage from the roof and surrounding landscape, install adequate ventilation in bathrooms, allow proper drainage of air-conditioning coils, and design other building systems to control humidity.

F. Building Operation and Maintenance

- Green building measures cannot achieve their goals unless they work as intended. Building commissioning includes testing and adjusting the mechanical, electrical, and plumbing systems to ensure that all equipment meets design criteria. It also includes instructing the staff on the operation and maintenance of equipment.
- Over time, building performance can be assured through measurement, adjustment, and upgrading. Proper maintenance ensures that a building continues to perform as designed and commissioned.

IV. Elements Of Green Buildings

A. Displacement Ventilation

A displacement ventilation system uses 100% outdoor air to ventilate the building. Introducing fresh air at floor level, the air rises as it warms until it reaches exhaust ducts at the ceiling. Air moves slowly enough that it does not displace dirt from the floors. Any air pollutants that are produced within the building are not re-circulated. Heat is transferred from outgoing air to incoming air, and so that very little energy is wasted.

Benefits: Excess heat is removed from the building efficiently. Air pollutants are removed from the environment. Fresh air is circulated through the building making for a more comfortable working environment.

Drawbacks: This system is fairly complicated to install and may be difficult to incorporate with other systems. The incoming air must be maintained at approximately the same temperature as the room to avoid excessive cooling/heating.

B. Atrium

A greenhouse atrium may be incorporated in a green building. The atrium houses growing plants and water features. The glass ceiling allows daylight to filter down through the levels of the building. The atrium also acts as a route for air within the building. Stale, hot air flows into the atrium, rises to the ceiling level, where it is readily exhausted. The atrium allows natural light to penetrate the core of the building, reducing lighting expenses.

Figure 2 An **example of a green building with a greenhouse atrium**

C. Radiant / Passive Heating

Radiant solar heating is a way to save on heating costs within a building. In this system, dense tiles or concrete are used as flooring or as wall paneling. During the day the floors and walls absorb heat produced by the sun. As the building cools at night, the tiles release the heat energy retained from the day.

A passive heating system would greatly reduce heating expenses within the building for a little extra initial cost. This system increases the building's temperature in the summer, and therefore slightly increases air conditioning expenses. However, this is a minor concern because the heat is released at night when the building is cooler, and during the summer the building is not as extensively used as in winter. Also, shades can be put into place during the summer to block direct sunlight and reduce heat into the building.

D. Day lighting / Passive Lighting

A green building would typically have many large windows that maximize the amount of light admitted into the building. Passive lighting works well with smart lighting; the two systems work together to reduce energy consumption while providing ample light to the occupants of the building. This reduces the building's demand on natural resources and save money.

Benefits: Day lighting reduces reliance on electric lighting, reducing the cost of electricity in the long run. Day lighting also improves the light quality within the building; electric lights only produce a partial light spectrum, while daylight brings the full light spectrum into the building giving better illumination of spaces. Also studies are available that show increased productivity for people working in naturally lit buildings.

Drawbacks: Shades will need to be installed to reduce direct sunlight penetrating the building in the summer causing the building to heat up. Also, shades will be needed so that rooms can be made dark for presentations. If cheaper windows are installed the building will not be as energy efficient because windows may allow in extra heat. Large amounts of natural light also produce glare that may be uncomfortable to the building's occupants, steps need to be taken to reduce glare.

E. Smart Lighting/ Power Saving Electronics

Smart lighting and power saving electronics are a simple way to save energy. These devices are designed to shut down when not in use. Smart lights have photo sensors that read how much natural light is in the building and dim electric lights when there is substantial natural light. Smart lights are often equipped with motion sensors so that when there is no one in a room the lights automatically shut off. Power saving electronics shut down after not being used for a set amount of time.

Benefits: The major benefit to smart lighting and power saving electronics is the reduction in energy consumption. The reduction in energy implies reduced electricity costs. Also the sensors may increase security in the building.

Drawback: increased initial cost of the devices.

Computerized Windows

Computerized windows add to the HVAC system by opening automatically when the building reaches extreme temperatures. Computerized windows are often installed above large atriums and open to allow hot air to escape from the top of the building. Fans are not needed to push the air out because this system takes advantage of the natural motion of air within the building.

Benefits: Computerized windows reduce air conditioning costs as the windows open automatically when the building becomes too hot.

Drawbacks: Computerized window systems have slightly high initial costs. Also this system is not yet standard and can be a challenge for maintenance personnel, as they must learn how the new system operates.

Expenses: cost of heat sensors, mechanical window openers and computer system.

F. Photo Voltaic (PV) Cells, Battery system, and solar panels

Energy efficiency in photovoltaic system means using the building's individual components to do the same job as less efficient components for less money over the long-term.

Energy-efficiency applies to everything from the building skin or shell, which includes energy efficient windows, lighting, insulation, foundation, and the roof, to equipment that have built-in power management features. It also applies to space heating and cooling systems, whose efficiency may be improved by automated controls, ventilation, improved duct systems, and other advanced technologies.

Energy efficiency can also apply to water heating, which can be improved using solar panels, combined with water-efficient appliances.

Benefits of Photovoltaics: Unlike any other known forms of electricity production, photovoltaics, or PV has no moving parts, is noiseless, produces no emissions during use and is completely scalable from very small to very large electrical generators in a totally modular way. It is therefore the only form of electrical energy generation that has the potential to be placed at the far end of the electricity distribution chain.

Mounting photovoltaic cells on buildings means there are is additional cost for installation, unlike solar generators. Nearly all photovoltaics in buildings (PVIB) systems are grid-connected. The dc electricity from the photovoltaic array is converted into mains-compatible ac by a special inverter, and the ac electricity is fed into the building's main electricity supply. Any excess not used within the building is exported to the electrical supply network (grid). As the electricity is generated where it is consumed, transmission and distribution losses are avoided, which reduces the utility's capital and maintenance costs. The value of the photovoltaic-generated electricity is equal to the avoided cost per kWh of the grid electricity that is saved (i.e. higher than the normal buying price of a utility).

The greatest challenge to all energy production is its impact on the environment. Solar power is one of the friendliest ways of producing electricity. In grid-connected systems, solar power has no effect on the environment, because the system does not include batteries that would need to be replaced.

G. Wind Turbine

Intro: Wind turbines are powered by the wind to produce energy. They do not use up natural resources and do not produce greenhouse gases. They are an efficient, clean way to produce energy.

Benefits: Wind turbines are relatively low-cost when compared to other green technologies (i.e. PV cells). A 50-kW turbine would not only provide power to the proposed Western Engineering Green Building, but could also send surplus electricity into the Thompson and Spencer buildings as well.

Drawbacks: Wind turbines are rather site-specific; an extensive site study would need to be performed to determine if winds are constant and strong enough to make a wind turbine worthwhile. A wind turbine will increase the insurance costs of the building.

Expenses: A new, 50kW wind turbine would cost Rs. 70 Lac including installation. A cement contractor would need to be hired to pour a platform to mount the turbine on.

H. Green Roof

Introduction: An effective green roof system is lightweight, low cost and low maintenance. A green roof has low maintenance plants and can be accessible as a rooftop garden, or can be left inaccessible to the building’s occupants.

Benefits: The green roof could serve as a research centre for botany students; the plants and soil could be used in research. A green roof would save energy because they increase the insulation of the roof. Green roofs tend to last longer than standard roofing; the components can last up to twice as long as conventional roofing. A green roof also improves air quality around the building, and acts as a habitat for local birds. Also, green roofs slow storm water run off, taking load off municipal storm sewers during rainy seasons. Green roofs slow the urban heat island effect.

Drawbacks: green roofs have certain maintenance requirements that must be met to insure a successful green roof. Knowledgeable maintenance staff would need to be hired to keep it in good condition. Green roofing has a higher initial material cost than the cost of a standard roof. A small irrigation system would also need to be installed to ensure that the plants get enough water to stay alive. Also, if the green roof is made accessible to the occupants of the building certain safety precautions need to be taken, for example, the provision of guard rails.

I. Water Use Reduction

Waterless urinals are urinals designed with a non-stick coating that eliminates the need to flush after use. The urinal has a trap in the base that contains a light liquid. The liquid creates a seal between the pipeline and the facility. The seal is designed to prevent bacterial growth and odours. These urinals require the same daily maintenance as flush urinals.

Benefits: These urinals use no water and therefore result in a 100% savings in water. Within a few years, these fixtures pay back their initial cost in water savings. There are no moving parts in these fixtures, therefore, they breakdown much less often. Also, since these urinals do not need to be flushed, there are no handles that can potentially transmit bacteria between users.

Drawbacks: These urinals are slightly more expensive than classic models and so will have a higher initial cost than lavatories fitted with flush urinals. After approximately every 7,000 uses, the liquid trap must be changed.

Expenses: The cost of each urinal is approximately Rs. 10000 to 15000 per unit. Rental of a urinal costs approximately Rs. 275 to 500 per unit per month, based on a five year contract. The installation is optional. Cartridge replacements cost approximately Rs. 1300 to 1700 each depending on how many are bought at a time. The urinals rarely breakdown, so repair costs are negligible.

J. Rainwater Collection

A rainwater collection system is a simple way for the operation of a building to conserve water use. The rainwater would be collected as it runs off the building and would be stored in cisterns until it is needed. The water can be used to water the rooftop garden, or treated for potable uses within the building.

Benefits:

A rainwater collection system if installed would reduce water use and utility bills. There are also many environmental benefits such as less stress or load on municipal storm sewers and less demand on freshwater resources.

Drawbacks:

The system would need to be highly insulated if it is to be kept in working order during the winter months; conversely, the system could be shut down during the winter months, this seems somewhat impractical because winter is the time of year when the building would be getting the most use.

Expenses:

The rainwater collection system would have to be designed and built to suit needs. The cost of cistern construction ranges by size and material type and whether or not a purification system is installed to make the water potable. For example a 20 000 gallon cistern, with a pump and purification system can cost up to Rs. 6 lakh. The cistern alone can cost as little as Rs. 2.5 lakh.

K. Energy Efficiency in Building Design and Construction

A study conducted by Energy Information Administration, (EIA), U.S. Department of Energy indicates that there is a visible trend across the globe wherein the growth rate in total energy consumption has been greater than the population growth rate.

In the developed countries the energy consumption growth rate is only marginally higher compared to the population growth rate. For example, in USA, energy consumption is projected to grow at 1.3% while the population growth rate is projected to grow at 0.8%.

In contrast, in developing countries like India population growth rate is expected to grow at 1.3% while the energy consumption rate is expected to grow at 4.3%.This trend would strain the energy sector to a large extent.

The construction industry in the country is growing at a rapid pace and the rate of growth is 10 % as compared to the world average of 5.2%. Hence energy efficiency in the building sector assumes tremendous importance.

Commercial buildings are one of the major consumers of energy and are the third largest consumers of energy, after industry and agriculture. Buildings annually consume more than 20% of electricity used in India.

The potential for energy savings is 40 – 50% in buildings, if energy efficiency measures are incorporated at the design stage. For existing buildings, the potential can be as high as 20-25% which can be achieved by implementing house keeping and retrofitting measures.

The incremental cost incurred for achieving energy efficiency is 5-8% vis-à-vis conventional design cost and can have an attractive payback period of 2-4 years.

Typical Energy Consumption Pattern in Buildings:

In a typical building, air conditioning is the highest consumer of energy followed by lighting and other miscellaneous equipment. Therefore, if the initial design considers energy efficiency measures in these areas, substantial energy savings can be realised.

Typical break-up of energy consumption in a building is as shown in Figure

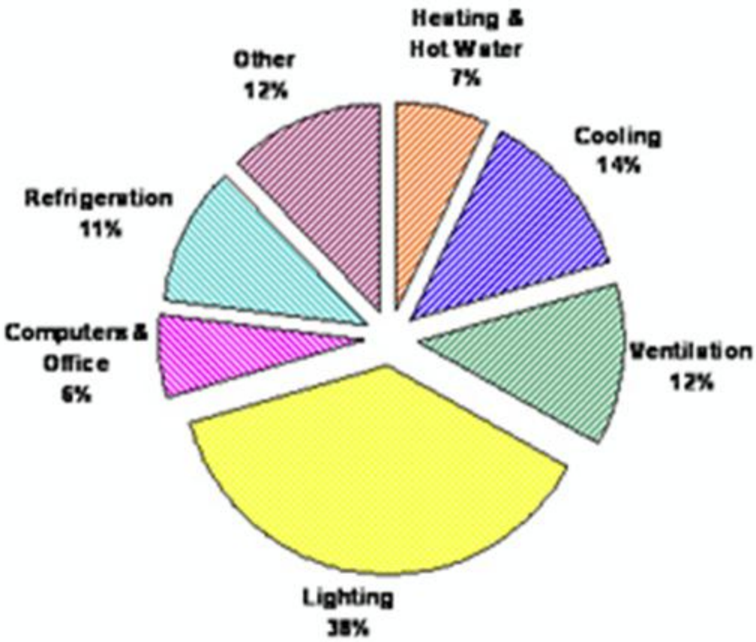


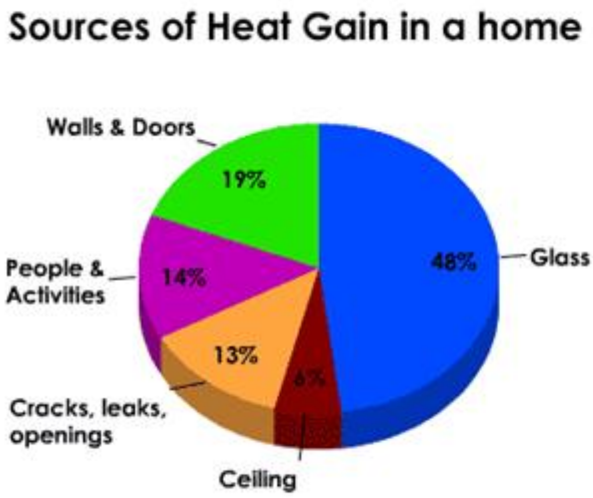
Figure Break-up of energy consumption in a building

Typical Energy Saving Approach In Buildings:

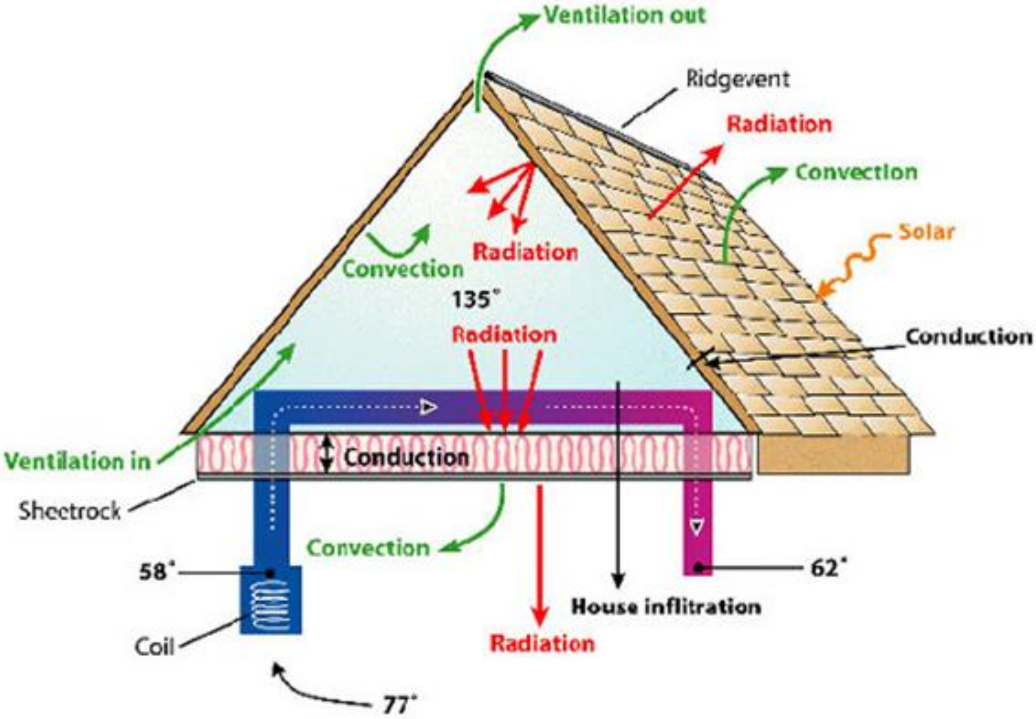
Orientation:

This is the first step to achieve energy efficiency. The following measures can be adopted:

- Minimize exposure on the south and west.
- Use simulation tools and techniques which canhelp in designing the orientation to minimize heat ingress and enhance energy efficiency.



Building Envelope:



Figure
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The following envelope measures can be considered:

- Select high performance glazing with low U-value, low Shading Coefficient and high VLT (Visual Light Transmittance).
- Insulate the wall. The options for insulation materials can be – Extruded polystyrene, Expanded polystyrene (thermocol), Glass wool etc.,
- Brick wall with air cavity can also significantly reduce the heat ingress.
- Hollow blocks, Fly ash bricks and Autoclaved Aerated Concrete (AAC) Blocks are also good insulators.
- The heat ingress through the roof can be as high as 12-15%. Insulating the roof can substantially reduce the heat ingress.
- Consider shading devices for window openings.

Equipment & systems:

- Select chillers with high Coefficient of Performance (CoP).
- Install Variable Frequency Drives (VFD) for supply & return air fans and pumps.
- Select high efficiency cooling towers.
- Use high efficiency motors, transformers and pumps.
- Install Heat recovery wheels and economizers
- Consider night purging with ambient air to flush out the heat trapped within the building during the day
- Adopt Controls & Building Management Systems for effective control
- Engage a Commissioning Authority to ensure that savings are realised once the building becomes operational

Lighting:

- Design in such a way that the building gets maximum day lighting.
- Overall lighting power density can be designed as less as 1.0 W/sq.ft.
- Use daylight-cum-dimmer controls
- Install occupancy sensors
- Select energy efficient luminaires like CFL, T-5, LED, etc.

L. Challenges & Opportunities

Achieving energy efficiency in building poses a number of challenges and at the same time presents a host of opportunities. A few of them are discussed below:

- **Awareness & Training:**

Incorporating energy efficiency measures at designstage requires knowledge of the green building concepts. There is now a need for skilled and knowledgeable professionals who have deep understanding of architecture and energy systems.
IGBC is addressing this through number of training and awareness programmes all over the country. Thus far, 3500 professionals have been trained on these concepts.
Energy simulation programmes are excellent tools to design energy efficient buildings. The tools typically used are Visual DOE, Energy Plus and Lumen Micro. As of now, the number of trained professionals on these tools and techniques is scarce. IGBC is facilitating training of professionals on these tools.

- **Availability of Materials, Equipment and Technologies:**
  The availability and affordability of materials/equipment which contribute to energy efficiency is another major challenge. Tremendous potential exists for materials & equipment like heat resistive paints, fly ash blocks, insulation materials, high efficiency chillers, variable frequency drives, high efficiency cooling towers, building management systems, lighting controls, BIPV (Building Integrated Photo Voltaics), etc., New technologies like wind towers, geothermal systems etc., are gaining importance.
  The business opportunity for these products and technologies in India expected to cross 25 billion USD / annum by 2010. To facilitate the penetration of these products, IGBC has platforms like Green Building Congress,
- **Sustained Savings:**
  A building can have the best of materials, equipment and systems in place at the design stage; however, the building can sustain the savings only if it is monitored on a continuous basis.
  LEED rated buildings use IPMVP (International Performance Measurement and Verification Protocol) to monitor and sustain the savings. Proper measurement & verification of savings will help the building owner to fine-tune the base line and achieve high level of savings.
  Applying rating programmes like LEED EB (LEED for Existing Buildings) can help buildings to sustain energy efficient practices over the life of the building.
- **National Codes and Standards:**
  Government of India has launched the 'Energy Conservation Building Code (ECBC) code. This code is voluntary and applicable to buildings or building complexes that have a connected load of 500 KW or a contract demand of 600 KVA, whichever is greater. This code addresses the minimum performance standards forenergy efficiency in a building covering building envelope, mechanical systems & equipment, service hot water heating, interior & exterior lighting and electrical power& motors. This is an excellent initiative which will enable design of high performance buildings.

V. Conclusions And Examples

A green building may cost more up front, but saves through lower operating costs over the life of the building. The green building approach applies a project life cycle cost analysis for determining the appropriate up-front expenditure. This analytical method calculates costs over the useful life of the asset.

These and other cost savings can only be fully realized when they are incorporated at the project's conceptual design phase with the assistance of an integrated team of professionals. The integrated systems approach ensures that the building is designed as one system rather than a collection of stand-alone systems.
Some benefits, such as improving occupant health, comfort, productivity, reducing pollution and landfill waste are not easily quantified. Consequently, they are not adequately considered in cost analysis. For this reason, consider setting aside a small portion of the building budget to cover differential costs associated with less tangible green building benefits or to cover the cost of researching and analyzing green building options.
Even with a tight budget, many green building measures can be incorporated with minimal or zero increased up-front costs and they can yield enormous savings

Steps to Ensure Success

- Establish a vision that embraces sustainable principles and an integrated design approach.
- Develop a clear statement of the project's vision, goals, design criteria, and priorities.
- Develop a project budget that covers green building measures. Allocate contingencies for additional research and analysis of specific options. Seek sponsorship or grant opportunities.
- Seek advice of a design professional with green building experience.
- Select a design and construction team that is committed to the project vision. Modify the RFQ/RFP selection process to ensure the contractors have appropriate qualifications to identify, select, and implement an integrated system of green building measures.
- Develop a project schedule that allows for systems testing and commissioning.

- Develop contract plans and specifications to ensure that the building design is at a suitable level of building performance.
- Create effective incentives and oversight.

LISTING OF SOFTWARE FOR ANALYZING GREEN BUILDINGS

Atrium Performance: from the (IRC –Canada), Atrium buildings combine attractive aesthetics and delighting features and are proliferating in new and renovated buildings in Canada. Being often complex in their design, atriums have been reported to have high overall energy consumption. Through field-monitoring and computer simulations, IRC investigates ways to reduce these energy costs, while maximizing the atrium delighting, thermal, acoustical and smoke performance.

Daylight-linked Lighting Control Systems: from the (IRC –Canada), IRC investigates the effect of manual and automatic venetian blinds on the performance of two types of automatic lighting control systems: on/off and continuous dimming. Measured data will provide information on the field performance of existing daylighting technologies and the basis for guidelines for proper installation and calibration in Canadian buildings.

Daysim (Dynamic Daylight Simulations): from the (IRC –Canada), Description and source code for various validated and easy-to-use daylight simulation tools to predict the annual daylight availability and artificial lighting demand in a building. The tools are based on the RADIANCE raytracing engine, the concept of daylight coefficients and the Perez sky model.

Adeline: lighting software in simulating the daylight distribution and the electrical lighting consumption of an existing atrium building.

Cost-effective Open-Plan Environments (COPE): from the (IRC –Canada), Lighting is just one of the indoor environment aspects addressed in this multidisciplinary project. COPE will look at the effects of open-plan office design (e.g. workstation size, partition height) on the indoor environment and occupant satisfaction. One outcome will be a software tool to enable designers to perform cost-benefit analyses on different design options.

SkyVision: SkyVision is a new WINDOWS software tool from the IRC –Canada, to calculate the optical and daylighting performance of various shapes and types of conventional and tubular skylights. Currently available for beta testing, the software is a useful tool for engineers, architects or building designers.

BEES (Building for Environmental and Economic Sustainability):

Powerful technique for selecting cost-effective, environmentally preferable building products. Tool from the National Institute of Standards and Technology (USA), for builders, designers, engineers and architects. Strengths: Offers a unique blend of environmental science, decision science, and economics. It uses life-cycle concepts, is designed to be practical, flexible, and transparent. Weaknesses: Includes environmental and economic performance data for only 200 building products covering 23 building elements.

HOT2000: Is an energy analysis and design software. Up-to-date heat loss or gain and system performance models provide an accurate way of evaluating building designs. This evaluation takes into account the thermal effectiveness of the building and its components, the passive solar heating owing to the location of the building and the operation and performance of the building's ventilation, heating and cooling systems. Helps to build comfort, sustained energy performance and lower operating costs into new buildings and major renovation construction projects.

Energy-10: a user-friendly computer software program from (NREL)/USA. designed to make it easier for architects, engineers and builders to integrate solar technologies and energy efficiency features into the design of commercial and institutional buildings

SERIRES: a simulation tool from (NREL)/USA, to assist in the design of passive solar residential buildings.

STEM: a short term monitoring method from (NREL)/USA, for verifying building performance in the field.

BESTEST: a building energy software test method from (NREL)/USA, that is being adopted as the industry standard.

Swift: is a design tool from canREN (Canada), that uses an hour-by-hour energy balance to calculate building ventilation loads and predict the thermal performance of one or more solar wall system planned for the building. It may also be used to estimate the cost of the system, the fuel cost savings available from its operation and the economics of investing in it.

Federal Renewable Energy Screening Assistant (FRESA): Developed by NREL-USA, this Windows-based software tool screens federal renewable energy projects for economic feasibility. It is able to evaluate many renewable technologies including solar hot water, photovoltaics, and wind.

TRNSYS: software, available from the University of Wisconsin. Main applications include: solar systems (solar thermal and photovoltaic systems), low energy buildings and HVAC systems, renewable energy systems, cogeneration, fuel cells TRNSYS has become reference software for researchers and engineers around the world.

software, available from the University of Waterloo -Canada. Used to simulate behaviour of solar heating **WATSUN:** systems.

WATSUN-PV: software, available from the University of Waterloo - Canada. Used to simulate behaviour of solar photovoltaic.

FCHART: correlation method, available from the University of Wisconsin - USA. System Types: Water storage heating, pebble bed storage heating, building storage heating, domestic Water Heating, passive direct-gain, passive collector-storage wall. Features: Life-cycle economics with cash flow, weather data for over 300 locations, weather data can be added, monthly parameter variation, 2-D incidence angle modifiers, english and SI units.

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