Energy Conservation and Green Building (315316)

MSBTE Diploma · K-Scheme · Model Question Paper — Set A · Model Answers

How to use: Answers are written point-wise in MSBTE model-answer style. Facts about rating systems (GRIHA, IGBC, LEED), codes (ECBC/ECSBC) and government schemes change from time to time — they are given as on Oct 2026; points marked 'check current version' should be verified from the official website before quoting exact numbers.

Q.1

a) Define energy conservation. 2 M

Energy conservation means reducing the quantity of energy used by avoiding wastage and unnecessary use, and by using energy more efficiently, without reducing the required comfort, service or production.

Example: switching off lights and fans when a room is empty; replacing old tube lights with LED tubes.

(Definition 2 M)

b) Define green building. 2 M

Green building: A green building is a building which, in its design, construction, operation, maintenance and demolition, uses less energy, water and materials, produces less waste and pollution, and provides a healthy and comfortable indoor environment for its occupants, thereby reducing its overall impact on the environment.

Examples: CII-Sohrabji Godrej Green Business Centre (Hyderabad), Indira Paryavaran Bhawan (New Delhi).

(Definition 2 M)

c) Four principles of green building. 2 M

1. **Sustainable site design**
2. **Energy efficiency and conservation**
3. **Water efficiency and conservation**
4. **Materials selection and life cycle**
5. **Indoor environmental quality (IEQ)**

(Any four, ½ M each)

d) Define IEQ; two factors. 2 M

Indoor Environmental Quality (IEQ) is the quality of the environment inside a building — indoor air quality, thermal comfort, lighting, acoustics and ergonomics — as it affects the health, comfort and productivity of the occupants.

Factors:

- Indoor air quality (fresh air, CO_2 level, VOCs from paints and adhesives)

- Thermal comfort (temperature, humidity, air movement)
- Visual comfort (daylight, glare-free artificial light)

(Definition 1 M, any two factors 1 M)

e) Four sustainable materials. 2 M

1. Bamboo
2. Fly-ash bricks / AAC blocks
3. Hempcrete
4. Cross-laminated timber (CLT)
5. Recycled plastic lumber
6. Ferrock

(Any four, ½ M each)

f) Define green building audit. 2 M

Green building audit is a systematic, documented examination of a building to assess how efficiently it uses energy, water and materials, how it manages waste, and the quality of its indoor environment — comparing actual performance with green building standards/benchmarks and recommending improvements.

(Definition 2 M)

g) Two ethical responsibilities of a civil engineer. 2 M

1. Honesty — no 'green-washing' (false green claims) in reports or marketing.
2. Follow codes (ECBC/ECSBC, NBC) and rating requirements honestly.
3. Protect health and safety of workers and occupants.
4. Consider life-cycle impact, not only initial cost.

(Any two, 1 M each)

Q.2

a) Salient features of the Energy Conservation Act, 2001. 4 M

The Energy Conservation Act, 2001 was enacted by the Parliament of India to provide for efficient use of energy and its conservation. Its salient features are:

1. **Bureau of Energy Efficiency (BEE):** The Act set up BEE (operational from 1 March 2002) under the Ministry of Power as the statutory body to frame policies and programmes for energy efficiency.
2. **Designated consumers:** Energy-intensive users notified under the Act (e.g. thermal power stations, cement, iron & steel, aluminium, fertiliser, textile, pulp & paper, chlor-alkali, railways) must appoint a certified energy manager, get mandatory energy audits done by accredited energy auditors, report energy use and meet the energy-consumption norms given to them.
3. **Standards and labelling:** The Central Government can specify energy-consumption standards for equipment and appliances and make the energy label (star label) compulsory, and can stop the sale of appliances that do not meet the standards.

4. **Energy Conservation Building Code (ECBC):** Energy-efficiency norms for new commercial buildings above a threshold load; State Governments may modify the code for local climate and enforce it.
5. **State Designated Agencies (SDA):** Each State Government designates an agency (in Maharashtra: MEDA) to co-ordinate, regulate and enforce the provisions of the Act in the state.
6. **Energy Conservation Funds:** A Central Energy Conservation Fund and State Energy Conservation Funds for promoting energy-efficiency activities.
7. **Energy managers and auditors:** Certification of energy managers and accreditation of energy auditors through a national examination conducted by BEE.
8. **Penalties:** Penalties for non-compliance by designated consumers, manufacturers and others (amounts revised by later amendments).
9. **Amendments:** Amended in 2010 and by the Energy Conservation (Amendment) Act, 2022 — the 2022 amendment added a carbon credit trading scheme, use of non-fossil energy sources by designated consumers, and an Energy Conservation and Sustainable Building Code that can also cover large residential buildings.

(Any four features, 1 M each)

b) Role of green building in sustainable development. 4 M

Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Brundtland Commission report, 1987).

Green buildings support all three dimensions (pillars) of sustainable development:

1. **Environmental protection:** less energy and water use, use of renewable energy and recycled materials reduce resource depletion, CO_2 emission and pollution.
2. **Economic sustainability:** lower operating cost (electricity and water bills), longer life and higher asset value of the building.
3. **Social sustainability:** better daylight, fresh air and thermal comfort improve health and productivity of occupants; local materials and labour support the community.
4. **Resource conservation for future:** rainwater harvesting, waste recycling and efficient design leave resources for future generations — which is the core idea of sustainable development.
5. **Climate change mitigation:** buildings consume a large share of electricity; green buildings reduce this share and help national climate targets.

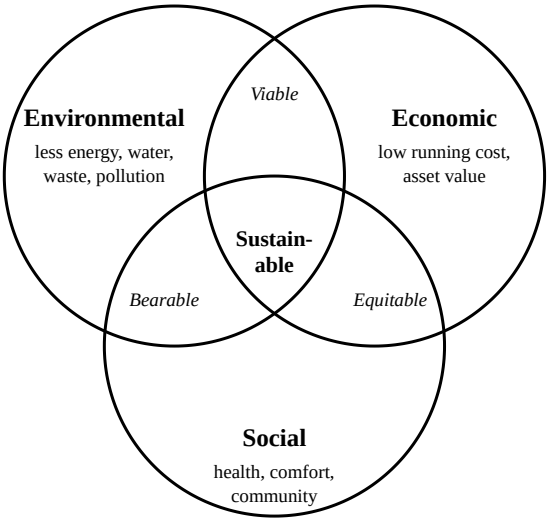

Fig.: Three dimensions of sustainable development / construction

(Any four points 4 M (diagram optional))

c) Four salient features of green building with sketch. 4 M

1. **Proper orientation and passive design** — long sides facing North–South, shading devices, cross-ventilation.
2. **Energy-efficient envelope** — insulated roof/walls, high-performance glazing, cool roof.
3. **Renewable energy** — roof-top solar PV and solar water heater.
4. **Efficient lighting and equipment** — LED lights, daylight sensors, star-labelled appliances, efficient HVAC.
5. **Water conservation** — rainwater harvesting, low-flow taps and dual-flush cisterns, recycling of grey water.
6. **Sustainable materials** — fly-ash bricks, AAC blocks, bamboo, recycled steel, low-VOC paints.

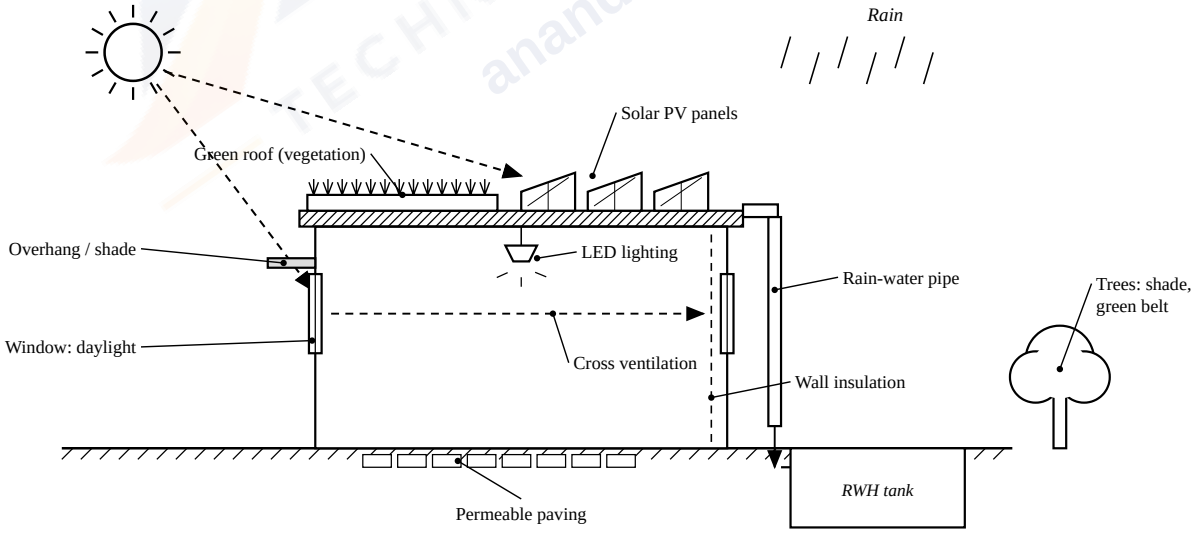

Fig.: Main features of a green building (section)

(Any four features 2 M, sketch 2 M)

d) Environmental, economic and social benefits. 4 M

Environmental	Economic	Social
• Reduced energy use and greenhouse-gas emissions. • Conservation of water through efficient fixtures and rainwater harvesting. • Less waste going to landfill; less use of virgin materials. • Protection of biodiversity and reduced heat-island effect.	• Lower electricity and water bills (lower operating cost). • Lower maintenance cost and longer building life. • Higher market/rental value of the building. • Incentives in some cities/states (e.g. extra FAR, rebates) for rated buildings.	• Better health and comfort of occupants (daylight, fresh air). • Higher productivity of workers and better learning of students. • Improved quality of life and awareness in the community. • Use of local materials and labour supports the local economy.

(Each type with two points; 4 M)

Q.3

a) Characteristics of bamboo, hempcrete, ferrock and CLT. 4 M

Bamboo:

- Fast-growing grass, harvestable in about 3–5 years (rapidly renewable).
- High tensile strength-to-weight ratio, light and flexible.
- Low embodied energy; absorbs CO_2 while growing.
- *Uses:* Scaffolding, roofing, walls, flooring, panels, reinforcement in low-cost houses.
- *Limitation:* Needs chemical treatment against insects and fungus; prone to fire and moisture decay; not uniform in size.

Hempcrete:

- Bio-composite of hemp shiv (woody core), lime binder and water.
- Light-weight, good thermal and sound insulation.
- Breathable — regulates humidity; carbon-negative due to lime carbonation and plant CO_2 uptake.
- *Uses:* Non-load-bearing infill walls, insulation of walls and roofs.
- *Limitation:* Low compressive strength (needs a structural frame); slow drying; limited availability in India.

Ferrock:

- Iron-based binder made mainly from waste steel dust and silica (e.g. from ground glass) as an alternative to cement.
- Absorbs CO_2 while curing (carbon-negative claim).
- Reported to be stronger and more flexible than ordinary cement mortar in tests.
- *Uses:* Paving, small precast items, marine and decorative work (still emerging).
- *Limitation:* Limited production and codes; availability of steel dust; long-term data still limited.

Cross-laminated timber (CLT):

- Engineered wood panels made by gluing layers of timber at right angles.
- High strength and dimensional stability; prefabricated, so fast and clean construction.
- Stores carbon; much lighter than concrete.
- *Uses:* Floors, walls and roofs of mid-rise buildings, prefabricated houses.
- *Limitation:* Needs sustainably sourced timber; fire and moisture protection required; high cost and limited availability in India.

(Each material 1 M)

b) Role of HVAC in green building with schematic. 4 M

HVAC = Heating, Ventilation and Air Conditioning. Its role in a green building:

1. **Thermal comfort:** HVAC (Heating, Ventilation and Air Conditioning) keeps temperature and humidity in the comfort range for occupants.
2. **Indoor air quality:** brings in filtered fresh air and removes CO_2, odours and pollutants (part of IEQ).
3. **Largest energy user:** in air-conditioned buildings HVAC is usually the largest single electricity load, so its efficiency decides the building's energy performance.
4. **Energy-efficient equipment:** high-COP chillers / star-rated or inverter ACs, VFDs on fans and pumps, efficient motors.
5. **Controls:** thermostats, CO_2 (demand-controlled) ventilation, occupancy sensors and BMS schedules avoid wastage.
6. **Heat recovery:** energy-recovery wheels pre-cool fresh air using exhaust air.
7. **Right sizing:** a good envelope and shading reduce the cooling load, so smaller HVAC plant is needed.

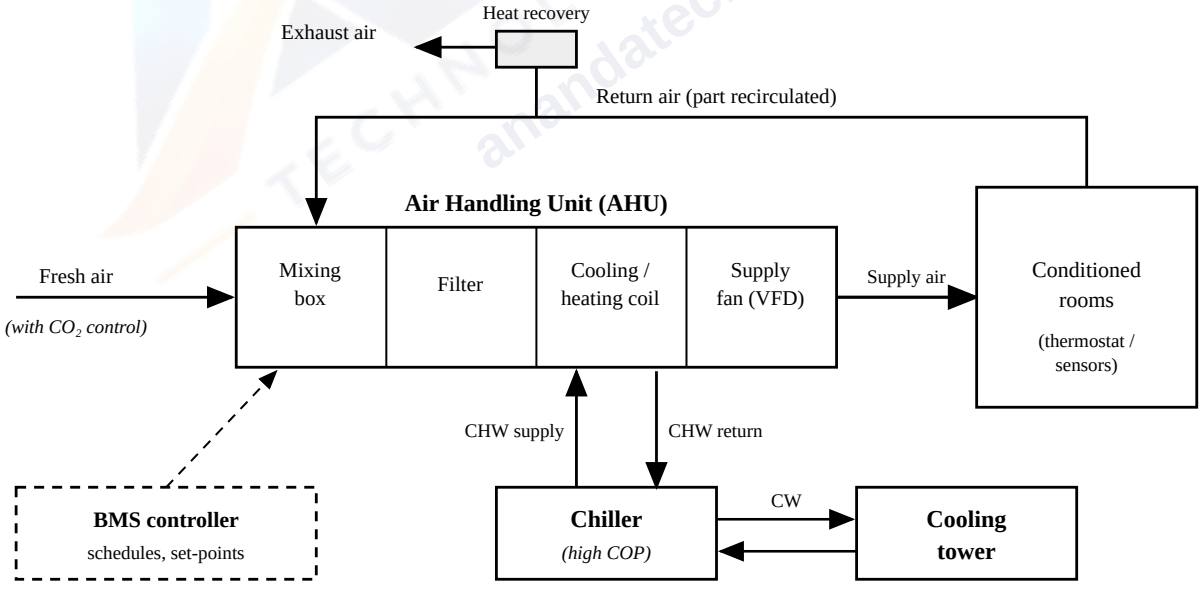

Fig.: Central HVAC system with energy-saving features (schematic)

(Any four points 2 M, sketch 2 M)

c) Key elements in planning a green building audit. 4 M

1. **Audit objectives:** decide why the audit is done — energy saving, water saving, rating preparation, compliance.
2. **Scope and boundary:** which buildings, systems (lighting, HVAC, water, waste, IEQ) and time period are included.
3. **Audit team:** lead auditor, energy/water experts, facility staff; define responsibilities.
4. **Audit criteria / benchmarks:** codes and rating systems against which performance is judged (ECBC, GRIHA, IGBC, past data).
5. **Data and documents required:** electricity and water bills (12 months), drawings, equipment list, maintenance records.
6. **Checklist and instruments:** prepare checklists; arrange instruments — power analyser, lux meter, thermometer/hygrometer, CO_2 meter, flow meter.
7. **Schedule and budget:** dates of walk-through and detailed audit, interviews; cost of audit.
8. **Communication and reporting format:** inform occupants, decide report format and presentation to management.

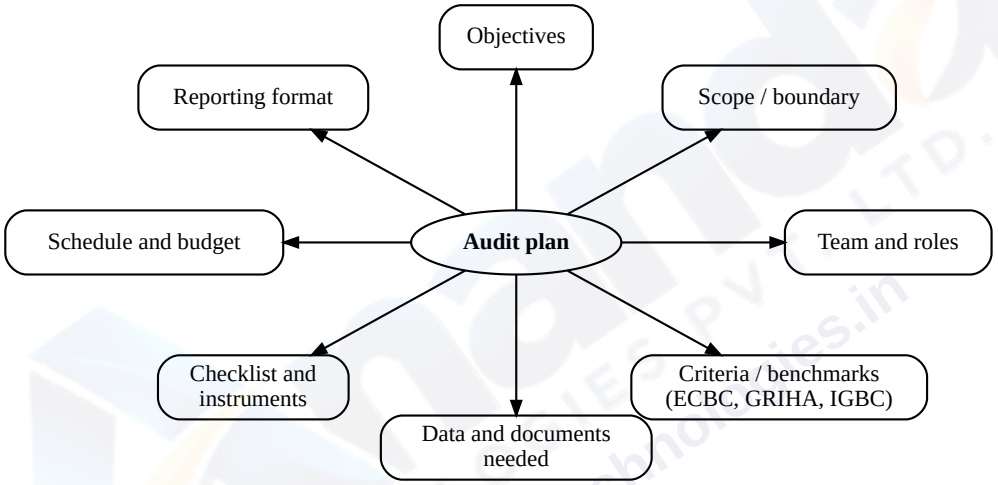

Fig.: Key elements of planning a green building audit

(Any four elements, 1 M each)

d) Passive solar design for hot climate. 4 M

Passive solar design uses the building's own form, orientation, openings and materials to control solar heat and daylight without (or with little) mechanical equipment.

1. **Orientation:** long axis East–West so that the long walls face North and South; minimum openings on East and West.
2. **Shading:** horizontal overhangs (chajjas) over South windows cut off the high summer sun but admit the low winter sun; vertical fins on East/West.
3. **Thermal mass:** thick walls and floors absorb heat in the day and release it at night (useful in hot-dry climate).
4. **Insulation and cool roof:** the roof receives maximum sun in India — insulate it and use a reflective finish.
5. **Natural ventilation:** cross-ventilation and stack effect (high-level vents) remove hot air.

6. **Daylighting:** North light and light shelves reduce artificial lighting.

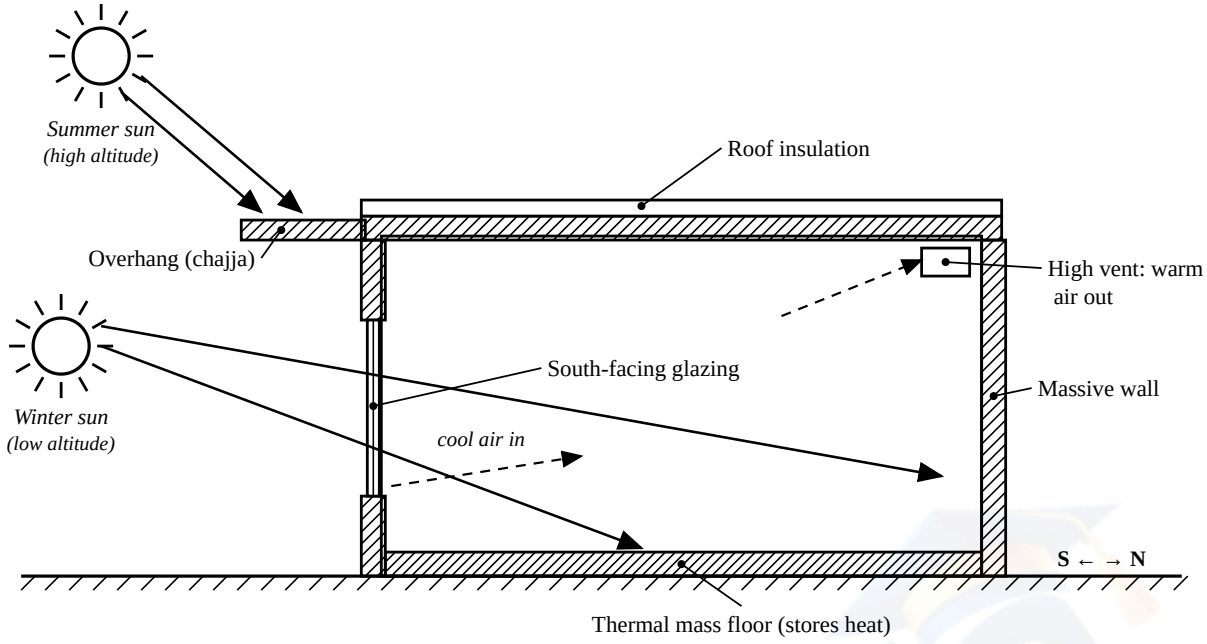

Fig.: Passive solar design — overhang blocks high summer sun, admits low winter sun

(Explanation 2 M, sketch 2 M)

Q.4

a) GRIHA vs IGBC.

4 M

Sr.	Point	GRIHA	IGBC
1	Full form	Green Rating for Integrated Habitat Assessment	Indian Green Building Council
2	Original development	Developed by TERI (The Energy and Resources Institute) with MNRE; adopted as the national rating system in 2007; now run by GRIHA Council.	Set up in 2001 by CII (Confederation of Indian Industry); industry-led council.
3	Nature	Government-supported national rating; strong focus on Indian climate and actual performance.	Voluntary, consensus-based, market-driven rating.
4	Certification levels	1 to 5 stars (★ to ★★★★★) according to points scored.	Certified, Silver, Gold, Platinum (points per level depend on the rating type/version).
5	Rating validity	Usually stated as 5 years (performance data to be submitted after occupancy).	Usually stated as 3 years, after which re-certification is needed (check rating version).

6	Area of assessment	Sections such as site planning, construction management, energy optimisation, occupant comfort, water, solid waste, materials, life-cycle costing, socio-economic strategies, performance monitoring.	Categories such as sustainable architecture & design, site selection & planning, water conservation, energy efficiency, building materials & resources, IEQ, innovation.

> **Note:** Validity and point ranges change with rating versions — check the current GRIHA / IGBC manual.

(Any four points, 1 M each)

b) Functions of MNRE. 4 M

1. **Nodal ministry** of Government of India for all matters of new and renewable energy — solar, wind, small hydro, bio-energy, green hydrogen. (Set up as Ministry of Non-Conventional Energy Sources in 1992; renamed MNRE in 2006.)
2. **Policy and planning:** frames national policies, targets and missions for renewable energy (India's target: 500 GW non-fossil capacity by 2030).
3. **Schemes and financial support:** subsidies/central financial assistance, e.g. roof-top solar programme (PM Surya Ghar: Muft Bijli Yojana, 2024), PM-KUSUM for solar pumps (scheme names as on 2026 — check MNRE website).
4. **Research and development:** through national institutes — NISE (solar), NIWE (wind), NIBE (bio-energy).
5. **Implementing and financing agencies:** SECI (Solar Energy Corporation of India) and IREDA (finance) work under MNRE.
6. **Standards and quality control** of renewable energy products and approved lists of models/manufacturers.
7. **Promotion of green buildings:** supported development of GRIHA with TERI; promotes solar water heaters and solar systems in buildings.

(Any four functions, 1 M each)

c) LEED credit categories and certification levels. 4 M

LEED (Leadership in Energy and Environmental Design) is a green building rating system developed by the **U.S. Green Building Council (USGBC)** (launched 1998), used worldwide including India.

Credit categories (LEED v4/v4.1 for new construction):

1. **Integrative Process** — early team work of architect, engineers and owner to find green opportunities.
2. **Location and Transportation** — site near public transport and amenities; bicycle facilities; reduced parking; EV charging.
3. **Sustainable Sites** — erosion control, protect habitat, open space, rainwater management, reduce heat-island and light pollution.
4. **Water Efficiency** — reduce indoor and outdoor water use, water metering, cooling-tower water management.

5. **Energy and Atmosphere** — minimum energy performance, commissioning, metering, renewable energy, refrigerant management.
6. **Materials and Resources** — storage and collection of recyclables, construction waste management, life-cycle impact, responsibly sourced materials.
7. **Indoor Environmental Quality** — minimum indoor air quality, no smoking, low-emitting materials, thermal comfort, daylight, quality views, acoustics.
8. **Innovation** — exceptional or new green strategies; LEED Accredited Professional on team.
9. **Regional Priority** — bonus credits for issues important in that region.

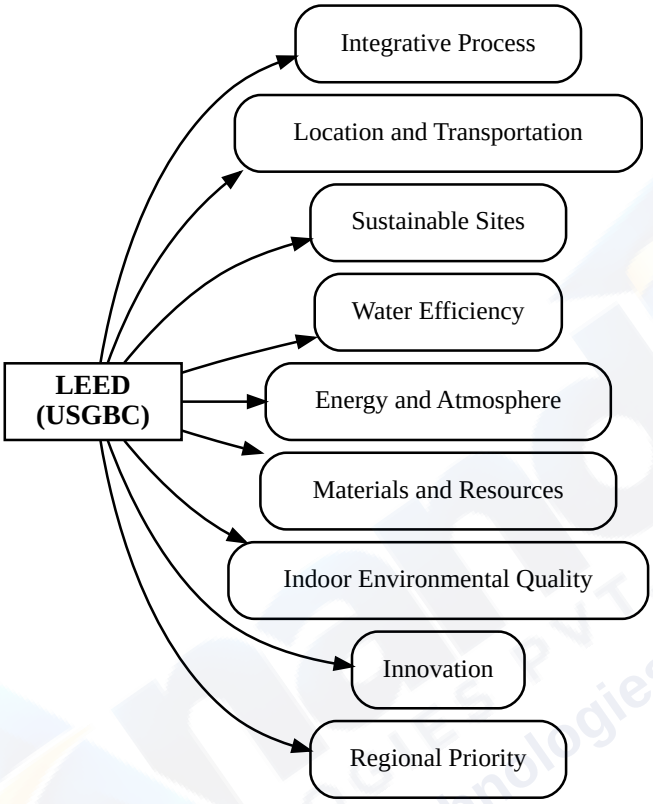

Fig.: LEED credit categories (LEED v4 / v4.1 BD+C)

Certification levels (out of 110 points):

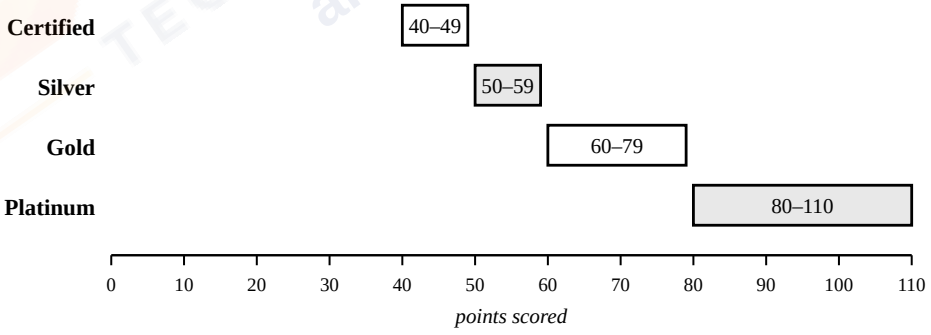

Fig.: LEED certification levels (v4 / v4.1)

> **Note:** USGBC released LEED v5 in 2025; credit names and points differ slightly between versions.

(Categories 2 M, levels 2 M)

d) Role of BEE in energy conservation. 4 M

1. **Statutory body** under the Ministry of Power, set up on 1 March 2002 under the Energy Conservation Act, 2001, to reduce the energy intensity of the Indian economy.
2. **Standards and Labelling (S&L) programme:** star labels (1 to 5 stars) for appliances such as ACs, refrigerators, fans, LED lamps, motors; mandatory for several appliances.
3. **Building codes:** Energy Conservation Building Code (ECBC 2007, updated 2017) for commercial buildings; Eco-Niwas Samhita (2018) for residential buildings; the Energy Conservation and Sustainable Building Code (ECSBC) after the 2022 amendment (check latest notification); star rating of existing buildings.
4. **Industry:** PAT (Perform, Achieve and Trade) scheme for designated consumers; energy audits and energy managers.
5. **Certification:** national examination for energy managers and energy auditors; accreditation of energy auditors.
6. **Demand-side management** programmes for municipalities, agriculture and SMEs.
7. **Awareness:** National Energy Conservation Day (14 December), National Energy Conservation Awards, school programmes.

(Any four roles, 1 M each)

e) Four corrective actions after audit of an office building. 4 M

1. Replace fluorescent / CFL lamps with LED and add occupancy and daylight sensors.
2. Replace old fans with BLDC fans and old ACs with 5-star inverter ACs; set AC temperature at 24–25 °C.
3. Install VFDs on pumps and AHU fans; improve power factor with capacitors.
4. Repair leaking taps and pipes; fit aerators, low-flow taps and dual-flush cisterns.
5. Provide rainwater harvesting and grey-water recycling for flushing / gardening.
6. Apply cool-roof coating / roof insulation and external shading on east and west windows.

Each action should be listed in the action plan with cost, expected saving and payback, and its result checked by monitoring.

(Any four actions, 1 M each)

Q.5

a) Applying green building principles to a college hostel. 6 M

1. **Sustainable site:** build on already-disturbed land; keep existing trees; provide walking paths and cycle stands; permeable paving in open areas.
2. **Orientation and passive design:** long axis East–West; rooms on North/South; corridors, toilets and stairs on West as heat buffer; chajjas and fins; cross-ventilated rooms.
3. **Energy efficiency:** LED lights with occupancy sensors in corridors and toilets, BLDC fans, 5-star appliances; roof insulation / cool roof.
4. **Renewable energy:** solar water heater for bathrooms (large hot-water demand in hostels) and roof-top solar PV.

5. **Water efficiency:** low-flow taps and showers, dual-flush cisterns, rainwater harvesting, recycling of grey water for flushing and gardening, water meters per block.
6. **Materials:** fly-ash bricks / AAC blocks, local stone, recycled steel, low-VOC paints, bamboo for pergolas and furniture.
7. **IEQ:** large windows with daylight, fresh air, quiet study areas, no-smoking policy.
8. **Waste management:** separate bins for wet/dry waste, composting of mess kitchen waste (or biogas plant), e-waste collection.

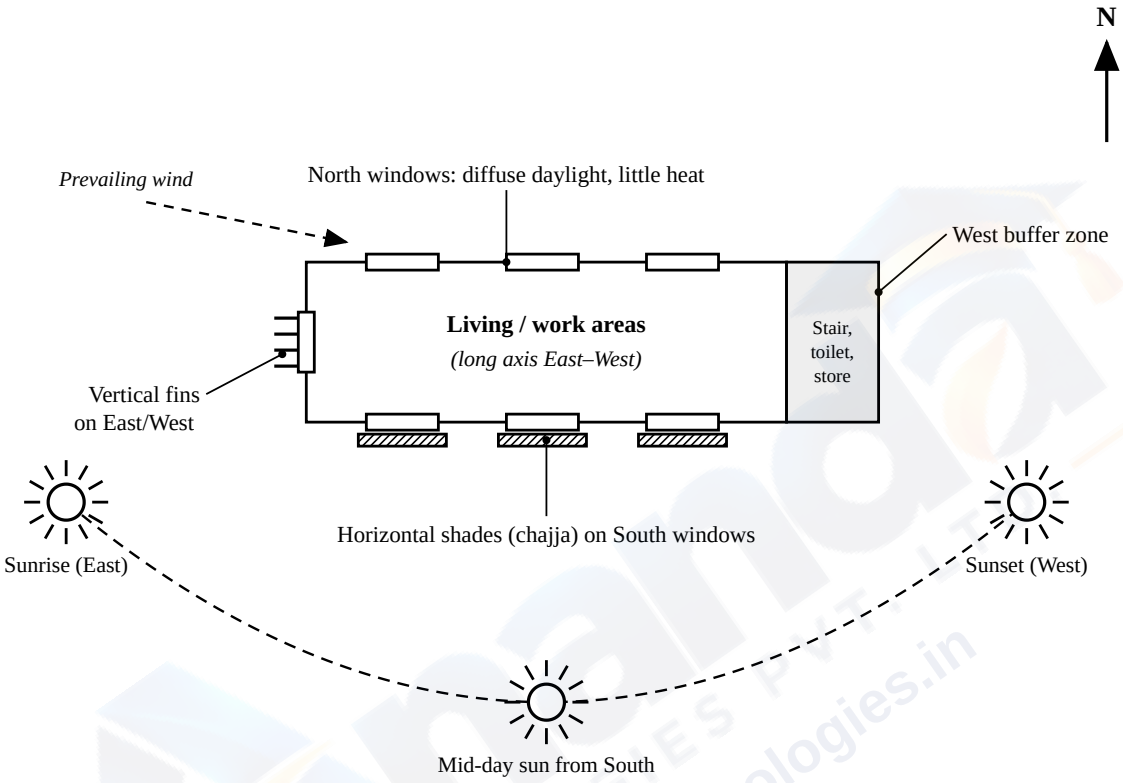

Fig.: Orientation of hostel block (plan) — long axis East–West

(Any six principles applied, 1 M each)

b) Green roof — layers and benefits. 6 M

Green roof (vegetated or living roof) is a roof of a building that is partly or completely covered with vegetation and a growing medium, laid over a waterproofing membrane. Types: **extensive** (thin soil, 75–150 mm, grass/sedum, light weight, low maintenance) and **intensive** (deeper soil, shrubs and small trees, heavier, needs strong slab and regular maintenance).

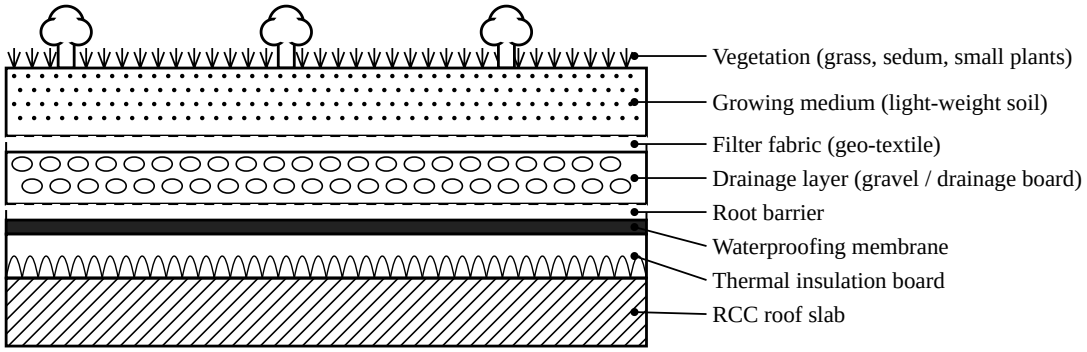

Fig.: Typical layers of a green (vegetated) roof

Benefits:

1. Reduces heat gain through the roof — cooler top floor and lower AC load.
2. Reduces urban heat-island effect.
3. Retains rainwater and delays storm-water run-off.
4. Protects the waterproofing membrane from UV and temperature changes, increasing its life.
5. Improves air quality and biodiversity (birds, insects).
6. Gives sound insulation and attractive usable space; adds points in GRIHA/IGBC/LEED.

(Explanation 2 M, sketch with layers 2 M, benefits 2 M)

c) School audit — EPI and LED retrofit. 6 M

Given: Area A = 2,400 m²; consumption = 9,600 kWh/month; 180 tube lights × 48 W → 20 W LED; 8 h/day; 250 days/year; tariff ₹9/kWh; LED cost ₹450 each.

i) EPI = Annual energy ÷ built-up area
Annual energy = 9,600 × 12 = 1,15,200 kWh/year
EPI = 1,15,200 ÷ 2,400 = **48.0 kWh/m²/year**

ii) Annual saving
Old lighting energy = 180 × 48 × 8 × 250 ÷ 1000 = 17,280 kWh/year
New lighting energy = 180 × 20 × 8 × 250 ÷ 1000 = 7,200 kWh/year
Energy saving = 17,280 − 7,200 = **10,080 kWh/year** (8.75 % of total)
Cost saving = 10,080 × 9 = **₹90,720 per year**

iii) Simple payback
Investment = 180 × 450 = ₹81,000
Payback = Investment ÷ annual saving = 81,000 ÷ 90,720 = **0.89 year** ≈ 10.7 months

iv) EPI after retrofit = (1,15,200 − 10,080) ÷ 2,400 = **43.8 kWh/m²/year**

Item	Before	After
Lighting energy (kWh/yr)	17,280	7,200
Total energy (kWh/yr)	1,15,200	1,05,120
EPI (kWh/m²/yr)	48.0	43.8

Conclusion: The LED retrofit pays back in less than one year, so it is a highly recommended corrective action of the audit. The EPI should also be compared with the benchmark for school buildings given by BEE for the climate zone.

(EPI 1 M, energy saving 2 M, cost saving and payback 2 M, new EPI 1 M)

Q.6

a) Role of MEDA in energy conservation in Maharashtra. 6 M

1. **About:** Maharashtra Energy Development Agency, set up in 1985 by the Government of Maharashtra (head office Pune), works as the **State Designated Agency (SDA)** under the Energy Conservation Act, 2001 and as the **state nodal agency for renewable energy**.
2. **Enforcing the EC Act in the state:** co-ordinates with BEE, monitors designated consumers, promotes ECBC for buildings in Maharashtra.
3. **Energy audits:** promotes and supports energy audits of government buildings, municipal bodies, industries and institutions.
4. **Municipal energy efficiency (in the city):** energy-efficient street lights, efficient water-pumping systems, solar systems on municipal buildings.
5. **Renewable energy promotion:** roof-top solar, solar water heaters, solar pumps, wind, small hydro, biomass and bagasse co-generation projects; implements state and MNRE schemes.
6. **Awareness and training:** Energy Conservation Week, seminars, training programmes for engineers and students.
7. **Awards:** Maharashtra state energy conservation awards for industries, buildings and institutions.
8. **Demonstration projects** in government offices, schools and hospitals to show energy saving.

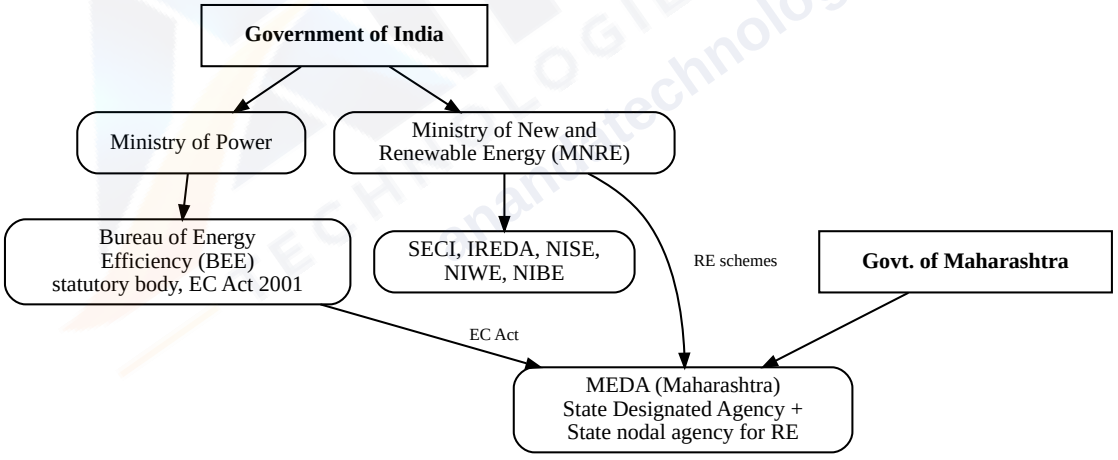

Fig.: Government bodies for energy conservation (India / Maharashtra)

(Any six roles, 1 M each)

b) Benefits to a college after green rating. 6 M

1. **Lower running cost:** rated buildings typically save a good part of energy and water use (savings of about 20–30 % energy and 30–50 % water are often quoted by IGBC; actual savings vary).

2. **Healthy and productive environment:** better daylight, fresh air and comfort improve health, attendance and learning/working performance.
3. **Third-party verification:** certification proves the green claims — avoids green-washing.
4. **Recognition and image:** improves reputation; useful for NAAC/NBA (green campus / environment indicators) and for attracting tenants or students.
5. **Higher asset value** and easier green finance.
6. **Incentives:** some states and cities give extra FAR, faster approvals or fee rebates for rated buildings.
7. **Awareness and education:** the building itself becomes a teaching tool on sustainability.
8. **Long-term sustainability:** re-certification and performance monitoring make sure the building keeps performing, not only at design stage.

For a college in particular: lower electricity and water bills free funds for academics; the campus becomes a live laboratory for civil students (RWH, solar, waste); it supports green-campus indicators in accreditation.

(Any six benefits, 1 M each)

c) Need for green building audit of college; flow chart. 6 M

Need (applying the concept of sustainability):

1. A college uses a lot of electricity (lights, fans, computer labs, workshops) and water (hostels, canteen, toilets); an audit finds wastage and saving opportunities — *economic sustainability*.
2. Reduces carbon footprint, water use and waste of the campus — *environmental sustainability*.
3. Checks daylight, ventilation and comfort in classrooms — healthier learning, *social sustainability*.
4. Gives baseline data and targets; prepares the campus for green rating and accreditation (green campus indicators).
5. Creates awareness and participation of students and staff.

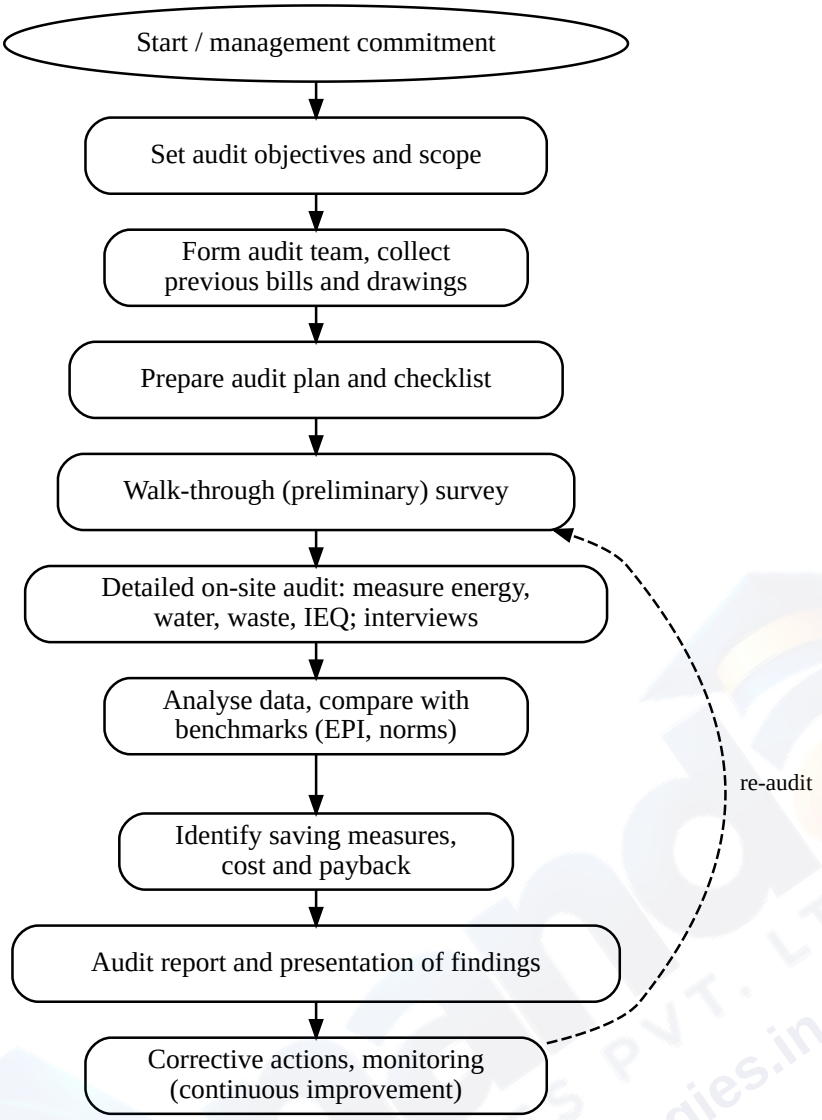

Fig.: Steps of a green building audit (flow chart)

(Need 3 M, flow chart 3 M)

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