UNIT-III: Green Building Design

1. Green Building Design Introduction

- ✓ Green Building Design refers to the planning, construction, operation, and maintenance of buildings in an environmentally responsible and resource-efficient manner
- ✓ The main aim is to minimize the negative environmental impact of buildings and maximize the comfort, health, and productivity of occupants.
- ✓ It integrates architecture, engineering, environmental science, and sustainability practices.
- ✓ Green design reduces energy consumption, water usage, and construction waste.
- ✓ It ensures better air quality, natural lighting, and thermal comfort.
- ✓ Concepts of passive design, orientation, ventilation, and insulation are fundamental.
- ✓ Buildings are designed to consume fewer natural resources during their lifecycle.
- ✓ It follows rating systems like LEED, IGBC, and GRIHA in India.
- ✓ Site selection and planning are critical to avoid ecological damage.
- ✓ Material selection is based on renewability, recyclability, and local availability.
- ✓ The design process emphasizes minimal disturbance to the ecosystem.
- ✓ The building should adapt to the local climate and culture.
- ✓ Renewable energy integration is encouraged in the design phase.
- ✓ Waste management systems like rainwater harvesting and sewage treatment are included.
- ✓ Energy-efficient HVAC (Heating, Ventilation, and Air Conditioning) systems are promoted.
- ✓ Landscaping with native plants reduces irrigation demand.
- ✓ Use of low-VOC paints ensures healthier indoor air.
- ✓ Building orientation enhances daylighting and reduces artificial lighting needs.
- ✓ Smart systems like IoT-based energy monitoring are integrated.
- ✓ Sustainability is balanced with cost-effectiveness.
- ✓ The design considers life-cycle costs instead of just initial construction cost.
- ✓ Indoor comfort factors such as temperature, humidity, and noise are carefully addressed.
- ✓ Net Zero Energy Building (NZEB) concept is a major goal.
- ✓ Building automation ensures real-time efficiency.
- ✓ Construction should minimize soil erosion and pollution.
- ✓ Integration of modular construction techniques reduces waste.
- ✓ Design includes proper stormwater management.
- ✓ High-performance glazing reduces heat gain.
- ✓ Roof gardens and green walls enhance insulation.
- ✓ Ventilation systems maximize fresh air circulation.
- ✓ Smart meters track water and power consumption.
- ✓ The design must comply with local building codes and sustainability standards.
- ✓ Urban heat island effect is reduced by reflective roofing materials.
- ✓ Life-cycle assessment helps measure sustainability.
- ✓ Post-occupancy evaluation ensures long-term efficiency.
- ✓ Designers collaborate with environmental consultants for optimization.
- ✓ Smart irrigation systems ensure sustainable landscaping.
- ✓ Building should be adaptable for future expansion.
- ✓ Technology-driven innovations make buildings smarter and greener.
- ✓ Ultimately, the goal is to create sustainable habitats that balance **people, planet, and prosperity**.

2. Reduction in Energy Demand

- ✓ Energy demand reduction is the first and most important step in sustainable buildings
- ✓ It focuses on minimizing the total energy consumption of the building.
- ✓ Passive design strategies such as proper orientation and insulation reduce demand.
- ✓ Use of natural daylight reduces dependency on artificial lighting.
- ✓ Installing efficient glazing and shading devices lowers cooling loads.
- ✓ Building envelope design plays a key role in energy efficiency.
- ✓ Thermal mass materials stabilize indoor temperature fluctuations.
- ✓ Energy-efficient lighting systems like LEDs reduce power use.
- ✓ Occupancy sensors and daylight sensors help in intelligent lighting control.
- ✓ Building automation systems optimize energy distribution.
- ✓ Using high-efficiency HVAC systems reduces cooling and heating demand.
- ✓ Demand-side management strategies ensure energy use only when needed.
- ✓ Smart appliances consume less energy compared to conventional ones.
- ✓ Proper roof insulation prevents heat loss and gain.
- ✓ Orientation towards prevailing winds improves natural ventilation.
- ✓ Cross-ventilation design eliminates the need for artificial cooling.
- ✓ Solar chimneys increase natural airflow.
- ✓ Green roofs and walls reduce cooling loads.
- ✓ Efficient elevator and escalator systems minimize power consumption.
- ✓ Thermal comfort is achieved with minimal mechanical assistance.
- ✓ Using locally available materials reduces energy spent on transportation.
- ✓ Light-colored surfaces reduce absorption of solar radiation.
- ✓ Demand for hot water is reduced by using solar water heating systems.
- ✓ Energy recovery ventilators (ERVs) recycle conditioned air.
- ✓ Minimizing plug loads by using energy-efficient electronics.
- ✓ Demand-based ventilation reduces unnecessary HVAC operation.
- ✓ Smart building management systems monitor energy usage.
- ✓ Waste heat recovery from industrial processes reduces external demand.
- ✓ Insulating pipes and ducts reduces thermal losses.
- ✓ Adaptive lighting control reduces power during low occupancy hours.
- ✓ Optimizing ceiling heights reduces HVAC loads.
- ✓ High-performance windows lower energy leakage.
- ✓ Rainwater harvesting reduces pumping energy demand.
- ✓ Use of district cooling/heating systems lowers building demand.
- ✓ Awareness programs encourage occupants to save energy.
- ✓ Power factor correction reduces electricity wastage.
- ✓ Regular maintenance of systems ensures peak efficiency.
- ✓ Demand minimization makes renewable integration easier.
- ✓ Reduced energy demand extends equipment life.
- ✓ The result is a **sustainable, cost-effective, and eco-friendly building operation**.

3. Onsite Sources and Sinks

- ✓ Onsite sources and sinks refer to energy generation and utilization at the building site itself.

- ✓ This reduces dependency on external energy supply.
- ✓ Solar power is the most widely used onsite energy source.
- ✓ Rooftop solar panels convert sunlight into electricity.
- ✓ Solar water heaters provide hot water efficiently.
- ✓ Small-scale wind turbines can supply electricity in windy areas.
- ✓ Biomass energy systems convert organic waste into energy.
- ✓ Geothermal heat pumps use the earth's temperature for heatingcooling.
- ✓ Onsite waste-to-energy plants recycle waste into power.
- ✓ Rainwater harvesting is an onsite water source.
- ✓ Greywater recycling systems act as water sinks.
- ✓ Building-integrated photovoltaics (BIPV) provide dual function – façade + energy.
- ✓ Micro-hydropower systems in flowing water areas generate electricity.
- ✓ Thermal storage systems store heat for later use.
- ✓ Battery energy storage systems (BESS) store excess power.
- ✓ Onsite sources help reduce peak load demand.
- ✓ They provide backup during power outages.
- ✓ Onsite sinks like energy-efficient lighting absorb less energy.
- ✓ Data centers in buildings can reuse waste heat as sinks.
- ✓ Cogeneration units act as both sources and sinks.
- ✓ Organic waste digesters generate biogas onsite.
- ✓ Renewable microgrids support building power needs.
- ✓ Heat sinks such as cooling ponds reduce HVAC energy.
- ✓ Smart grids integrate onsite sources with external supply.
- ✓ Rain gardens act as natural sinks for stormwater.
- ✓ Recharge pits replenish groundwater onsite.
- ✓ Urban farming on rooftops provides food sinks.
- ✓ District energy sharing between nearby buildings optimizes onsite systems.
- ✓ Hydrogen fuel cells act as clean onsite power sources.
- ✓ Electric vehicle (EV) charging stations enhance onsite energy use.
- ✓ Onsite renewable integration reduces transmission losses.
- ✓ Smart meters optimize consumption from onsite sources.
- ✓ Hybrid systems combine solar, wind, and biogas onsite.
- ✓ Wastewater treatment plants recycle water for landscaping.
- ✓ Phase change materials (PCM) act as thermal sinks.
- ✓ Passive cooling designs like earth-air tunnels act as natural sinks.
- ✓ Onsite systems create self-sufficient communities.
- ✓ They reduce carbon footprint drastically.
- ✓ They increase resilience against energy shortages.
- ✓ Thus, onsite sources and sinks make buildings more **independent and sustainable**.

4. Maximising System Efficiency

- ✓ System efficiency means getting the maximum output from every resource with minimal input.
- ✓ Green buildings aim to maximize efficiency in HVAC, lighting, water, and power systems.
- ✓ HVAC systems are optimized with energy-efficient chillers and boilers.
- ✓ Variable Frequency Drives (VFDs) adjust motor speeds based on demand.
- ✓ Zoning in HVAC ensures cooling/heating only in occupied spaces.

- ✓ Building automation systems (BAS) coordinate all building utilities.
- ✓ Lighting systems use LEDs with occupancy sensors for efficiency.
- ✓ Daylight harvesting controls artificial lights based on natural daylight.
- ✓ High-performance glass reduces heating and cooling demand.
- ✓ Efficient insulation minimizes energy losses through walls and roofs.
- ✓ Greywater recycling maximizes water efficiency.
- ✓ Rainwater harvesting reduces dependency on municipal supply.
- ✓ Demand-based pumping reduces wastage of electricity.
- ✓ Cogeneration systems use waste heat to generate power.
- ✓ Tri-generation systems produce power, heat, and cooling simultaneously.
- ✓ Solar thermal systems supply hot water efficiently.
- ✓ Energy recovery ventilators recycle exhaust air.
- ✓ Smart elevators with regenerative braking improve efficiency.
- ✓ Data-driven analytics identify system inefficiencies.
- ✓ Smart grids balance supply and demand automatically.
- ✓ Energy-efficient appliances reduce plug loads.
- ✓ Thermal storage systems shift energy use to off-peak hours.
- ✓ Building Integrated Photovoltaics (BIPV) combine structure with energy.
- ✓ Electric Vehicle (EV) integration helps optimize power use.
- ✓ Efficient fire and safety systems lower standby power.
- ✓ Landscaping with drip irrigation minimizes water loss.
- ✓ Using native plants reduces irrigation demand.
- ✓ Waste segregation and composting reduce disposal energy.
- ✓ Digital twins simulate system performance for better efficiency.
- ✓ Smart sensors track temperature, occupancy, and air quality.
- ✓ Automated shading devices reduce cooling demand.
- ✓ Building orientation maximizes passive heating/cooling.
- ✓ Combined use of renewable and grid power increases efficiency.
- ✓ Proper maintenance ensures equipment works at peak performance.
- ✓ Training staff enhances efficiency of operation.
- ✓ Benchmarking helps compare system efficiency with best practices.
- ✓ Life-cycle costing ensures long-term efficiency investments.
- ✓ AI-driven systems predict faults and optimize performance.
- ✓ Maximising efficiency reduces operational costs.
- ✓ Ultimately, system efficiency ensures **sustainable performance with minimal wastage**.

5. Steps to Reduce Energy Demand and Use Onsite Sources and Sinks

- ✓ Energy reduction starts with demand minimization, followed by renewable integration.
- ✓ Step 1: Analyze building load profile and identify peak demands.
- ✓ Step 2: Apply passive design strategies like shading, orientation, and insulation.
- ✓ Step 3: Reduce lighting load with daylighting and LED systems.
- ✓ Step 4: Optimize HVAC design with zoning and smart controls.
- ✓ Step 5: Incorporate efficient windows and thermal insulation.
- ✓ Step 6: Use smart meters to monitor real-time consumption.

- ✓ Step 7: Reduce water pumping energy by rainwater harvesting.
- ✓ Step 8: Introduce solar water heating for hot water demand.
- ✓ Step 9: Optimize plug loads with energy-efficient appliances.
- ✓ Step 10: Encourage behavior change through occupant awareness.
- ✓ Step 11: Integrate rooftop solar PV to supply onsite electricity.
- ✓ Step 12: Use Building Integrated Photovoltaics (BIPV) in façades.
- ✓ Step 13: Implement small wind turbines where feasible.
- ✓ Step 14: Install biogas plants for kitchen and organic waste.
- ✓ Step 15: Use geothermal systems for heating and cooling.
- ✓ Step 16: Incorporate battery storage for energy backup.
- ✓ Step 17: Use waste heat recovery systems for additional energy.
- ✓ Step 18: Greywater recycling reduces water energy needs.
- ✓ Step 19: Use EV charging as a flexible energy sink.
- ✓ Step 20: Smart load management distributes energy efficiently.
- ✓ Step 21: Adopt demand response strategies during peak hours.
- ✓ Step 22: Install automated shading and ventilation devices.
- ✓ Step 23: Encourage green roofs for passive cooling.
- ✓ Step 24: Apply district cooling/heating systems if available.
- ✓ Step 25: Integrate solar thermal for industrial hot water needs.
- ✓ Step 26: Install rain gardens as water sinks.
- ✓ Step 27: Use pervious pavements to recharge groundwater.
- ✓ Step 28: Create microgrids with local energy sharing.
- ✓ Step 29: Use energy-efficient pumps, fans, and motors.
- ✓ Step 30: Optimize elevators and escalators for reduced energy.
- ✓ Step 31: Apply IoT sensors for predictive energy control.
- ✓ Step 32: Reuse condensate water from HVAC as sinks.
- ✓ Step 33: Implement cooling ponds for industrial heat sinks.
- ✓ Step 34: Introduce phase-change materials for energy storage.
- ✓ Step 35: Use demand forecasting to align sources and sinks.
- ✓ Step 36: Blend multiple renewables (solar, wind, biomass).
- ✓ Step 37: Apply energy codes (ECBC, IGBC) for compliance.
- ✓ Step 38: Regular audits improve energy balance.
- ✓ These steps make buildings **self-reliant, efficient, and sustainable**.

6. Use of Renewable Energy Sources

- ✓ Renewable energy sources are essential for green building sustainability.
- ✓ They reduce dependency on fossil fuels and cut carbon emissions.
- ✓ Solar energy is the most common renewable source.
- ✓ Solar PV systems provide onsite electricity generation.
- ✓ Solar water heaters reduce the need for electric heaters.
- ✓ Building Integrated PV (BIPV) combines aesthetics with function.
- ✓ Wind energy is used in small-scale rooftop turbines.
- ✓ In coastal and windy zones, wind power is highly effective.
- ✓ Biomass systems convert organic waste into electricity or biogas.
- ✓ Biogas from food and agricultural waste is used for cooking.
- ✓ Geothermal systems provide heating and cooling by tapping underground heat.

- ✓ Hydropower micro-turbines can be installed near flowing water.
- ✓ Hybrid renewable systems balance energy supply.
- ✓ Renewable energy reduces electricity bills drastically.
- ✓ It increases energy independence and reliability.
- ✓ Renewable adoption aligns with government incentives.
- ✓ Excess solar energy can be sold back to the grid (net-metering).
- ✓ Solar air conditioning reduces grid dependency.
- ✓ Rooftop solar reduces transmission and distribution losses.
- ✓ Biofuel-based generators replace diesel in factories.
- ✓ Hydrogen fuel cells provide clean backup power.
- ✓ Tidal and wave energy have future potential in coastal buildings.
- ✓ Solar-powered streetlights save municipal energy.
- ✓ Renewable energy integrates with smart grids for optimization.
- ✓ Thermal storage stores excess solar energy as heat.
- ✓ EV charging stations run on solar or wind power.
- ✓ Community solar plants serve multiple buildings.
- ✓ Concentrated solar power (CSP) generates high-temperature heat.
- ✓ Solar cookers reduce LPG dependency in residential areas.
- ✓ Wind-solar hybrid systems provide continuous energy supply.
- ✓ Smart meters track renewable energy contribution.
- ✓ Renewable microgrids increase resilience in remote areas.
- ✓ Storage batteries make renewable use more reliable.
- ✓ Renewable energy has lower operating cost compared to fossil fuels.
- ✓ It supports national renewable energy targets.
- ✓ Green credits and carbon credits reward renewable usage.
- ✓ Industries can achieve carbon neutrality through renewable use.
- ✓ Renewable sources future-proof buildings against energy crises.
- ✓ Public awareness accelerates renewable adoption.
- ✓ Renewable energy ensures **sustainable, clean, and resilient buildings**.

7. Eco-Friendly Captive Power Generation for Factories

- ✓ Captive power means power generated by an industry for its own use.
- ✓ Eco-friendly captive power reduces dependence on fossil-fuel grids.
- ✓ Solar captive plants are widely adopted by industries.
- ✓ Rooftop solar panels power machinery during the day.
- ✓ Ground-mounted solar farms serve large industrial complexes.
- ✓ Wind turbines are effective for industries in windy regions.
- ✓ Biomass-based captive power plants utilize agricultural waste.
- ✓ Co-generation uses waste heat to generate additional electricity.
- ✓ Tri-generation provides power, heat, and cooling together.
- ✓ Biogas plants process organic waste into useful energy.
- ✓ Hydrogen fuel cells are emerging as green captive power sources.
- ✓ Captive renewable systems reduce peak power tariffs.
- ✓ Factories become self-reliant and less affected by grid failures.
- ✓ Waste heat recovery systems reduce energy wastage.
- ✓ Industries can sell excess captive renewable power to the grid.

- ✓ Captive power reduces carbon footprint of industries.
- ✓ Small hydropower systems serve factories near rivers.
- ✓ Captive plants cut down transmission losses.
- ✓ Hybrid systems ensure continuous supply (solar + biomass + grid).
- ✓ Battery storage adds resilience to captive power systems.
- ✓ Energy-efficient boilers improve factory power efficiency.
- ✓ Steam turbines can be coupled with biomass fuel.
- ✓ Factories use cogeneration with turbines for efficiency.
- ✓ Captive renewable plants get government incentives.
- ✓ Rooftop solar lowers electricity bills of industries.
- ✓ Eco-friendly captive plants reduce pollution compared to diesel generators.
- ✓ Hydrogen-based systems provide future-ready solutions.
- ✓ Digital control systems optimize captive power output.
- ✓ Industries can track emissions reduction with captive plants.
- ✓ CHP (Combined Heat & Power) systems improve efficiency.
- ✓ Biomass briquettes replace coal in factory furnaces.
- ✓ Carbon credits can be earned through eco-friendly captive systems.
- ✓ Smart captive plants integrate with IoT monitoring.
- ✓ Circular economy concepts reuse waste for power.
- ✓ Solar carports provide power while sheltering vehicles.
- ✓ Modular micro-captive plants scale easily with demand.
- ✓ Captive renewable plants improve brand sustainability image.
- ✓ They help industries comply with environmental regulations.
- ✓ Eco-friendly captive plants provide cost savings in long term.
- ✓ Thus, captive power makes industries **sustainable, efficient, and resilient**.

8. Building Requirements

- ✓ Green building requirements ensure sustainability during design, construction, and operation.
- ✓ The site must be chosen with minimal environmental impact.
- ✓ Building orientation should maximize daylight and ventilation.
- ✓ Use of eco-friendly, recyclable, and local materials is essential.
- ✓ Adequate insulation reduces heating and cooling loads.
- ✓ Energy-efficient windows and doors are required.
- ✓ Compliance with Energy Conservation Building Code (ECBC) is mandatory.
- ✓ Rainwater harvesting systems must be included.
- ✓ Greywater recycling systems should be installed.
- ✓ Solar panels or renewable systems must be integrated.
- ✓ Adequate landscaping with native species is required.
- ✓ Green roofs and reflective materials minimize heat island effect.
- ✓ Indoor Air Quality (IAQ) standards must be maintained.
- ✓ Use of low-VOC paints and adhesives is compulsory.
- ✓ Waste management facilities should be provided onsite.
- ✓ Smart metering for water and electricity is required.
- ✓ Efficient HVAC systems must be installed.
- ✓ Buildings must provide thermal and acoustic comfort.
- ✓ Natural lighting and ventilation should be prioritized.

- ✓ Fire safety and emergency systems must be energy-efficient.
- ✓ Universal accessibility must be ensured.
- ✓ Indoor spaces should prevent glare and overheating.
- ✓ Adequate shading devices must be included
- ✓ Use of non-toxic and durable materials is preferred.
- ✓ Energy modeling must be conducted during design phase.
- ✓ Structural integrity must support renewable integration.
- ✓ Occupancy sensors for lights and HVAC must be included.
- ✓ Pervious pavements for stormwater management are required.
- ✓ Smart building management systems should be installed.
- ✓ Construction waste must be segregated and recycled.
- ✓ Adequate parking with EV charging stations should be included.
- ✓ Building should aim for net-zero energy operation.
- ✓ Water-efficient fixtures are compulsory.
- ✓ Efficient elevators and escalators must be installed.
- ✓ Post-construction audits should verify compliance.
- ✓ The building should qualify for IGBC/LEED/GRIHA ratings.
- ✓ Durability and adaptability of the design should be ensured.
- ✓ Life-cycle assessment of materials should be conducted.
- ✓ The requirements ensure people's comfort, safety, and sustainability.
- ✓ Thus, meeting building requirements guarantees a **green, safe, and future-ready environment**.

Green Building Design (with Indian Implementation)

✓ 1. Green Building Design Introduction

- ✓ **Concept:**
  Green building design focuses on creating buildings that reduce environmental impact, use resources efficiently, and ensure the health and comfort of occupants. It considers site planning, energy, water, materials, and indoor environmental quality.
- ✓ **Key Features:** Passive design, energy efficiency, renewable energy use, waste reduction, and integration with nature.
- ✓ **Implementation in India:**
- ✓ The **Indian Green Building Council (IGBC)** promotes rating systems like IGBC Green Homes, IGBC Green Factories, and IGBC Net Zero.
- ✓ **GRIHA (Green Rating for Integrated Habitat Assessment)** is India's national green building rating system developed by TERI and MNRE.
- ✓ Cities like **Hyderabad, Pune, and Bengaluru** have large clusters of IGBC-rated green buildings.
- ✓ Examples: **Infosys Mysuru campus** (energy-efficient design), **CII-Sohrabji Godrej Green Business Centre, Hyderabad** (first IGBC Platinum building in India).
- ✓ The **Energy Conservation Building Code (ECBC)** ensures compliance for large commercial buildings.

2. Reduction in Energy Demand

- ✓ **Concept:**
  The first step in sustainability is lowering energy demand before adding renewable sources. This is done by using passive strategies, efficient appliances, and smart controls.

- ✓ **Techniques:** Orientation for daylighting, insulation, energy-efficient windows, LEDs, HVAC optimization.
- ✓ **Implementation in India:**
- ✓ **ECBC 2017** mandates minimum energy performance for commercial buildings.
- ✓ **LED adoption under UJALA scheme** reduced national energy demand by replacing incandescent bulbs.
- ✓ **Indira Paryavaran Bhavan, New Delhi** reduced energy demand by using natural daylight, efficient HVAC, and solar passive design.
- ✓ Smart meters under **Smart Cities Mission** optimize electricity consumption.
- ✓ Modern airports like **Delhi T3 Terminal** use high-performance glazing to cut cooling load.

3. Onsite Sources and Sinks

- ✓ **Concept:**
  Onsite sources are renewable energy systems within the premises (solar, wind, biomass). Sinks are mechanisms that store or absorb energy/water (thermal storage, groundwater recharge, rain gardens).
- ✓ **Implementation in India:**
- ✓ Rooftop **solar PV systems** are promoted under **Rooftop Solar Programme Phase II** (MNRE).
- ✓ **Infosys Pune campus** uses rooftop solar and biogas plants as onsite sources.
- ✓ **Rainwater harvesting** is mandatory in states like Tamil Nadu, Karnataka, and Delhi to act as onsite water sinks.
- ✓ **GIFT City, Gujarat** uses district cooling and onsite sewage treatment as sinks.
- ✓ **Bengaluru IT Parks** integrate battery storage with solar onsite sources.

4. Maximising System Efficiency

- ✓ **Concept:**
  Efficiency is improved by combining energy-efficient technologies with intelligent building management.
- ✓ **Techniques:** Smart HVAC systems, IoT controls, waste heat recovery, demand-based lighting.
- ✓ **Implementation in India:**
- ✓ **Indira Paryavaran Bhavan, New Delhi** achieved 70% energy savings using chilled beam HVAC systems.
- ✓ **Infosys campuses** use Building Management Systems (BMS) to cut energy by real-time monitoring.
- ✓ **Delhi Metro Rail Corporation (DMRC)** adopted regenerative braking in trains (returns energy to the grid).
- ✓ **SEZ IT campuses in Chennai** use efficient chillers and VFD-based motors to maximize efficiency.
- ✓ Indian companies are adopting **ISO 50001 Energy Management Systems** for efficiency tracking.

5. Steps to Reduce Energy Demand and Use Onsite Sources and Sinks

- ✓ **Concept:**
  The combined approach involves first lowering consumption, then adding renewables, and finally managing surplus energy and water.
- ✓ **Steps:** Passive design → Energy-efficient equipment → Onsite renewables → Storage systems → Smart management.

- ✓ **Implementation in India:**
- ✓ **CII-Sohrabji Godrej GBC Hyderabad**: reduced demand by daylighting, used solar onsite, and stored excess energy in batteries.
- ✓ **IIT Gandhinagar campus**: designed for low energy demand, uses solar PV as onsite source, rainwater harvesting as sink.
- ✓ **Chandigarh Administration** mandated rooftop solar for new government buildings.
- ✓ **Kerala IT Parks** use biogas plants to process food waste onsite.
- ✓ Smart Cities like **Pune and Bhopal** integrate rooftop solar + storage + rainwater recharge.

6. Use of Renewable Energy Sources

- ✓ **Concept:**
  Renewable sources (solar, wind, biomass, small hydro, geothermal) reduce fossil fuel dependency and carbon footprint.
- ✓ **Implementation in India:**
- ✓ **India's solar mission (Jawaharlal Nehru National Solar Mission)** promotes rooftop and ground-mounted solar.
- ✓ **Infosys Bengaluru** and **IIT Bombay** run partially on solar energy.
- ✓ **Suzlon One Earth Campus, Pune** is powered by a combination of wind and solar.
- ✓ **Biomass plants in Punjab and Haryana** convert agricultural waste into power.
- ✓ **Geothermal projects** in Ladakh and Himachal Pradesh are being piloted.
- ✓ **Small hydropower plants** are common in Himalayan states (Uttarakhand, Himachal).
- ✓ Government promotes **net-metering** policies to sell surplus renewable power to the grid.

7. Eco-Friendly Captive Power Generation for Factories

- ✓ **Concept:**
  Captive power is generated by industries for self-use. Eco-friendly captive generation uses renewable or low-carbon technologies instead of coal/diesel.
- ✓ **Implementation in India:**
- ✓ **Textile mills in Tamil Nadu** use wind captive power extensively.
- ✓ **Biomass captive plants** in sugar industries use bagasse (sugarcane waste).
- ✓ **Solar captive plants** in Gujarat serve pharmaceutical and chemical industries.
- ✓ **Co-generation units in steel and cement plants** reuse waste heat for power.
- ✓ **Reliance Jamnagar refinery** uses cogeneration to improve efficiency.
- ✓ **Amul Dairy, Anand** uses biogas from cattle waste as captive power.
- ✓ The **Perform Achieve and Trade (PAT) Scheme** under the Bureau of Energy Efficiency (BEE) encourages industries to adopt captive green power.

8. Building Requirements

- ✓ **Concept:**
  Green building requirements ensure sustainability in site selection, design, materials, energy, water, waste, and indoor environment.
- ✓ **Key Requirements:**
  Site selection with minimal ecological impact, passive design, water efficiency, renewable integration, waste management, low-VOC materials, compliance with ECBC, and IGBC/GRIHA rating systems
- ✓ **Implementation in India:**
- ✓ **Mandatory rainwater harvesting** in states like Tamil Nadu, Kerala, and Rajasthan.
- ✓ **Bureau of Indian Standards (BIS) and ECBC** regulate energy efficiency requirements.
- ✓ **LEED & IGBC certifications** for IT parks in Hyderabad, Bengaluru, and Pune.
- ✓ **Delhi Metro Bhawan, NBCC New Delhi** are GRIHA-rated government projects.
- ✓ **Kerala Government Secretariat building** retrofitted for energy efficiency.
- ✓ IGBC-certified **residential complexes in Mumbai and Chennai** promote water recycling and renewable integration.
- ✓ Smart Cities projects demand compliance with sustainability norms.

UNIT-IV

Air Conditioning Introduction, CII Godrej Green Business Centre, Design Philosophy, Design Interventions, Energy Modeling, HVAC System Design, Chuller Selection, Pump Selection, Selection of Cooling towers, Selection of Air Handling Units, Pre-Cooling of Fresh Air, Interior Lighting Systems, Key Features of The Building, Eco-Friendly Captive Power Generation for Factories, Building Requirements.

UNIT-V

Material Conservation Handling of Non-Process Waste, Waste Reduction During Construction, Materials With Recycled Content, Local Materials, Material Reuse, Certified Wood, Rapidly Renewable Building Materials and Furniture, Indoor Environment Quality and Occupational Health Air Conditioning, Indoor Air Quality, Sick Building Syndrome, tobacco Smoke

UNIT – IV: AIR CONDITIONING AND GREEN BUILDING ENERGY DESIGN

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1. Air Conditioning – Introduction

Definition:

Air Conditioning = process of controlling temperature, humidity, purity, and distribution of air to achieve comfort.

Used in **buildings, industries, hospitals, and laboratories**.

Objectives:

Maintain **comfort conditions** (Temperature ≈ 22–25°C, RH = 50–60%).

Ensure **indoor air quality**.

Provide **ventilation** and **remove contaminants**.

Main Elements:

Temperature control

Humidity control

Air circulation

Air filtration

Pressure maintenance

Classification:

Based on purpose:

Comfort A/C → offices, theatres.

Industrial A/C → data centers, clean rooms.

Based on season:

Summer A/C

Winter A/C

Year-round A/C

Components:

Compressor

Condenser

Expansion valve

Evaporator

Air Handling Unit (AHU)

Ducts & diffusers

FLOWCHART:

```
Air → Filter → Cooling Coil → Dehumidifier → Supply Duct → Room
                                   ↑
                          Return Duct ← Exhaust
```

Example:
CII Godrej Green Business Centre maintains indoor air comfort using **VAV (Variable Air Volume) systems** and **treated fresh air units** to optimize energy use.

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2. CII Godrej Green Business Centre (CII-GBC), Hyderabad

Introduction:

India's first **LEED Platinum-rated green building** (2003).

Located in Hyderabad, designed by **Karan Grover & Associates**.

Design Highlights:

80% daylight utilization.

55% energy savings compared to conventional buildings.

35% reduction in water consumption.

Key Features:

Passive cooling techniques (north-lighting, wind towers).

Solar photovoltaic panels for power.

Use of fly-ash-based concrete.

Zero discharge water system.

FLOWCHART – Green Concept Integration:

```
Site Planning → Energy Efficiency → Water Conservation → Material Optimization →
Indoor Quality
```

Example:

Uses **Earth Air Tunnel (EAT)** for natural pre-cooling of fresh air.

Efficient HVAC and lighting controlled through **BMS (Building Management System**

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3. Design Philosophy

Meaning:

Fundamental thinking approach used in planning energy-efficient buildings.

Core Principles:

Orientation – Maximize north light, minimize west heat.

Envelope Design – Proper insulation & glazing.

Material Selection – Locally available and recyclable.

Integration of Active & Passive Systems.

Steps in Design Process:

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Climate Study → Zoning of Spaces → Material Selection → HVAC Planning → Lighting
Layout → Renewable Integration
```

Example:
CII-GBC used orientation to reduce solar heat gain and maximize daylight through skylights.

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4. Design Interventions

Definition:
Specific **technological or architectural measures** adopted to improve building performance.

Examples of Interventions:

- Double-glazed windows.
- Shading devices (louvers, fins).
- Rainwater harvesting.
- Green roofs and solar panels.

FLOWCHART – Intervention Process:

Identify Problem → Analyze Building Energy Use → Apply Solutions → Monitor & Improve

Example:
In Infosys Mysore campus, **chilled beam system** reduces A/C load by 30%.

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5. Energy Modelling

Definition:
Simulation process to estimate building's **energy performance** before construction.

Purpose:

- Optimize HVAC and lighting systems.
- Predict energy consumption.
- Support **LEED/GRIHA certification**.

Software Used:

- eQUEST
- EnergyPlus
- DesignBuilder

FLOWCHART:

Input Building Data → Simulate Thermal Loads → Analyze HVAC → Optimize Design → Report Savings

Example:
CII-GBC used eQUEST to model various façade orientations and selected the best performing one.

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6. HVAC System Design

Full Form: Heating, Ventilation, and Air Conditioning.

Design Objectives:

- Maintain comfort.
- Reduce energy cost.
- Improve indoor air quality.

Design Steps:

Load Estimation → Equipment Selection → Duct Design → Controls Integration → Commissioning

Energy-efficient HVAC Tips:

- Use **VFDs (Variable Frequency Drives)** on pumps & fans.
- Zonal control with sensors.
- Thermal insulation of ducts.

Example:
ITC Green Centre uses **chilled water-based HVAC** with heat recovery wheels.

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7. Chiller Selection

Definition:
Chillers remove heat from liquid using vapor-compression or absorption cycles.

Types:

- **Air-cooled** → simple, for smaller loads.
- **Water-cooled** → higher efficiency, used in large buildings.
- **Absorption chillers** → use waste heat or steam.

Selection Criteria:

- Capacity (TR – Tons of Refrigeration)
- Energy Efficiency Ratio (EER)
- Cooling load variations
- Part-load performance

Example:
CII-GBC uses **water-cooled screw chillers** with COP > 5.5.

FLOWCHART – Chiller Working:

```
Compressor → Condenser → Expansion Valve → Evaporator → Chilled Water → Cooling Coil
```

---

8. Pump Selection

Purpose:
Circulates chilled water or condenser water in HVAC systems.

Selection Criteria:

- Flow rate (m^3/hr)
- Head (m)
- Efficiency (%)
- Power (kW)

Types:

- Centrifugal pumps
- Vertical inline pumps
- End-suction pumps

Energy-Saving Measures:

- Use of VFDs
- Proper pipe sizing

- Pump scheduling in BMS

Example:
Infosys Hyderabad uses **variable-speed drives** on condenser pumps.

---

9. Selection of Cooling Towers

Purpose:
Rejects waste heat from condenser water to atmosphere.

Types:

- Induced draft
- Forced draft
- Crossflow / Counterflow

Selection Parameters:

- Cooling range
- Approach temperature
- Water flow rat
- Fan power

Example:
CII-GBC cooling tower designed for **5°C approach** for energy saving.

FLOWCHART – Cooling Tower Process:

```
Hot Water from Condenser → Spray Nozzles → Fill Media → Air Flow → Evaporation → Cool Water Return
```

---

10. Selection of Air Handling Units (AHUs)

Function:
Condition and distribute air through ductwork.

Components:

Mixing chamber

Filters

Cooling coil

Blower

Supply & return ducts

Selection Points:

Air flow rate (CFM)

Static pressure

Coil face area

Noise level

Example:
Treated Fresh Air (TFA) units in CII-GBC provide 100% fresh air with heat recovery.

---

11. Pre-Cooling of Fresh Air

Purpose:
Reduces cooling load by **using ambient or exhaust air** to pre-cool incoming fresh air.

Methods:

Earth Air Tunnel (EAT)

Heat Recovery Wheel (HRW)

Evaporative cooling

FLOWCHART:

```
Hot Fresh Air → Pass through Earth Tunnel → Temperature Drops → Sent to AHU → Final Cooling
```

Example:
CII-GBC uses **Earth Air Tunnel** to pre-cool air by 8–10°C naturally.

---

12. Interior Lighting Systems

Design Goals:

- Maximize natural daylight.
- Minimize artificial lighting load.
- Use sensors & LED technology.

Design Strategies:

- Daylight sensors (auto dimming)
- Task lighting
- Reflective ceiling paints

Example:
CII-GBC achieves **80% daylight autonomy** using skylights & light shelves.

---

13. Key Features of the Building

Features:

- Renewable energy integration
- Zero water discharge
- High-performance façade
- BMS automation
- Recycled building materials

FLOWCHART:

Efficient Envelope → Smart HVAC → LED Lighting → Water Reuse → Renewable Energy

---

⚡ 14. Eco-Friendly Captive Power Generation for Factories

Definition:
On-site generation of electricity using renewable or waste heat sources.

Sources:

Solar PV panels

Biomass gasifiers

Waste heat recovery units

Advantages:

Reduced transmission loss

Energy independence

Lower carbon footprint

Example:
CII-GBC uses **solar PV (75 kWp)** system to meet 20% energy demand.

---

15. Building Requirements (Green Standards)

Key Requirements:

Orientation & passive design

Efficient HVAC & lighting

Waste management plan

Renewable energy use

Indoor air quality standards

Example:
LEED Platinum Building requires:

30–50% energy savings

40% water efficiency

Use of eco-materials

1. Air Conditioning – Introduction

- ✓ Air conditioning (AC) refers to the process of controlling the temperature, humidity, air purity, and air movement inside a building to ensure comfort and healthy indoor air quality.In green building design, air conditioning aims to minimize energy consumption while maintaining comfort.Traditional systems rely heavily on electricity, but sustainable AC integrates renewable energy and passive cooling strategies.

- ✓ Key functions include cooling, dehumidification, and air circulation.
Modern green systems emphasize variable refrigerant flow (VRF), chilled beams, and geothermal cooling.Designers follow ASHRAE Standard 55 for comfort and ASHRAE 62.1 for ventilation.In tropical climates like India, optimizing cooling load through insulation, shading, and reflective surfaces is crucial.

- ✓ System selection depends on building type—residential, commercial, or industrial.Smart thermostats and **IoT-based controls** enable energy-efficient operation.Thermal energy storage systems (e.g., ice storage) shift cooling load to off-peak hours.AC efficiency is measured using **EER (Energy Efficiency Ratio)** or **COP (Coefficient of Performance).**For green buildings, integrating **natural ventilation** and **passive design** reduces dependency on mechanical cooling.Hybrid systems combine evaporativecooling and mechanical refrigeration.The focus is not just cooling but **indoor air quality (IAQ)**improvement.Maintaining **relative humidity between 40–60%** is ideal for comfort and health.Filters (HEPA, activated carbon) ensure clean air free from dust and pollutants.AC systems are integrated with **Building Management Systems (BMS)** for automated control.The challenge lies in balancing energy savings with human comfort.Sustainable AC design minimizes refrigerant emissions by adopting **eco-friendly gases** like R-32 or R-290 instead of CFCs/HCFCs.Regular maintenance ensures longevity and performance consistency.Thus, air conditioning in green buildings evolves from energy-intensive comfort systems to **smart, low-carbon cooling technologies**.

---

2. CII Godrej Green Business Centre

The CII-Sohrabji Godrej Green Business Centre (GBC) in Hyderabad is India's first LEED Platinum-rated green building, established by the Confederation of Indian Industry (CII).It serves as a demonstration and resource center promoting energy efficiency, water conservation, and renewable energy.Commissioned in 2004, the building showcases sustainable design and construction practices.The total area is about 20,000 square feet, functioning as both an office and training center.It is located in a hot semi-arid climate, making passive cooling strategies essential.The architectural orientation minimizes solar heat gain while maximizing daylight.More than 80% of occupied spaces receive natural daylight.Solar photovoltaic panels generate a portion of the building's electricity needs.Rainwater harvesting and wastewater recycling achieve zero water discharge.The HVAC system uses energy-efficient chillers and variable air volume (VAV) systems.Building materials are locally sourced and include fly ash-based concrete and recycled steel.Reflective paints and green roofs reduce the heat island effect.Indoor air quality is maintained through CO_2 sensors and low-VOC materials.The building achieves a 50% reduction in energy use compared to conventional offices.Lighting systems use daylight sensors and occupancy controls.The landscape uses native drought-resistant plants.
The GBC symbolizes India's leadership in sustainable construction.It acts as a knowledge hub for IGBC (Indian Green Building Council) certification.It demonstrates how economic and environmental goals can coexist.Overall, CII-GBC stands as an iconic model inspiring energy-efficient design across Indian industries and institutions.

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3. Design Philosophy

Design philosophy in green building aims at harmony between built and natural environments.It prioritizes reducing environmental footprint through energy efficiency, water conservation, and material optimization.Architectural form, orientation, and envelope design are fundamental.The philosophy begins with passive design principles—shade, ventilation, and thermal mass usage.It focuses on life-cycle cost instead of initial cost.Design integrates architecture, mechanical, electrical, and plumbing (MEP) systems synergistically.User comfort, productivity, and health are considered equally with aesthetics.
Site planning ensures minimum disturbance to natural ecosystems.Designers prefer north–south orientation to control solar exposure.Envelope design includes insulation, double glazing, and air sealing.Energy modeling supports optimization of HVAC and lighting loads.Building materials are selected for recyclability, low embodied energy, and local availability.Indoor environmental quality guides decisions on finishes and ventilation.Renewable energy integration (solar, wind, geothermal) forms part of the strategy.The goal is net-zero energy and carbon neutrality.Designs follow ECBC (Energy Conservation Building Code)

and IGBC norms.Flexibility and adaptability for future retrofits are ensured.Waste management is considered during design itself. Simplicity in design reduces operational complexity and cost.In summary, the design philosophy promotes sustainability, efficiency, and resilience through integrated thinking and technology.

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4. Design Interventions

Design interventions are specific strategies to achieve sustainability targets.They include architectural, mechanical, and operational improvements.Examples include solar shading devices, daylight shelves, green roofs, and natural ventilation shafts.
High-performance glazing minimizes heat ingress while maximizing daylight.Use of light-colored roofing materials reduces heat absorption.Courtyards and atriums enhance cross ventilation.Green walls and vertical gardens reduce urban heat island effects.
Implementation of energy recovery ventilators (ERVs) conserves conditioned air energy.Sensors and automation ensure smart energy management.Use of demand-controlled ventilation based on occupancy optimizes air flow.Rainwater harvesting and greywater reuse are key water interventions.Material interventions include fly ash concrete, bamboo flooring, and recycled aggregates.Solar panels integrated into façades (BIPV) supply clean electricity.Thermal insulation in walls and roofs improves building performance.Efficient lighting design uses LEDs and motion sensors.Acoustic design enhances occupant well-being.
Zoning in HVAC allows localized comfort control.Low-flow fixtures and efficient plumbing save water.Waste segregation points are designed at the source.Thus, design interventions translate green philosophy into measurable and visible outcomes.

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5. Energy Modelling

Energy modeling simulates building energy consumption to predict performance.It helps compare design alternatives before construction.Software like eQUEST, EnergyPlus, IES-VE, and DesignBuilder are commonly used.Inputs include geometry, orientation, envelope properties, and system efficiencies.Energy models estimate cooling/heating loads, lighting demand, and plug loads.They support code compliance under ECBC or LEED energy credits.Simulation enables optimization of chiller capacities and air distribution.Solar gain analysis helps refine window-to-wall ratios.Models predict annual energy consumption (kWh/m^2/year) for benchmarking.It identifies energy-saving potential and payback periods.Scenarios for occupancy schedules and climate conditions are analyzed.Lighting control strategies and daylight dimming are tested.HVAC zoning efficiency is verified through models.Renewable energy generation potential (PV/wind) is simulated.Results guide system sizing and cost estimation.Post-occupancy data can calibrate models for accuracy.Energy models ensure that design intent equals operational performance.They also support obtaining green building certification points.Thus, energy modeling is a crucial design decision tool for net-zero and high-performance buildings.

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6. HVAC System Design

HVAC stands for Heating, Ventilation, and Air Conditioning.System design ensures thermal comfort and indoor air quality.
Key components include chillers, air handling units, ducts, diffusers, and control systems.System selection depends on load, space, climate, and budget.Centralized HVAC systems are used for large buildings; split or VRF systems for smaller ones.
Proper load estimation avoids oversizing, saving capital and energy.Duct layout minimizes pressure drops and noise.
Chilled water and condenser water loops are optimized for flow efficiency.Variable frequency drives (VFDs) control pump and fan speeds.Zoning allows independent control of different building areas.Filtration systems maintain clean air circulation.
Heat recovery units reclaim exhaust energy.Controls include thermostats, CO_2 sensors, and BMS integration.The system must adhere to ASHRAE 90.1 energy standards.Pipe insulation prevents thermal losses.Commissioning ensures correct operation and balancing.Maintenance schedules are critical for sustained performance.In green buildings, HVAC consumes ~40–50% of total energy—optimization is vital.Efficient design leads to low operational costs and superior comfort.

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7. Chiller Selection

Chillers produce chilled water for air conditioning.Selection depends on cooling load, efficiency, refrigerant type, and cost.
Two main types: air-cooled and water-cooled chillers.Water-cooled are more efficient but need cooling towers.
Efficiency is expressed as kW/TR (kilowatt per ton of refrigeration).Lower kW/TR values mean better efficiency.Centrifugal, screw, and scroll chillers are common types.Part-load efficiency is critical as chillers rarely run at full load.Variable-speed drives (VSDs) enhance part-load performance.Selection must consider ambient temperature and humidity.Refrigerants should be eco-friendly with low GWP (global warming potential).Maintenance accessibility and redundancy are considered.System integration with thermal storage can reduce peak demand.Chiller plants may include multiple units for flexibility.Energy modeling helps size chillers accurately.Proper control sequencing prevents short cycling.Water treatment is vital to prevent scaling and corrosion.Chillers should comply with BEE Star Rating or AHRI standards.Thus, correct selection ensures reliability and significant energy savings.

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8. Pump Selection

Pumps circulate water in HVAC, plumbing, and fire systems.Efficiency directly impacts overall building energy consumption Selection considers flow rate, head, fluid type, and operating hours.Common pump types include centrifugal, vertical inline, and split-case pumps.Pumps must be selected at the best efficiency point (BEP).Oversized pumps waste energy; undersized pumps reduce performance.Variable speed drives adjust flow to demand, saving power.Pump materials must resist corrosion and scaling.NPSH (Net Positive Suction Head) is checked to avoid cavitation.Seal-less magnetic drive pumps are used for eco-safety.Piping layout affects pump performance; short, straight runs are preferred.System resistance curves help select optimal operating points.Multiple smaller pumps with staging improve flexibility.Pump control integrates with BMS for energy monitoring.Regular alignment and balancing maintain efficiency.Leakage and vibration monitoring prevent failure.Pump efficiency typically ranges 70–85%; aim for top tier.Selection ensures reliability, low maintenance, and reduced life-cycle cost.

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9. Selection of Cooling Towers

Cooling towers reject heat from water-cooled chillers.They transfer waste heat from condenser water to the atmosphere.Two main types: induced draft and forced draft.Water conservation and drift loss minimization are vital.Material of construction—FRP, concrete, or galvanized steel—depends on application.Tower capacity depends on chiller tonnage and heat rejection rate.High efficiency fans reduce power consumption.Use of variable speed fans matches cooling demand.Proper fill media improves air–water contact efficiency.Drift eliminators reduce water loss.Make-up water systems compensate for evaporation losses.Legionella control ensures health safety.Blowdown cycles control water concentration of dissolved solids.Automation optimizes fan and pump operation.Location selection ensures proper air circulation.Noise and plume control are design considerations.Regular cleaning prevents biological growth.Cooling towers significantly affect chiller efficiency.Sustainable design includes hybrid or dry cooling towers to save water.

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10. Selection of Air Handling Units (AHU)

AHUs condition and distribute air in HVAC systems.Components include filters, coils, fans, dampers, and controls.
Selection depends on airflow rate (CFM) and cooling/heating load.Modular AHUs allow flexibility for maintenance.Casing should be double-skinned with thermal insulation.Filters of multiple stages (pre-filter, fine filter, HEPA) maintain IAQ.Coil design ensures efficient heat transfer.Fans must be energy-efficient with backward-curved impellers.Variable air volume (VAV) systems reduce part-load energy use.Dampers control air distribution zones.AHUs integrate with heat recovery systems.Condensate drains must be properly trapped.Noise and vibration isolation enhance comfort.AHUs may include humidifiers or dehumidifiers as required.Integration with BMS provides operational control.Casing leakage class should comply with Eurovent standards.Access panels allow easy maintenance.Selection considers installation space and service clearances.Proper design ensures balanced comfort, IAQ, and energy performance.

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11. Pre-Cooling of Fresh Air

Pre-cooling treats hot outdoor air before entering HVAC systems.It reduces load on main cooling coils and saves energy. Methods include heat recovery wheels, evaporative pre-coolers, or DX coils.Energy recovery ventilators (ERVs) use exhaust air to pre-cool incoming air.In hot climates, this improves chiller performance.Indirect evaporative cooling adds efficiency without increasing humidity.Pre-cooled air improves indoor comfort faster.System design includes controls for bypass during mild weather.This approach enhances IAQ without excessive energy use.Combining with economizer cycles optimizes system operation.It supports ECBC and IGBC energy performance credits.Regular maintenance of coils and filters ensures consistent results.Overall, pre-cooling is an effective passive–mechanical hybrid strategy for tropical regions like India.

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12. Interior Lighting Systems

Lighting contributes significantly to building energy load.Efficient design balances natural and artificial light.Use of LEDs reduces power and heat generation.Daylight sensors and motion detectors avoid wastage.Zonal control and dimming systems enhance flexibility.Reflective interior surfaces distribute light uniformly.Luminous efficacy (lumens/watt) measures efficiency.Lighting design complies with NBC Part 8 and ECBC standards.Color temperature (CCT) affects occupant mood and productivity.Task lighting reduces need for high general lighting levels.Glare control improves visual comfort.Integration with BMS allows energy monitoring.Emergency lighting ensures safety during power failures.Daylight harvesting systems adjust artificial lighting automatically.Maintenance of fixtures ensures sustained illumination.Sustainable interiors use fixtures made from recycled materials.Lighting contributes to LEED and IGBC credits for energy performance and visual comfort.

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13. Key Features of the Building

Green buildings integrate architecture and technology for sustainability.Key features include passive design, efficient HVAC, water management, renewable energy, and material optimization.Orientation and shading minimize solar gain.Natural ventilation and daylight reduce mechanical load.Water efficiency through rainwater harvesting and reuse.Waste segregation and recycling systems are built-in.Smart meters monitor electricity and water usage.Use of low-VOC paints and adhesives ensures healthy air.Materials with high recycled content reduce embodied energy.Solar panels and wind turbines supplement power needs.Landscaping with native plants reduces irrigation.High-performance glass improves thermal comfort.Vertical gardens enhance aesthetics and air quality.Flexible spaces accommodate multiple uses over time.Automation and BMS improve control and efficiency.Each design feature contributes to overall resource conservation and occupant well-being.

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14. Eco-Friendly Captive Power Generation for Factories

Captive power means on-site electricity generation for factory use.Eco-friendly systems use renewable or low-emission technologies.Solar photovoltaic (PV), biomass gasifiers, and small wind turbines are common.Combined heat and power (CHP) systems increase overall efficiency.Waste heat recovery units utilize exhaust energy.Bio-diesel and natural gas generators reduce carbon footprint.Cogeneration simultaneously produces electricity and steam.Systems reduce dependency on grid electricity.Excess power can sometimes be fed to the grid.Factory rooftops and open areas are ideal for solar arrays.Energy storage (battery banks) ensures reliability.Monitoring through SCADA or BMS optimizes operation.Compliance with environmental regulations (CEA & MoEFCC) is mandatory.Such systems reduce operating cost and emissions, supporting sustainable industrial operations.

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15. Building Requirements

Green building requirements align with IGBC, LEED, and GRIHA guidelines.They include site planning, energy efficiency, water conservation, and indoor environmental quality.Envelope insulation and air sealing minimize energy loss.Water-saving fixtures reduce potable water use.Rainwater harvesting systems must be included.Energy-efficient lighting and HVAC are mandatory. Renewable energy integration is encouraged.Use of local and recycled materials is prioritized.Proper waste segregation and disposal systems are necessary.Accessibility for maintenance and operation is required.Buildings must comply with ECBC and NBC standards.Post-occupancy evaluation ensures performance meets intent.Documentation and commissioning are vital for certification.The overall goal is a safe, healthy, resource-efficient, and durable building.

UNIT－V: MATERIAL CONSERVATION AND INDOOR ENVIRONMENTAL QUALITY

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1. Material Conservation – Introduction

Definition:
Material conservation means minimizing the use of virgin construction materials by reusing, recycling, or sourcing locally available sustainable materials.

Objective:

Reduce embodied energy in materials.

Promote reuse and recycled content.

Reduce waste to landfill.

Approach:

Use local materials (within 400–800 km).

Choose materials with **recycled content** (fly ash, slag cement)

Reuse salvaged components (doors, windows).

Use renewable and certified materials.

FLOWCHART:

Material Selection → Source Evaluation → Energy Impact Assessment → Use → Reuse / Recycle → Disposal

Example:
CII-GBC used **fly-ash bricks** and **recycled steel**, reducing embodied energy by 25%.

---

2. Handling of Non-Process Waste

Definition:
Non-process waste includes materials like paper, packaging, plastics, and e-waste generated during building operation.

Objectives:

- Segregation at source.
- Recycling and reuse.
- Safe disposal.

Steps for Management:

Identify Waste → Segregate → Reuse / Recycle → Dispose in Eco-friendly Manner

Example:
Infosys campuses use **three-bin system**:

- Green – biodegradable,
- Blue – recyclables,
- Red – non-recyclable.

Best Practices:

- Paper recycling units.
- Composting of biodegradable waste.
- E-waste tie-ups with authorized recyclers.

---

3. Waste Reduction During Construction

Purpose:
Minimize material wastage and debris generation on-site.

Methods:

- Accurate estimation (BIM-based).
- Pre-cutting of steel/rebar.

Modular design.

Segregation and reuse of debris.

FLOWCHART:

Design Stage Planning → Material Storage Control → On-site Waste Segregation → Reuse or Recycling → Documentation

Example:
ITC Green Centre reduced construction waste by **60%** using modular partitions and reusable shuttering.

---

4. Materials with Recycled Content

Definition:
Materials that contain **reused or reprocessed industrial waste**.

Common Examples:

Fly ash → in cement.

GGBS (Ground Granulated Blast Furnace Slag).

Recycled steel, aluminum.

Plastic composites.

Benefits:

Reduces environmental impact.

Conserves raw resources.

Improves sustainability ratings (LEED/GRIHA credits).

Example:
CII-GBC used **30% fly ash in concrete** and **recycled aggregate** in flooring sub-base.

---

5. Local Materials

Definition:
Materials manufactured and sourced within **400–800 km radius** of the building site.

Advantages:

Reduces transportation energy

Promotes local economy.

Minimizes carbon footprint.

FLOWCHART:

Material Demand → Identify Local Suppliers → Evaluate Sustainability → Procure → Install

Example:
Use of **local granite flooring** and **Andhra clay tiles** in CII-GBC.

---

6. Material Reuse

Definition:
Reusing recovered or salvaged materials to avoid new production.

Types of Reuse:

Structural reuse → steel members.

Architectural reuse → doors, tiles, frames.

Furniture reuse → partitions, cabinets.

FLOWCHART:

Salvage Assessment → Material Cleaning → Testing → Integration into New Project

Example:
Infosys Pune reused **demolished building bricks** for compound wall construction.

---

7. Certified Wood

Definition:
Wood certified by recognized agencies (FSC, PEFC) ensuring it comes from responsibly managed forests.

Benefits:

Prevents deforestation.

Encourages sustainable forestry.

Provides LEED points.

FLOWCHART:

Forest → Sustainable Harvest → Certification → Supplier → Construction Use

Example:
ITC Green Centre used **FSC-certified teak wood** for interiors.

---

8. Rapidly Renewable Building Materials and Furniture

Definition:
Materials that can regenerate within **10 years or less**.

Examples:

Bamboo → flooring, furniture.

Cork → insulation, boards.

Linoleum → eco-flooring.

Jute → composites, panels.

Advantages:

Reduces dependency on non-renewable resources.

Biodegradable and eco-friendly

FLOWCHART:

Harvesting → Processing → Product Fabrication → Installation → Natural Renewal Cycle

Example:
CII-GBC used **bamboo blinds** and **jute boards** in interiors.

---

9. Indoor Environmental Quality (IEQ)

Definition:
Quality of indoor air and overall comfort experienced by occupants.

Major Components:

Thermal comfort

Air quality

Lighting quality

Acoustic comfort

Visual comfort

FLOWCHART:

Source Control → Ventilation → Air Filtration → Monitoring → Occupant Comfort

Example:
CII-GBC ensures CO_2 concentration < 600 ppm using **demand-controlled ventilation**.

👷 10. Occupational Health

Meaning:
Ensuring safe, healthy conditions for building occupants and workers.

Aspects:

Ergonomically designed furniture.

Non-toxic materials.

Proper ventilation and lighting.

Noise level control.

Example:
Infosys Mysore campus provides **indoor air monitoring** and **noise level sensors** for employee comfort.

Benefits:

Higher productivity.

Fewer sick leaves.

Better indoor satisfaction.

---

11. Air Conditioning (Linked to IEQ)

Objective:
Maintain optimal indoor thermal comfort with minimal energy use.

Comfort Parameters:

Temperature: 22–25°C

Relative Humidity: 50–60%

Air movement: 0.15–0.25 m/s

Control Measures:

Zonal thermostats

Smart sensors

Fresh air pre-treatment

Example:
CII-GBC uses **VAV systems** to maintain comfort with less power.

---

12. Indoor Air Quality (IAQ)

Definition:
Condition of indoor air concerning pollutants, humidity, and ventilation.

Sources of Pollution:

Paints, adhesives (VOCs)

Dust, pollen

Smoking areas

Chemical cleaners

Improvement Techniques:

Low-VOC Materials → Ventilation System → Air Filtration → Plant-based Air Purification

Example:
Infosys Chennai uses **low-VOC paints** and **activated carbon filters** in AHUs.

---

13. Sick Building Syndrome (SBS)

Definition:
Condition where occupants experience health discomforts linked to indoor air quality.

Symptoms:

- Headache
- Eye irritation
- Fatigue
- Respiratory problems

Causes:

- Poor ventilation
- VOCs
- Biological contaminants

FLOWCHART – SBS Prevention:

Identify Source → Improve Ventilation → Monitor Air Quality → Use Low-Emission Materials

Example:
Offices using **HEPA filters** and **regular IAQ audits** show reduced SBS cases.

---

14. Tobacco Smoke Control

Objective:
To protect non-smokers from exposure to environmental tobacco smoke (ETS).

Measures:

Designated smoking areas outside building envelope.

Separate ventilation for smoking zones.

Proper signage and air sealing.

FLOWCHART:

Identify Smoking Zone → Isolate with Barriers → Independent Exhaust → Filter → Release Outside

Example:
CII-GBC prohibits indoor smoking and maintains outdoor zones away from fresh air intakes.

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15. Integration of All Green Material Strategies

Holistic Approach:

Waste Reduction → Reuse → Recycled Content → Local Material → Renewable Resource → Healthy Indoor Air

Final Objective:

Sustainable construction

Minimal environmental impact

Enhanced occupant health

Example:
All IGBC/GRIHA certified buildings follow this material integration hierarchy for green performance.

1. Material Conservation

Material conservation in green building design means minimizing the consumption of non-renewable materials and using resources efficiently.It emphasizes the concept of “reduce, reuse, recycle.”The aim is to lower embodied energy, environmental impact, and waste generation.Designers focus on materials with low environmental footprint and long life cycles.Local sourcing reduces transport emissions and supports regional economies.Structural design optimization reduces material usage without compromising safety.Prefabricated and modular construction techniques minimize onsite waste.Recycled aggregates, fly ash cement, and GGBS concrete reduce virgin material demand.The selection of high-durability finishes extends maintenance cycles. Life Cycle Assessment (LCA) tools help compare environmental impacts.The use of renewable materials like bamboo, cork, and coir boards is promoted.Material efficiency is linked with cost-effectiveness and energy savings.Construction wastemanagement plans ensure segregation and reuse.Building Information Modelling (BIM) aids material quantity optimization.Specifyingstandard modular sizes minimizes cutting and wastage.Material passports record data for reuse in future projects.Designers must comply with IGBC credit points for “Material and Resources.”The goal is to build more with fewer resources, achieving sustainability through smart choices.Material conservation ensures environmental protection, economic efficiency, and structural sustainability throughout the building's lifecycle.

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2. Handling of Non-Process Waste

Non-process waste refers to materials not directly involved in production but generated from construction and operation. Examples include packaging materials, paper, plastics, metals, glass, and organic waste.Efficient waste management minimizes landfill disposal.Waste handling starts with segregation at source—biodegradable, recyclable, and hazardous.Color-coded bins ensure easy sorting and recycling.Recyclables like steel and aluminum can be sold to authorized recyclers.Organic waste is composted to produce manure for landscaping.Hazardous waste (paints, batteries) is disposed of per CPCB guidelines.Waste collection areas should be well-ventilated and accessible.Factories and large buildings must have Material Recovery Facilities (MRFs).Waste reduction also includes minimizing paper use through digitization.Construction waste is reused as backfill or road sub-base.Contractors should maintain waste generation logs for audit.Waste tracking ensures accountability in material management.Non-process waste management is a criterion under IGBC "Solid Waste Management."Educational signage and employee training increase awareness.Waste-to-energy conversion adds value in industrial campuses.The aim is to move toward zero-waste building operations.Proper waste handling protects environment, health, and aligns with Swachh Bharat Mission.

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3. Waste Reduction During Construction

Construction activities generate large amounts of waste like concrete debris, wood scraps, packaging, and soil.Effective reduction starts with planning and material estimation accuracy.BIM tools and quantity take-offs minimize overordering.Standardization of building components avoids cutting waste.Off-site prefabrication ensures controlled production and less onsite loss.Reusing formwork materials multiple times saves wood and metal.Use of modular design reduces errors and waste.Segregating metal, concrete, and wood waste simplifies recycling.Excavated soil can be reused for landscaping or leveling.Leftover concrete is crushed and reused as coarse aggregate.Contractors are encouraged to adopt lean construction practices.Procurement policies should prioritize bulk packaging to reduce waste.Waste audits quantify efficiency and identify problem areas.Rain protection for stored materials prevents spoilage.Use of durable tools and machinery avoids replacement waste.Waste reduction saves cost and minimizes environmental impact.Documenting all waste management actions supports certification credits.Goal: Achieve at least 75% construction waste diversion from landfill.Thus, sustainable construction integrates both efficiency and responsibility.

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4. Materials with Recycled Content

Recycled content refers to materials containing pre-consumer or post-consumer recycled matter.Using them reduces extraction of virgin resources.Examples include recycled steel, aluminum, glass, fly ash concrete, and plastic composites.Fly ash and slag replace portions of cement in concrete to reduce CO_2 emissions.Recycled steel maintains strength equal to virgin steel with less embodied energy.Carpet tiles made from PET bottles exemplify innovative reuse.Gypsum boards often contain recycled paper facings.Aluminum panels with high recycled content are durable and lightweight.Manufacturers must declare recycled content percentages in product data.LEED and IGBC offer points based on total recycled material value.Recycled materials support circular economy and resource recovery.However, quality control is essential to ensure performance consistency.Material safety data sheets (MSDS) confirm non-toxicity.Local sourcing of recycled materials reduces transportation emissions.Examples from India include

ACC Fly Ash Blocks and **JSW GGBS Cement.**Recycled content materials symbolize innovation and environmental stewardship.They contribute significantly to green building certification points.

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5. Local Materials

Local materials are sourced within a defined radius (typically 400–800 km from site).This reduces fuel consumption and supports local economies.It also lowers embodied energy from transport.Common local materials include clay bricks, laterite stone, granite, bamboo, and lime.Locally manufactured cement, steel, and glass are preferable to imports.Sourcing policies align with **IGBC "Regional Materials" credits.**Local artisans and industries benefit from sustainable procurement.It promotes cultural continuity and vernacular architecture.Availability ensures timely delivery and reduced costs.Quality standards must match national codes (IS/ASTM).Using local materials also ensures easy maintenance and replacements.In rural or semi-urban projects, local resources can drastically cut costs.Local materials often have thermal properties suited to climate.Example: mud blocks in hot regions, stone masonry in cold climates.It integrates sustainability, economics, and heritage in one practice.

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6. Material Reuse

Material reuse involves salvaging materials from existing buildings or previous projects.It reduces waste and conserves energy needed for new production.Commonly reused items: doors, windows, steel frames, flooring, and bricks.Reclaimed wood is often repurposed for furniture or interiors.Structural steel sections can be reused after inspection.Old concrete can be crushed into recycled aggregates.Reuse reduces demolition waste and landfill pressure.Deconstruction, not demolition, facilitates efficient recovery.Reusing materials preserves historical or architectural value.Safety checks ensure reused materials meet strength requirements.Documentation is needed for certification credits under IGBC "Reused Materials."Cost savings and environmental benefits make reuse practical.Innovative design can integrate reused components aesthetically.Circular economy principles encourage continuous reuse cycles.Material reuse embodies sustainable design thinking beyond just recycling.

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7. Certified Wood

Certified wood comes from responsibly managed forests verified by agencies like **FSC (Forest Stewardship Council)** or **PEFC.**Certification ensures legality, sustainability, and biodiversity protection.It avoids wood from endangered or illegally logged forests.FSC-certified timber promotes social and environmental responsibility.Wood used in doors, furniture, and flooring can carry certification labels.Manufacturers must provide chain-of-custody documentation.Bamboo and engineered wood products can also be certified.In India, FSC-certified suppliers are increasingly available.Use of certified wood earns IGBC/LEED credits under "Sustainable Materials."It supports global forest conservation efforts.Certified wood ensures durable quality and ethical sourcing.Avoids deforestation and habitat loss impacts.Use of local certified timber combines both regional and sustainable benefits.

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8. Rapidly Renewable Building Materials and Furniture

Rapidly renewable materials regenerate within 10 years or less.Examples: bamboo, cork, jute, hemp, coir, and linoleum.They offer low embodied energy and high strength-to-weight ratios.Bamboo flooring, jute carpets, and cork panels are eco-friendly options.These materials support sustainable agriculture and rural livelihoods.Coir-based boards replace synthetic laminates effectively.Such resources reduce dependency on slow-growing forests.Rapid renewables are biodegradable and low in VOCs.They provide aesthetic diversity and indoor comfort.Furniture made from bamboo and agricultural waste adds sustainability.Maintenance is simple, and carbon footprint is minimal.LEED and IGBC grant points for rapidly renewable material use.
Their growing popularity supports India's Make-in-India sustainability goals.

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9. Indoor Environmental Quality and Occupational Health

Indoor Environmental Quality (IEQ) ensures comfort, safety, and health for occupants.It includes air quality, lighting, acoustics, and thermal comfort.Good IEQ enhances productivity and well-being.Poor ventilation leads to accumulation of pollutants.Green buildings maintain CO_2 < 1000 ppm in occupied zones.Use of **low-VOC paints, sealants, and adhesives** improves air purity.Thermal comfort is maintained as per ASHRAE 55 standards.Adequate daylight reduces fatigue and eye strain.Noise insulation minimizes distractions and stress.Humidity control prevents mold growth.Regular monitoring of IAQ ensures healthy environments.Workplace ergonomics further enhance occupational health.Sick Building Syndrome (SBS) is prevented by maintaining airflow and cleanliness.Occupational health also includes safety in lighting, fire, and accessibility design.IEQ compliance is mandatory under IGBC/LEED.A holistic IEQ design fosters **health, happiness, and high performance.**

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10. Air Conditioning

Indoor air conditioning directly affects IAQ and comfort.Improper design leads to stale or contaminated air.
Fresh air intake must meet minimum ventilation standards.Filtration systems capture dust and allergens.
Energy-efficient AC reduces carbon emissions.CO_2 and VOC sensors control air exchange rates.Proper duct cleaning prevents microbial growth.Humidity control is essential for comfort and health.AC system maintenance supports long-term IAQ stability.Integration with green design ensures balanced energy and comfort.Avoiding overcooling conserves power and prevents dryness.Smart AC systems respond to occupancy patterns dynamically.Hence, air conditioning is both a comfort and environmental responsibility factor.

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11. Indoor Air Quality

Indoor Air Quality (IAQ) refers to the cleanliness and freshness of indoor air.Contaminants include CO_2, VOCs, particulates, and microbial spores.High IAQ reduces health risks and improves comfort.Ventilation rate must be sufficient as per ASHRAE 62.1.Mechanical and natural ventilation can be combined.Air filters (MERV 13 or higher) improve air purity.Air testing is conducted before building occupancy.Low-emission materials and finishes maintain air freshness.Regular monitoring ensures continuous compliance.Plants and biophilic elements enhance air purification.Good IAQ is mandatory for LEED and IGBC health credits.

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12. Sick Building Syndrome

Sick Building Syndrome (SBS) describes illness symptoms linked to poor indoor environments.Occupants experience headaches, irritation, fatigue, or nausea.Causes include inadequate ventilation, chemical emissions, and microbial growth.Low lighting and high CO_2 worsen the problem.Maintaining IAQ,humidity, and ventilation prevents SBS.Use of low-VOC materials and routine cleaning are preventive steps.Air ducts should be inspected for mold or dust.Employee feedback can detect early SBS signs.Integrating IAQ sensors into BMS helps ongoing control.Healthy indoor environments lead to higher productivity and satisfaction.

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13. Tobacco Smoke

Tobacco smoke severely deteriorates indoor air quality.It releases carcinogens, CO, and fine particulates. Second-hand smoke causes respiratory and cardiac diseases.Green buildings enforce **no-smoking zones** and designated outdoor areas.Building codes prohibit smoking within 25 feet of entries or air intakes.Ventilation systems should not recirculate smoke-contaminated air.Signages and awareness programs promote a smoke-free environment.LEED and IGBC require documented smoke-control policies.Ensuring clean indoor air supports both **health and certification compliance.**

✅**Summary:**

Unit IV focused on *energy efficiency and HVAC integration*.

Unit V centers on *material sustainability and human health inside buildings*.
Together they complete the **Green Building Design and Operation Framework**, directly aligned with **IGBC and ECBC India** practices.