

Course: BEE755B | Energy Conservation and Audit**MODULE 5 - Study Notes**

Academic Year 2026-27

TOPICS COVERED IN THIS MODULE**UNIT A: Energy Audit Applied to Buildings**

- Energy-Saving Measures in New Buildings
- Water Audit
- Method of Audit
- General Energy-Saving Tips for New and Existing Buildings

UNIT B: Demand Side Management (DSM)

- Scope of DSM
- Evolution of DSM Concept
- DSM Planning and Implementation
- Load Management as a DSM Strategy
- Applications of Load Control
- End-Use Energy Conservation
- Tariff Options for DSM

UNIT A: ENERGY AUDIT APPLIED TO BUILDINGS

Buildings account for approximately 40% of global final energy consumption and around 33% of total greenhouse gas emissions. In India, the building sector (residential + commercial) consumes about 33% of the total electricity generated. With rapid urbanisation and a growing middle class, energy use in buildings is projected to triple by 2050 without intervention. Energy auditing of buildings is therefore a critical step toward achieving national energy conservation targets mandated under the Energy Conservation Act, 2001 and the Bureau of Energy Efficiency (BEE) guidelines.

Table A-1: Energy Consumption Profile – Indian Building Sector

Sub-Sector	% of Building Energy	Dominant End-Use	Avg. EPI (kWh/m ² /yr)
Residential	65%	Lighting & Appliances	80–200
Commercial Offices	20%	HVAC (40–60%)	150–350
Retail / Malls	8%	Lighting & HVAC	300–500
Hospitals	4%	HVAC & Medical Equip.	200–400
Hotels	3%	HVAC & Hot Water	250–500

Source: BEE, MoEFCC, GRIHA estimates. EPI = Energy Performance Index.

A.1 Energy-Saving Measures in New Buildings

New buildings offer the most cost-effective opportunity for energy efficiency because architectural, structural, and mechanical-electrical (MEP) decisions are made at the design stage. Retrofitting the same measures later typically costs 3–5 times more. The Energy Conservation Building Code (ECBC 2017) and its enhanced version ECBC+ / SuperECBC mandate energy performance indices for new commercial buildings.

A.1.1 Building Envelope Design

The building envelope (walls, roof, glazing, floor) is the primary thermal boundary between conditioned and unconditioned spaces. Poor envelope design can increase HVAC loads by 50% or more.

Table A-2: ECBC 2017 Prescriptive Envelope Requirements (Hot-Dry Climate)

Component	ECBC Min.	ECBC+	SuperECBC
Roof U-value (W/m ² K)	≤ 0.33	≤ 0.20	≤ 0.15
Wall U-value (W/m ² K)	≤ 0.44	≤ 0.33	≤ 0.22
Window SHGC	≤ 0.25	≤ 0.22	≤ 0.15
Window U-value (W/m ² K)	≤ 3.30	≤ 2.00	≤ 1.20
WWR (max.)	40%	30%	25%

WWR = Window-to-Wall Ratio; SHGC = Solar Heat Gain Coefficient

- Insulation: Use extruded polystyrene (XPS) or mineral wool of 50–75 mm thickness on roofs to reduce U-value below 0.25 W/m²K.
- Cool Roofs: White / reflective roofs with Solar Reflectance Index (SRI) ≥ 78 can reduce roof surface temperature by 30–40°C and cooling load by 10–15%.
- Green Roofs: Reduce Urban Heat Island (UHI) effect; add 50–100 mm soil layer + vegetation.

- Double/Triple Glazed Windows: Use Low-E coatings to achieve U-value $< 1.5 \text{ W/m}^2\text{K}$ and SHGC < 0.20 .
- External Shading: Chajjas, overhangs, louvers, and vertical fins oriented to block direct summer sun while admitting diffuse light.

A.1.2 Passive Solar Design

- Building Orientation: Orient the major glazed facade toward North in India to minimise direct solar gain while maximising daylight.
- Natural Ventilation: Stack effect and cross-ventilation can eliminate or reduce mechanical cooling needs in mild climates. ASHRAE 62.1 recommends 0.15 CFM/ft^2 fresh air.
- Thermal Mass: Materials like concrete, brick, and rammed earth absorb heat during the day and release it at night, dampening temperature swings by up to 10°C .
- Earth Berming: Partially burying a structure utilises ground temperature ($18\text{--}22^\circ\text{C}$) for passive cooling.
- Atrium / Courtyard: Central open spaces with landscaping promote natural ventilation and reduce indoor temperatures by $4\text{--}6^\circ\text{C}$.

A.1.3 HVAC System Optimisation

HVAC systems account for 40–60% of energy use in commercial buildings. Selecting correctly sized and efficient equipment is critical.

Table A-3: Minimum COP / EER Requirements (ECBC 2017 & BEE Star Ratings)

Equipment	Min. EER/COP	BEE 5-Star	Remarks
Split AC ($< 1.5 \text{ TR}$)	$\text{EER} \geq 2.70$	$\text{EER} \geq 3.50$	ISEER metric
Packaged AC ($1.5\text{--}5 \text{ TR}$)	$\text{EER} \geq 2.80$	$\text{EER} \geq 3.20$	
Centrifugal Chiller	$\text{COP} \geq 5.60$	$\text{COP} \geq 6.10$	IPLV $>$ base
Screw Chiller	$\text{COP} \geq 3.80$	$\text{COP} \geq 4.40$	
VRF / VRV System	$\text{COP} \geq 3.00$	$\text{COP} \geq 3.50$	Part-load efficient

COP = Coefficient of Performance; EER = Energy Efficiency Ratio; IPLV = Integrated Part Load Value

- Variable Air Volume (VAV) Systems: Throttle airflow to match actual load; save 30–50% fan energy vs. Constant Air Volume (CAV).
- Variable Speed Drives (VSD/VFD): Applying VFDs to AHU fans & chiller pumps saves 40–60% motor energy. Fan Laws: $P \propto N^3$.
- Economiser Cycle: Use outside air for free cooling when $\text{OAT} < 18^\circ\text{C}$; can eliminate mechanical cooling for 500–1500 hours/year.
- Heat Recovery: Enthalpy Wheel (Energy Recovery Ventilator) can recover 70–80% of exhaust air energy.
- Building Automation System (BAS/BMS): Integrates control of HVAC, lighting, and access; typical savings 15–25%.

A.1.4 Efficient Lighting Design

Table A-4: Lighting Power Density (LPD) Limits – ECBC 2017

Space Type	ECBC LPD (W/m^2)	ECBC+ LPD	SuperECBC LPD
Office (open plan)	10.8	8.5	7.0
Retail	14.0	11.0	9.0

Hotel Guest Room	11.0	8.5	7.0
Hospital Ward	9.5	7.5	6.0
Staircase / Corridor	6.5	5.0	4.0

LPD = Lighting Power Density

- LED Lighting: LEDs achieve 80–120 lm/W vs 15 lm/W for incandescent and 60–70 lm/W for fluorescent. Potential savings: 50–75%.
- Daylight Harvesting: Photosensors dim/switch artificial lighting when sufficient daylight is available; save 20–40% lighting energy.
- Occupancy Sensors: PIR or ultrasonic sensors switch off lights in unoccupied areas; save 30–50% in intermittently used spaces.
- Task Lighting: Combine lower ambient LPD ($\leq 5 \text{ W/m}^2$) with individual task lights for office workstations.
- Light Pipes / Tubular Daylighting Devices (TDD): Channel natural light into deep-plan spaces up to 10 m from facade.

A.1.5 Renewable Energy Integration

- Rooftop Solar PV: ECBC 2017 recommends minimum 1 W/m^2 of conditioned floor area from on-site renewable energy. A 100 kWp system generates ~140,000 kWh/year in India.
- Solar Water Heating (SWH): Flat-plate or evacuated-tube collectors can meet 60–70% of domestic hot water demand; payback typically 3–5 years.
- Building-Integrated PV (BIPV): PV panels integrated into facade or glazing elements; dual function — power generation + shading.
- Ground Source Heat Pump (GSHP): COP of 4–5 vs. 2.5–3.5 for conventional AC; uses stable ground temperature.

A.1.6 Building Rating Systems in India

Rating System	Agency	Scale	Key Focus
GRIHA	TERI / MoEFCC	1–5 Stars	Site, energy, water, materials, comfort
LEED India	IGBC / USGBC	Certified to Platinum	Energy (35% weightage), Water, IEQ
ECBC Compliance	BEE	ECBC / + / Super	Energy performance mandatory
IGBC Green Homes	IGBC	Certified to Platinum	Residential green rating

A.2 Water Audit

A Water Audit is a systematic assessment of water use within a building to identify sources of waste, leakage, and inefficiency. It is the water equivalent of an energy audit. In commercial buildings, water use accounts for up to 30% of the total utility cost. The BEE and GRIHA rating systems require water audits for buildings seeking certification.

Definition

A Water Audit is a structured evaluation of all water inflows, outflows, uses, and losses within a facility to identify wastage and conservation opportunities. It quantifies the Water Use Index (WUI) = Total Water Used (L/day) / Building Occupancy.

A.2.1 Water End-Uses in Buildings

Table A-5: Typical Water Consumption by End-Use in Commercial Buildings

End-Use	% of Total	Litres/person/day	Conservation Potential
Sanitary (Toilets/Urinals)	35–45%	20–40	High (low-flow fixtures)
HVAC (Cooling Tower)	25–30%	Varies	High (cycles of concentration)
Domestic Hot/Cold Water	15–20%	10–20	Medium
Landscaping / Irrigation	10–15%	Site-dependent	High (drip irrigation)
Housekeeping / Cleaning	5–10%	5–10	Medium
Leakage / Unaccounted	10–20%	—	Very High (repair priority)

A.2.2 Steps in a Water Audit

1. Pre-Audit Survey: Collect utility bills for 12 months, building drawings (plumbing layout), occupancy data, and operational schedules.
2. Establish Water Balance: Water In = Metered Supply + Rainwater Harvested. Water Out = Productive Use + Losses (leakage, evaporation, discharge).
3. Walk-Through Inspection: Check all fixtures, fittings, cooling tower blowdown, irrigation systems, and identify leaks (listen for running water, check meters during off-hours).
4. Sub-Metering & Measurement: Install sub-meters on major end-use circuits. The Bucket Test measures actual flush volume vs. rated volume.
5. Leak Detection: Dye test for toilets; pressure testing for pipe networks; acoustic leak detection equipment for buried pipes.
6. Analysis & Reporting: Calculate WUI, compare with benchmarks, and prioritise corrective actions by ROI.

A.2.3 Key Performance Indicators

Building Type	Good Practice WUI	Average WUI	Unit
Office Building	20–25	45–60	L/person/day
5-Star Hotel	200–300	400–600	L/room/day
Hospital	350–450	700–900	L/bed/day
School	25–30	50–70	L/student/day

A.2.4 Water Conservation Measures

- Low-Flow Fixtures: Dual-flush toilets (4.5/3L vs. 9L conventional), low-flow faucet aerators (6–8 L/min vs. 15 L/min), and waterless urinals reduce sanitary water use by 40–60%.
- Cooling Tower Optimisation: Increase cycles of concentration (CoC) from 2 to 5 by chemical treatment, reducing makeup water by 60%. Install drift eliminators ($< 0.001\%$ of circulating flow).
- Rainwater Harvesting: Collect and store runoff from roofs and paved surfaces. A 1000 m² roof in Bengaluru can harvest ≈ 900 kL/year at 900 mm annual rainfall.
- Greywater Recycling: Treat handbasin and shower water for toilet flushing; can reduce fresh water demand by 30%.
- Sewage Treatment & Reuse: Tertiary-treated STP water for cooling towers, flushing, and irrigation. GRIHA mandates $\geq 50\%$ reuse.
- Drip Irrigation & Smart Controllers: Weather-based irrigation controllers cut landscape water use by 20–50%.

A.3 Method of Audit

The methodology for conducting an energy audit of buildings follows a structured process aligned with the Bureau of Energy Efficiency (BEE) Manual on Energy Audits and IS 14858:2000. The depth of audit is classified into three types based on the scope and cost–benefit detail required.

Table A-6: Types of Energy Audit – Comparison

Parameter	Level I: Walk-Through	Level II: General	Level III: Detailed
Also Called	Screening Audit	Energy Survey	Investment-Grade Audit
Duration	1–2 days	1–2 weeks	3–8 weeks
Data Collected	Utility bills, brief site visit	Metered data, equipment inventory	Detailed measurements, simulation
Output	Rough ECO list, order-of-magnitude savings	ECO list with simple payback	Life-cycle cost, financeable ECO packages
Cost	Low	Moderate	High
Typical User	Small buildings	Medium commercial	Large facilities / ESCOs

A.3.1 Pre-Audit Preparations

- Collect minimum 12 months of electricity, fuel, and water utility bills.
- Obtain as-built drawings: architectural, structural, HVAC, electrical single-line diagrams, and plumbing layouts.
- Prepare an equipment inventory: nameplates, ratings, operating hours, and maintenance records.
- Prepare energy balance worksheet: total energy input vs. disaggregated end-uses.
- Establish baseline: Energy Use Intensity (EUI) = Total Annual Energy (kWh or kBTU) / Gross Floor Area (m² or ft²).

A.3.2 Instruments and Measurements

Table A-7: Key Instruments Used in Building Energy Audits

Instrument	Measures	Accuracy	Typical Use
Clamp-on Power Analyser	kW, kVAR, PF, harmonics	± 0.5%	LT panel, motor loads
Lux Meter	Illuminance (lux)	± 3–5%	Lighting survey, daylight
Infrared Thermometer / Thermal Camera	Surface temperature, ΔT	± 1–2°C	Envelope, pipe insulation
Anemometer / Pitot Tube	Air velocity, CFM	± 2%	AHU, duct leakage
Ultrasonic Flow Meter	Water / liquid flow	± 1–2%	Chiller water, DHW
Combustion Analyser	O ₂ , CO ₂ , CO, flue temp.	± 0.3% O ₂	DG sets, boilers

U-value Meter (Heat Flux)	Thermal transmittance	$\pm 5\%$	Wall / roof insulation
Blower Door (Air Infiltration)	ACH (air changes/hr)	$\pm 4\%$	Envelope air tightness
Data Logger	Temp, RH, kWh, flow	Varies	Profile over 24 h – 2 wks

A.3.3 Energy Balance and Disaggregation

The energy balance ensures that all energy consumed can be accounted for by end-use. It is prepared using sub-meter readings and instrument measurements, and verified against utility bills.

Figure A-1: Typical Energy Disaggregation – Office Building (Indicative)

End-Use	Energy (MWh/yr)	% of Total	Savings Potential
HVAC (Chillers + AHU + Cooling Tower)	1800	45%	20–30%
Lighting (interior + exterior)	1000	25%	40–60%
Office Equipment (IT, plug loads)	600	15%	10–20%
Water Heating	200	5%	30–50%
Lifts / Elevators	160	4%	15–25%
Miscellaneous / Unaccounted	240	6%	—
TOTAL	4000	100%	—

A.3.4 Audit Report Structure (BEE Format)

- Executive Summary: Key findings, total savings potential (kWh/yr + Rs./yr), investment required, and simple payback.
- Building Profile: Location, construction year, gross floor area, occupancy type, operating hours.
- Energy Performance Baseline: 12-month utility analysis, EUI, load profile, power factor.
- End-Use Analysis: Disaggregated energy consumption with measurement data.
- Energy Conservation Opportunities (ECOs): Technical description, investment estimate, annual saving, simple payback, and priority ranking.
- Water Audit Findings: WUI analysis and water-saving measures.
- Renewable Energy Options: Solar PV/SWH potential, net metering considerations.
- Implementation Plan: Short-term (0–6 months, low/no cost), medium-term (6–18 months), long-term (> 18 months).
- Appendices: Measurement data, calculations, equipment datasheets, audit team credentials.

A.4 General Energy-Saving Tips – New and Existing Buildings

The following checklist of energy-saving measures is applicable to both new buildings (at design/construction stage) and existing buildings (as retrofit measures). They are classified by system and presented in order of typical cost-effectiveness.

A.4.1 Lighting

Measure	Energy Saving	Approx. Cost	Payback
Replace all T8 fluorescent with LED tubes	40–60%	Rs. 200–300/tube	1–2 yrs
Install occupancy sensors in meeting rooms	30–50%	Rs. 2000–5000/sensor	1–3 yrs
Daylight-linked dimming controls	20–40%	Rs. 8,000–15,000/zone	2–4 yrs
Upgrade to high-efficiency LED street/parking lights	50–70%	Rs. 5,000–15,000/point	2–4 yrs

A.4.2 HVAC

- Set thermostat at 24–26°C (BEE mandate for commercial: 24°C minimum setpoint). Each 1°C reduction increases energy use by ~6%.
- Clean air filters monthly; dirty filters increase fan energy by 15–25%.
- Ensure condenser coils are cleaned quarterly to maintain rated EER.
- Seal duct leakage (typically 20–30% of supply air); use mastic sealant, not duct tape.
- Schedule HVAC shutdown 30 minutes before occupancy ends (pre-cooling effect persists).
- Install VFDs on pumps and fans operating below 80% capacity.
- Periodic calibration of thermostats and building automation sensors.

A.4.3 Electrical Systems

- Maintain power factor above 0.95 using properly sized capacitor banks (PF penalty applies below 0.85 in many DISCOMs).
- Harmonics: Install passive filters for drives and UPS systems to reduce I²R losses.
- Right-size transformers: A transformer operating below 40% load has poor efficiency; replace with smaller unit or consolidate.
- Insulate all hot water and steam pipes; uninsulated steam pipe loses Rs. 30,000–80,000/metre/year.
- Use Energy Star-rated office equipment; enable sleep/hibernate mode after 5–10 minutes of inactivity.

A.4.4 Envelope & Infrastructure

- Apply white / reflective paint on roof to reduce cooling load by 10–15%.
- Seal gaps around doors, windows, service penetrations with weather stripping and foam sealant.
- Install solar films / window tints on east- and west-facing glass (SHGC reduction from 0.6 to 0.3 possible).
- Plant deciduous trees on east and west facades for natural summer shading (winter solar gain retained).
- Use automatic door closers and revolving/air-curtain entry to prevent conditioned air escape.

A.4.5 Behavioural / O&M Tips (No/Low Cost)

- Switch off lights, fans, and AC in unoccupied rooms and at end of working day.
- Use stairs instead of lifts for up to 3 floors.
- Avoid opening windows and doors when AC is operating.
- Print documents only when necessary; use double-sided printing.
- Defrost refrigerators before ice buildup exceeds 5 mm (reduces efficiency by 25%).
- Report leaking taps and flushing cisterns immediately; a single dripping tap wastes 40–50 L/day.

UNIT B: DEMAND SIDE MANAGEMENT (DSM)

Demand Side Management (DSM) refers to a set of strategies and programmes implemented by utilities and energy service providers to influence the amount and timing of electricity use by consumers. Rather than building new power plants to meet growing demand, DSM seeks to modify the demand curve through efficiency improvements, load shifting, and behavioural changes. DSM is now embedded in India's National Electricity Policy (2005), the Electricity Act (2003), and CERC/SERC regulations.

Definition (EPRI)

DSM is the planning, implementation, and monitoring of utility activities designed to encourage consumers to modify their level and pattern of electricity usage, including the timing and rate of use.

Table B-1: DSM vs. Supply-Side Management (SSM) – Key Differences

Parameter	Demand Side Management (DSM)	Supply Side Management (SSM)
Focus	Reduce / shift consumer demand	Increase generation / transmission capacity
Approach	Consumer end-use efficiency, load control	New power plants, T&D upgrades
Capital Intensity	Lower (1/3 to 1/5 of supply cost)	High
Lead Time	2–5 years	7–15 years
Environmental Impact	Positive (reduces emissions)	Depends on fuel mix
Indian Examples	UJALA scheme, Perform Achieve Trade (PAT)	Ultra Mega Power Projects, HVDC

B.1 Scope of Demand Side Management

DSM encompasses a broad spectrum of activities targeting the consumer side of the electricity meter. Its scope extends across all sectors of the economy and all time horizons.

B.1.1 Dimensions of DSM Scope

Table B-2: Scope of DSM – Sectoral and Functional Dimensions

Dimension	Categories	Examples / Schemes
Sectoral	Residential, Commercial, Industrial, Agricultural, Transport	UJALA (residential LEDs), MSME BEE schemes, Agriculture DSM pilots
Functional	Energy Efficiency, Load Shifting, Load Curtailment, Fuel Substitution	Star-labelling, TOU tariffs, DR programmes, CNG/LPG stoves
Temporal	Short-term (real-time), Medium-term (seasonal), Long-term (structural)	Direct load control, industrial rescheduling, building retrofit

Geographic	National, State, Feeder-level, Customer-level	National DSM Guidelines (MoP 2014), MSEDCL DSM, feeder DR
Technology	Smart metering, IoT, AI/ML, AMI infrastructure	Smart Grid pilots (Puducherry, Panipat), AMISP rollout

B.1.2 Benefits of DSM

- For Utilities: Deferred generation and T&D capacity investment; improved system load factor; reduced AT&C losses.
- For Consumers: Reduced electricity bills; improved power quality; greater control over usage.
- For Society/Nation: Reduced fuel imports (India imports $\approx 25\%$ of coal needs); lower GHG emissions; energy security.
- For Environment: Each unit of electricity saved at consumer end saves $\approx 1.5\text{--}2$ units at generation (accounting for T&D losses of 18–22% in India).

Table B-3: India's DSM Achievements – Key Schemes (as of 2024–25)

Scheme	Agency	Achievement	Annual Savings
UJALA (LEDs)	EESL / BEE	37+ crore LED bulbs distributed	47+ billion kWh/yr
PAT Scheme (Cycle I–VI)	BEE / MoP	13 sectors, 1000+ DCs	106 MToE cumulative
SEEP (Super Efficient ACs)	BEE / EESL	5-Star AC market development	600 MW peak demand
SLNP (Street Lighting)	EESL	1.4 crore LED street lights	9 billion kWh/yr
Agriculture DSM Pilots	State DISCOMs	Solar pump, demand shifting	State-level results

B.2 Evolution of the DSM Concept

The concept of DSM has evolved significantly over seven decades, driven by energy crises, environmental concerns, technological advances, and electricity market restructuring.

Table B-4: Historical Evolution of DSM – Timeline

Era / Period	Context	DSM Approach	Key Events
1950s–60s	Post-war growth; cheap energy	Load building: utilities encouraged MORE use to utilise excess capacity (valley filling)	Rural electrification, industrial boom
1970s	Oil Crisis 1973 & 1979	First conservation focus; fuel switching; efficiency mandates (EPCA 1975 – USA)	OPEC embargo; PURPA (1978 USA)

1980s	Integrated Resource Planning (IRP) era	DSM formally institutionalised; least-cost planning includes demand-side resources	EPRI DSM research; US utility DSM budgets rise
1990s	Deregulation / liberalisation	DSM programmes shrink due to competition; transition to market-based mechanisms	PUHCA repeal; restructuring debates
2000s	Climate change awareness; Smart Grid	DSM revived with GHG focus; Demand Response (DR) programmes emerge; Smart meters	Kyoto Protocol; FERC Order 719
2010s	Digitisation; RE boom; IoT	Smart DSM using AI/IoT; Vehicle-to-Grid (V2G); aggregator models; energy communities	Paris Agreement; SGAM; HOMER; India Energy Conservation Act
2020s–	Net Zero targets; prosumers	Transactive Energy; Flexibility markets; Building-to-Grid (B2G); VPP (Virtual Power Plants)	India DSM Guidelines 2022; AMISP 2.0

B.2.1 DSM in the Indian Context

- The Electricity Act 2003 and National Electricity Policy (NEP) 2005 provided the foundational framework for DSM in India.
- Bureau of Energy Efficiency (BEE) was established under the Energy Conservation Act 2001, with a specific mandate for DSM programmes.
- Ministry of Power issued National DSM Policy (2010) and National DSM Implementation Guidelines (2014) directing DISCOMs to prepare DSM Plans.
- Central Electricity Regulatory Commission (CERC) and State ERCs are mandated to create enabling regulations including Time-of-Use (ToU) tariffs.
- Smart Meter National Programme (SMNP) targets 250 million smart meters by 2025; foundational to real-time DSM.

B.3 DSM Planning and Implementation

DSM planning is a systematic process that identifies, evaluates, and selects the most cost-effective combination of demand-side resource options to meet utility objectives. It is an integral part of Integrated Resource Planning (IRP) which treats demand-side resources on an equal footing with supply-side resources.

B.3.1 Steps in DSM Planning

16. Market Assessment: Define the customer segments, estimate market size, and identify the most promising end-uses for DSM intervention.
17. Technical Potential Assessment: Determine the maximum theoretical savings assuming all cost-effective measures are adopted (typically 30–50% of total load in Indian buildings).
18. Economic Potential: Apply cost-effectiveness criteria to technical potential. Measures where NPV of savings > NPV of programme cost are economically feasible.
19. Achievable Potential: Adjust for market barriers (awareness, capital access, behaviour) to derive realistic near-term savings targets.
20. Programme Design: Select DSM programme types (rebates, audits, direct install, DR, financing), define incentive levels, and set targets (kWh saved, kW reduced, customers enrolled).
21. Cost-Benefit Analysis: Apply standard CBA tests (see Table B-5 below).
22. Implementation & Marketing: Deploy programmes through utility channels, energy service companies (ESCOs), and NGOs.
23. Monitoring, Verification & Evaluation (MV&E): Measure actual savings using IPMVP protocols; compare against baseline.

Table B-5: Standard DSM Cost-Benefit Tests

Test Name	Perspective	Benefits Counted	Costs Counted
Total Resource Cost (TRC)	Society / Total	Bill savings + avoided supply costs	Programme costs + participant costs
Programme Administrator Cost (PAC)	Utility	Avoided supply costs, T&D deferral	Utility programme costs only
Participant Test (PT)	Consumer	Bill savings + incentives received	Participant investment + time costs
Rate Impact Measure (RIM)	All Ratepayers	Avoided supply costs	Programme + lost revenue + incentives
Societal Test	Society (broad)	TRC + externality benefits (emissions)	TRC costs + externality costs

A B/C ratio > 1.0 for the relevant test indicates a cost-effective DSM programme.

B.3.2 DSM Programme Types

Programme Type	Mechanism	Indian Examples
Energy Efficiency Rebates	Cash rebate / subsidy for efficient equipment purchase	BEE Star-label AC subsidies; EESL LED bulk procurement

Audit & Advisory	Free/subsidised energy audits; BEE Certified Energy Auditor (CEA)	DISCOM-sponsored building audits; SME energy audit schemes
Direct Install	Utility installs efficient equipment (CFLs, LEDs, pumps) at no/low cost	UJALA scheme; SLNP street lights by EESL
Demand Response (DR)	Consumers reduce/shift load during peak periods in exchange for incentives	TATA Power DR pilot; MERC DR Regulations 2021
On-Bill Financing	Utility finances efficiency improvements; repaid through monthly bill savings	Proposed in BEE guidelines; limited implementation
Behaviour-Based DSM	Personalised energy reports; gamification; peer comparison	Opower model; Tata Power MyHome app

B.3.3 Monitoring, Verification & Evaluation (MV&E)

MV&E is the backbone of credible DSM implementation. The International Performance Measurement and Verification Protocol (IPMVP) defines four options:

- Option A: Partially measured retrofit isolation – Key parameter measured; others stipulated.
- Option B: Retrofit isolation with full measurement – All parameters metered before and after.
- Option C: Whole facility – Utility bill analysis using regression (pre- vs. post-installation, weather-normalised).
- Option D: Calibrated simulation – Energy model calibrated to metered data; used where Option C baseline is unavailable.

B.4 Load Management as a DSM Strategy

Load management (LM) is a subset of DSM that focuses on modifying the shape, timing, and magnitude of the electricity demand curve. It is particularly valuable for utilities managing system reliability during peak periods and deferring costly generation capacity.

B.4.1 Load Shape Objectives

Table B-6: Load Shape Modification Strategies

Strategy	Description	Example
Peak Clipping	Reduce peak demand only, usually by load control	Remotely switching off electric geysers during 6–9 PM
Valley Filling	Build off-peak load to improve load factor	Charge EV batteries at 2–5 AM; off-peak storage heating
Load Shifting	Move load from peak to off-peak; total consumption unchanged	Run dishwashers/washing machines at night; pre-cool buildings
Strategic Conservation	Overall reduction in consumption (permanent efficiency gains)	LED lighting replacing incandescent; motor rewind upgrade

Strategic Load Growth	Increase consumption to use surplus generation	EV charging to absorb excess RE; heat pumps for DHW
Flexible Load Shape	Consumer agrees to variable load to assist grid balancing	Interruptible contracts for large industrial consumers

B.4.2 Load Factor and Demand Factor

Key metrics in load management:

- Load Factor (LF) = Average Demand / Maximum Demand × 100%. A higher LF indicates better utilisation of generation assets. Indian grid LF historically 60–70%; improved through DSM to 72–75%.
- Demand Factor (DF) = Maximum Demand / Connected Load × 100%. Reflects the simultaneity of loads being energised.
- Diversity Factor (DivF) = Sum of individual maximum demands / Simultaneous maximum demand. DivF > 1 means not all loads peak simultaneously (typical DivF for residential feeders: 2–4).
- Coincidence Factor (CF) = 1 / DivF. The fraction of loads that coincide at system peak.

Table B-7: Typical Load Factors – Indian Context

Consumer Type	Typical LF (%)	Target LF (%)	Peak Hours
Residential	25–35	40–50	6–9 PM
Commercial (offices)	40–55	60–70	10 AM–1 PM
Industrial (continuous)	70–90	85–95	Variable
Agriculture	15–30	30–45	Day + night
State Grid (India avg.)	63–72	75–80	7–11 PM

B.5 Applications of Load Control

Load Control (LC) is the most direct form of DSM, involving direct or indirect control of consumer end-use equipment to reduce demand at specific times. It requires communication infrastructure between the utility and the controllable load.

B.5.1 Direct Load Control (DLC)

In DLC, the utility remotely cycles or switches off selected consumer appliances during peak periods, typically in exchange for a bill credit or reduced tariff. The consumer is notified in advance (typically 24–48 hours).

- Residential DLC Targets: Electric water heaters (EWH), air conditioners, swimming pool pumps, EV chargers.
- Technology: One-way or two-way radio/power-line carrier (PLC) switches; smart plugs; IoT gateways with AMI.
- Control Cycle: Typical 50% duty cycle – 15 minutes ON, 15 minutes OFF. Consumer comfort maintained; bill savings 5–15%.
- USA Example: Southern California Edison had 700,000+ enrolled water heater DLC customers achieving 700 MW of demand reduction.
- India Example: BESCOM (Bengaluru) pilots with smart AC control in residential apartments.

B.5.2 Indirect Load Control – Demand Response (DR)

DR involves price signals or financial incentives that motivate consumers to voluntarily reduce or shift loads, without direct utility control.

DR Programme Type	Mechanism	Typical Applications
Interruptible / Curtailable (I/C)	Consumer agrees to reduce load on notice (2–24 hrs)	Large industrial; data centres; cold storage
Real-Time Pricing (RTP)	Hourly or 15-min tariff reflecting wholesale market prices	Industrial with automated load shifting; C&I
Critical Peak Pricing (CPP)	Very high tariff (3–10x normal) for 10–15 critical days/year	Residential with smart thermostats; offices
Emergency DR (EDR)	Mandatory load reduction during grid emergencies	Large C&I consumers with interruptible contracts
Automated DR (OpenADR)	Machine-to-machine DR signals without human intervention	BAS-integrated buildings; smart factories

B.5.3 Smart Grid-Enabled Load Control

- Advanced Metering Infrastructure (AMI): Two-way communication between utility and smart meters enables real-time data exchange and remote disconnection/reconnection.
- Home Energy Management System (HEMS): Residential IoT platform that automates load scheduling (AC, EV charger, dishwasher) based on ToU tariff signals.
- Building Energy Management System (BEMS/BMS): Commercial equivalent – manages HVAC, lighting, and plug loads based on DR signals and BAS automation.
- Virtual Power Plants (VPP): Aggregation of distributed resources (batteries, DR, rooftop PV) into a dispatchable resource equivalent to a power plant. India pilots in progress (TATA Power, ReNew Power).
- Vehicle-to-Grid (V2G): EVs return stored energy to grid during peak periods; bidirectional chargers required. Japan, UK leading; India V2G policy under development.

B.6 End-Use Energy Conservation

End-use energy conservation addresses energy efficiency improvements at the point of consumption – the actual devices and systems that consume electricity. It is the most permanent and reliable form of DSM, resulting in structural reductions in the demand curve.

B.6.1 Residential Sector

Table B-8: End-Use Energy Conservation Measures – Residential Sector

End-Use	Measure	Saving (%)	Technology / Notes
Space Cooling (AC)	Upgrade to 5-Star Inverter AC	30–40%	ISEER $\geq$ 5.0; VFD compressor reduces cycling losses
Lighting	Replace incandescent / CFL with LED	50–80%	LED: 80–120 lm/W vs. 15 lm/W incandescent
Refrigerator	Replace pre-2010 model with 5-Star BEE	30–50%	Frost-free inverter compressor; door seal check
Water Heating	Solar water heater / heat pump	60–80%	FPC/ETC collectors; HP COP 3–4 vs. 1.0 for resistance
Washing Machine	Front-load 5-Star vs. top-load	30–45%	Also saves 40–50% water
Fans	BLDC fan replacing induction fan	50–65%	BLDC: 28–35 W vs. 75–85 W conventional
Cooking	Induction cooktop + pressure cooker	20–40%	Induction efficiency $\approx$ 85% vs. 40% gas

B.6.2 Commercial Sector

- HVAC: Variable Refrigerant Flow (VRF) systems are 25–40% more efficient than conventional FCU systems; Building Management System (BMS) integration further saves 10–20%.
- Lighting: Smart LED lighting with BACnet integration and DALI dimming reduces lighting energy by 50–70% vs. conventional fluorescent.
- IT Equipment: Server virtualisation reduces data centre IT load by 30–50%; free-air cooling reduces PUE from 2.0 to 1.2–1.4.
- Elevators: Regenerative drives on lifts recover braking energy (15–30% of lift energy); destination dispatch systems reduce trips.
- Power Factor Correction: Automatic Power Factor Controller (APFC) panel with capacitor banks maintains PF > 0.95 and avoids DISCOM surcharges.

B.6.3 Industrial Sector

Table B-9: Major End-Use Conservation in Industry

End-Use	Share of Ind. Energy	Saving Potential	Key Technology
Electric Motors & Drives	65–70%	20–30%	IE3/IE4 motors + VFD; correct sizing

Compressed Air Systems	10–15%	25–40%	Leak detection (Ultrasonic); VFD compressors
Boilers & Steam Systems	Varies (process heat)	15–25%	Condensate return; O ₂ trim control; insulation
Process Cooling / Refrigeration	5–15%	15–30%	Evaporative precooling; high-COP screw chillers
Lighting (Industrial)	5–10%	40–60%	LED high-bay (160 lm/W) replacing HPMV/HPSV

B.6.4 The Energy-Water Nexus in End-Use Conservation

Energy and water are deeply interlinked: it takes energy to pump, treat, and heat water; and it takes water to generate thermal electricity (cooling tower). DSM programmes that address both simultaneously yield greater returns. Key nexus points:

- Water pumping accounts for 25–30% of electricity consumed by Indian municipalities.
- Each kL of hot water saved (using SWH) saves ≈ 1.5 –2.5 kWh of electrical energy.
- Cooling tower water savings of 30% (by increasing CoC from 2 to 5) also reduce pump energy by 15–20%.

B.7 Tariff Options for DSM

Tariff design is one of the most powerful and market-efficient tools for DSM. By aligning the price of electricity with the actual cost of supply at different times and conditions, utilities can incentivise consumers to shift or reduce consumption without direct intervention. Tariff-based DSM is sometimes called Passive DSM.

B.7.1 Overview of DSM Tariff Instruments

Table B-10: DSM Tariff Options – Comprehensive Comparison

Tariff Type	Mechanism	DSM Objective	Consumer Response
Flat Rate (Baseline)	Single rate per kWh irrespective of time / volume	None (reference)	No incentive to shift
Time-of-Use (ToU)	Different rates for peak, off-peak, shoulder periods (typically 3 bands)	Load shifting	Shift loads to off-peak
Critical Peak Pricing (CPP)	Super-peak rate on 10–15 critical days + standard ToU otherwise	Peak clipping	Curtail during CPP events
Real-Time Pricing (RTP)	Rates change every hour or 15 minutes tracking wholesale spot price	Load following	Continuous adjustment (automated)
Inclining Block Rate (IBR)	Higher rate per kWh as monthly consumption increases	Conservation / efficiency	Reduce overall consumption

Declining Block Rate (DBR)	Lower rate for higher consumption (promotes load growth)	Valley filling (legacy)	Increase consumption (anti-DSM if overused)
Demand Charge	Rs./kVA or Rs./kW of maximum demand registered in billing period	Peak demand reduction	Shift or curtail peak loads
Interruptible / Curtailable Rate	Discounted rate for consumers who agree to load curtailment on utility request	Emergency DR	Accept interruptions for discount
Net Metering / Feed-in Tariff	Credit for surplus RE exported to grid; encourages prosumer behaviour	DG integration + DSM	Self-generate, export surplus

B.7.2 Time-of-Use (ToU) Tariff – Details

ToU tariffs are the most widely implemented DSM tariff in India and globally. They create a price differential between peak, off-peak, and (sometimes) shoulder periods, giving consumers a financial incentive to shift discretionary loads.

Table B-11: Example ToU Tariff Structure – HT Consumer (Illustrative, MSEDCL-type)

Period	Hours	Rate (Rs./kWh)	Remarks
Peak	06:00–09:00 & 18:00–22:00	9.50–12.00	Highest demand; AC peak, evening cooking
Normal / Shoulder	09:00–18:00 & 22:00–23:00	6.50–8.00	Daytime office loads
Off-Peak	23:00–06:00	3.50–4.50	Load incentive; EV charging; storage charging
Fixed/Demand Charge	Per billing month	Rs. 250–400/kVA	Based on max 15-min kVA in month

Peak-to-off-peak ratio: 2.5x to 3.5x. This ratio strongly influences consumer load shifting behaviour.

B.7.3 Inclining Block Rate (IBR) – Conservation Focus

- IBR structure: Block 1 (0–100 units): Rs. 3/kWh; Block 2 (101–300 units): Rs. 5.50/kWh; Block 3 (> 300 units): Rs. 7.50/kWh.
- Rationale: Low-income households use less electricity and pay lower average rates; heavy users pay progressively more.
- India Context: Most State DISCOMs already use IBR for LT residential consumers. MPERC, KERC, APERC have IBR slabs in their multi-year tariff orders.
- Conservation Effect: Studies show 10–15% reduction in average household consumption when IBR replaces flat rate, particularly in upper consumption bands.

B.7.4 Green Tariffs and Renewable Energy Certificates (RECs)

- Green Tariff: Premium tariff consumers pay to procure RE-backed power. Increasingly offered by DISCOMs and Open Access providers. Premium: Rs. 0.50–2.00/kWh.

- Renewable Energy Certificates (REC): Tradeable certificates representing 1 MWh of RE generation. Can be purchased by RPO (Renewable Purchase Obligation) obligated entities.
- Open Access DSM: Large HT consumers (> 1 MW) can procure power directly from RE generators under Open Access (Section 42, Electricity Act 2003), bypassing DISCOM peak charges.

B.7.5 Regulatory Framework for DSM Tariffs in India

Regulation / Policy	Year	Key DSM Tariff Provision
Electricity Act, 2003	2003	Sec. 61(g): Tariffs shall be progressive; Sec. 65: Subsidies via state budget, not cross-subsidy
National Electricity Policy	2005	Time-of-Day metering for all HT consumers; ToU tariffs for all consumers over time
National Tariff Policy (NTP)	2006 (rev. 2016)	Mandates ToU; Sec. 8.5: Smart meters prerequisite; 8.1: Cross-subsidy reduction roadmap
DSM Policy (MoP)	2010	DISCOMs must prepare DSM Plans; ToU tariff as mandatory DSM tool
CERC (DSM) Regulations	2010 (amended)	Intraday demand deviation penalties/incentives; Deviation Settlement Mechanism (DSM)
SERC DR Regulations (e.g. MERC)	2021	Framework for voluntary DR programmes; aggregator licensing; CPP provisions

MODULE 5 – CONSOLIDATED SUMMARY

Table S-1: Module 5 Topic Summary with Key Figures

Topic	Key Concepts	Important Figures / Standards
Energy-Saving Measures – New Buildings	Envelope (U-value, SHGC), HVAC (COP, IPLV), Lighting (LPD, lm/W), RE Integration, Cool Roofs	ECBC 2017; SRI ≥ 78 ; WWR $\leq 40\%$; LED: 80–120 lm/W; Chiller COP ≥ 5.6
Water Audit	Water Balance, WUI, Leak Detection, Greywater Recycling, Cooling Tower CoC, Rainwater Harvesting	Office WUI < 25 L/person/day; CT CoC = 5 saves 60%; 1000 m ² roof = 900 kL/yr (Bengaluru)
Method of Audit	Level I/II/III Audit, Energy Balance, Disaggregation, Instruments, IPMVP MV&E	HVAC = 45% of office energy; 12-month utility data baseline; BEE audit format
General Energy-Saving Tips	Lighting retrofits, HVAC setpoints (24°C), PF correction, envelope sealing, occupant behaviour	1°C rise in setpoint = 6% AC saving; PF > 0.95 ; LED savings 50–75%
Scope of DSM	Residential, C&I, Industrial, Agricultural; short/medium/long-term; national schemes	UJALA: 47 bn kWh/yr; PAT: 106 MTtoE; SLNP: 9 bn kWh/yr savings
Evolution of DSM	1950s load building → 1970s conservation → 1980s IRP → 2000s Smart Grid → 2020s VPP/V2G	Energy Conservation Act 2001; NEP 2005; DSM Policy 2010; SMNP 250 mn meters
DSM Planning & Implementation	Market assessment, Technical/Economic/Achievable potential, CBA tests, Programme types, MV&E	TRC, PAC, PT, RIM, Societal tests; B/C > 1.0 ; IPMVP Options A/B/C/D
Load Management	Peak clipping, Valley filling, Load shifting, Strategic conservation, Flexible load shape	LF = Avg./Max. demand; Indian grid LF 63–72%; DivF 2–4 for residential
Applications of Load Control	DLC (EWH, AC cycling), Demand Response (I/C, RTP, CPP, OpenADR), VPP, V2G, AMI	50% duty cycle DLC; SCE: 700 MW from DLC; India: BESCOM AC pilot
End-Use Energy Conservation	Residential (5-Star AC, LED, BLDC fan, SWH), Commercial (VRF, BMS), Industrial (IE4 motors, VFD, CA leaks)	Motors = 65% industrial energy; CA leaks = 30% loss typical; BLDC fan: 28–35 W vs 80 W
Tariff Options for DSM	ToU, CPP, RTP, IBR, DBR, Demand Charge, Interruptible Rate, Net Metering, Green Tariff	Peak: Rs. 9.5–12/kWh; Off-peak: Rs. 3.5–4.5/kWh; Peak:Off-peak ratio 2.5–3.5x; IBR saves 10–15%

Important Formulae – Quick Reference

Parameter	Formula	Unit
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Energy Use Intensity (EUI)	Total Annual Energy / Gross Floor Area	kWh/m ² /year
Load Factor	Average Demand / Maximum Demand × 100	%
Demand Factor	Max. Demand / Total Connected Load × 100	%
Diversity Factor	Sum of Individual Max. Demands / Simultaneous Max. Demand	Dimensionless (> 1)
Fan Law (Power)	$P_2/P_1 = (N_2/N_1)^3 = (Q_2/Q_1)^3$	kW
Simple Payback Period	Investment Cost / Annual Saving	Years
COP (Chiller / Refrigeration)	Cooling Effect (kW) / Power Input (kW)	Dimensionless
EER (Air Conditioner)	Cooling Output (BTU/h) / Power Input (W)	BTU/Wh
Lighting Power Density	Total Wattage of Luminaires / Floor Area	W/m ²
Water Use Index (WUI)	Total Water Used per day / No. of Occupants	L/person/day

Probable IGNOU Examination Questions

Short Answer Questions (5–6 marks):

24. Define DSM. What are the six load shape objectives in DSM?
25. Explain the significance of the Energy Conservation Building Code (ECBC) 2017.
26. What is a Water Audit? State the steps involved in conducting one.
27. Differentiate between Direct Load Control and Demand Response.
28. State any four DSM tariff options with brief descriptions.
29. What is Load Factor? How does DSM improve the load factor of a utility?

Long Answer Questions (10–12 marks):

30. Describe the methodology of conducting an energy audit of a commercial building. Include instruments used, types of audits, and the structure of an audit report.
31. What is DSM? Trace the evolution of DSM from 1950s to present day. Discuss DSM planning steps and cost-benefit tests.
32. Explain the energy-saving measures applicable to new buildings, covering envelope design, HVAC, lighting, and renewable energy integration. Provide relevant standards and figures.
33. Discuss the various tariff options for implementing DSM. Illustrate with an example ToU tariff structure and explain how IBR promotes energy conservation.
34. Write a detailed note on end-use energy conservation in the residential and industrial sectors, with efficiency data and technologies.

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— End of Module 5 Notes —