

ENERGY CONSERVATION AND AUDIT

BEE755B | AY 2026-27

MODULE 3: ENERGY AUDITING

LEARNING OBJECTIVES

After studying this module, you will be able to:

- ☐ Define energy audit and explain its objectives and importance
- ☐ Identify and describe the elements and types of energy audits
- ☐ Develop energy use profiles for industrial and commercial establishments
- ☐ Apply measurement techniques used during energy audits
- ☐ Compile and present energy audit reports professionally

3.1 Introduction to Energy Auditing

Energy auditing is a systematic inspection, survey, and analysis of energy flows in a building, process, or system to reduce the amount of energy input while maintaining or improving the level of service provided. It forms the cornerstone of any energy management programme and acts as the starting point for identifying and quantifying energy-saving opportunities.

The term energy audit was first used formally in the United States after the 1973 Arab oil embargo, which caused global energy prices to escalate sharply. The concept was later codified by international standards such as ISO 50001:2018 (Energy Management Systems) and the Bureau of Energy Efficiency (BEE) guidelines under the Energy Conservation Act, 2001 in India.

3.1.1 Definition

According to the Bureau of Energy Efficiency (BEE), Government of India:

"Energy Audit is the key to a systematic approach to decision-making in the area of energy management. It seeks to prioritise the energy uses according to the greatest to least cost effective opportunities for energy savings."

— Bureau of Energy Efficiency (BEE), India

3.1.2 Why Energy Auditing?

Energy is one of the major cost components in manufacturing, commercial establishments, and infrastructure. Energy costs typically account for 20–40% of total production costs in energy-intensive industries such as cement, steel, aluminium, and textile manufacturing.

Industry Sector	Energy Cost as % of Production Cost	Typical Energy Savings Potential
Cement	20 – 30%	10 – 25%
Steel & Iron	25 – 35%	15 – 20%
Textile	15 – 25%	10 – 30%
Pulp & Paper	20 – 30%	15 – 25%
Petrochemicals	30 – 40%	10 – 20%
Commercial Buildings	10 – 20%	20 – 40%

Table 3.1: Energy Cost and Savings Potential Across Sectors

3.1.3 Objectives of Energy Audit

The primary objectives of conducting an energy audit are:

- ☐ To identify all the energy inputs and their cost in the facility
- ☐ To quantify energy consumption by each end-use category
- ☐ To identify areas of energy waste and inefficiency
- ☐ To establish energy performance baselines and benchmarks
- ☐ To evaluate and rank energy conservation measures (ECMs) by cost-benefit
- ☐ To recommend technically feasible and economically viable energy-saving projects
- ☐ To monitor and verify energy savings post-implementation
- ☐ To support compliance with the Energy Conservation Act, 2001 (India) and related regulations

3.1.4 Regulatory Framework in India

The Energy Conservation Act, 2001, enacted by the Government of India, mandates energy audits for designated consumers — large energy users in specified sectors. Key provisions include:

Provision	Details
Section 3	BEE empowered to set energy consumption standards and direct audits

Provision	Details
Section 14	Designated consumers (DCs) must get energy audits by accredited energy auditors
Section 33	Penalties up to Rs. 10 lakhs for non-compliance; Rs. 1 lakh per day for continuing offences
Schedule DC	14 sectors notified: Thermal power, Iron & Steel, Cement, Fertiliser, Textile, Paper, Chlor-alkali, Aluminium, Railways, Transport, Petroleum, Petrochemicals, Hotels, Hospitals

Table 3.2: Key Provisions of Energy Conservation Act, 2001

NOTE: A Designated Consumer (DC) is typically an industrial unit or establishment consuming energy beyond prescribed thresholds (e.g., >500 TOE/year for some sectors). DCs must conduct mandatory energy audits every 3 years.

3.2 Elements of Energy Audits

An energy audit comprises several well-defined elements that together enable a thorough assessment of an organisation's energy performance. These elements form an interlocking framework — each feeds information to the next.

3.2.1 The Seven Core Elements

Element 1: Pre-Audit (Planning) Phase

This preparatory stage defines the scope, boundary, and objectives of the audit. Activities include:

- ☐ Review of utility bills (electricity, fuel, water) for the past 12–36 months
- ☐ Understanding the process flow and energy-intensive operations
- ☐ Identification of energy streams and major end-use equipment
- ☐ Preparation of audit questionnaire and data collection formats
- ☐ Scheduling plant visits and coordination with facility management
- ☐ Selection of appropriate instrumentation and measurement tools

Element 2: Energy Accounting and Data Collection

This element involves systematic collection and verification of all energy-related data:

- ☐ Collection of purchase records: electricity bills, fuel invoices, steam logs
- ☐ Recording equipment ratings, operating hours, and load factors
- ☐ Compilation of production data correlated with energy use
- ☐ Spot measurements of power, temperature, flow, illumination, etc.
- ☐ Verification of metering instruments for accuracy and calibration

The Energy Accounting Process can be summarised as:

Step	Action	Output
1	Collect energy purchase data	Energy input (kWh, kL, MT, GJ)
2	Measure energy use by equipment	Equipment-wise energy map
3	Correlate with production output	Specific Energy Consumption (SEC)
4	Compare with benchmarks/norms	Performance gap analysis

Step	Action	Output
5	Identify deviations	List of improvement areas

Table 3.3: Energy Accounting Process Steps

Element 3: Energy Balance (Sankey Diagram)

An energy balance tracks the flow of energy from input sources through various processes to useful outputs and losses. A Sankey diagram visually represents these flows, with the width of arrows proportional to energy quantity.

Energy Balance Equation:

$$\text{Energy Input} = \text{Useful Energy Output} + \text{Energy Losses} + \text{Energy Stored}$$

Typical energy distribution in a process industry:

Energy Stream	Typical Range (%)	Remarks
Useful product energy	40 – 65%	Varies by process
Flue gas losses	15 – 30%	Key target for heat recovery
Radiation & convection losses	5 – 10%	Surface insulation measures
Cooling water losses	3 – 8%	Heat exchangers / recuperators
Steam/condensate losses	2 – 5%	Steam traps, pipe insulation
Electrical conversion losses	3 – 8%	Motors, transformers, drives

Table 3.4: Typical Energy Distribution in Process Industry

Element 4: Analysis and Benchmarking

Benchmarking compares an organisation's energy performance against:

- ☐ Internal benchmarks: past performance of the same facility
- ☐ Industry benchmarks: national or international sectoral averages
- ☐ Technology benchmarks: best available technology (BAT) performance

Specific Energy Consumption (SEC) — the primary benchmarking metric — is defined as:

$$\text{SEC} = \frac{\text{Total Energy Consumed (GJ or TOE)}}{\text{Total Production Output (tonnes, units, etc.)}}$$

Unit: GJ/tonne | kWh/unit | TOE/MT etc.

NOTE: TOE = Tonne of Oil Equivalent. 1 TOE = 41.87 GJ = 11,630 kWh. This is the standard unit for comparing different fuel types.

Element 5: Identification of Energy Conservation Measures (ECMs)

Based on the energy balance and benchmarking analysis, potential ECMs are identified across three categories:

Category	Description	Examples
No-Cost ECMs	Operational & maintenance improvements requiring minimal or no investment	Good housekeeping, switching off idle loads, fixing steam leaks
Low-Cost ECMs	Minor investments, typically < Rs. 5 lakhs; payback < 1 year	Power factor correction capacitors, insulation of pipes, VFD on fans
Capital ECMs	Significant capital investment, payback 2–5 years or more	Boiler replacement, WHR system, high-efficiency motors, solar PV

Table 3.5: Categories of Energy Conservation Measures

Element 6: Cost-Benefit Analysis (CBA)

Each ECM is evaluated for financial viability using the following metrics:

Financial Metric	Formula	Decision Criterion
Simple Payback Period (SPP)	$SPP = \text{Initial Investment} / \text{Annual Energy Savings (Rs.)}$	$SPP < 3 \text{ years preferred}$
Net Present Value (NPV)	$NPV = \text{Sum of [PV of Annual Savings]} - \text{Initial Cost}$	$NPV > 0 \rightarrow \text{Viable}$
Internal Rate of Return (IRR)	Discount rate at which $NPV = 0$	$IRR > WACC \rightarrow \text{Viable}$
Benefit-Cost Ratio (BCR)	$BCR = \text{PV of Benefits} / \text{PV of Costs}$	$BCR > 1.0 \rightarrow \text{Viable}$

Table 3.6: Financial Metrics for ECM Evaluation

Element 7: Report Writing and Implementation Plan

The final element synthesises all findings into a structured audit report with an actionable implementation plan. This is discussed in detail in Section 3.6.

3.3 Types of Energy Audits

Energy audits vary in scope, depth, and resource requirements. The selection of audit type depends on the facility's size, complexity, budget, and specific objectives. Three principal types are recognised internationally (ASHRAE Standards 90.1 and 211; BEE Guidelines), as described below.

Characteristic	Type I: Walk-Through / Preliminary Audit	Type II: General / Standard Audit	Type III: Detailed / Investment-Grade Audit
Also Known As	Scoping Audit	Comprehensive Energy Audit	Investment-Grade Audit (IGA)
Duration	1–2 days	1–4 weeks	4–12 weeks or more
Depth	Superficial; visual inspection only	Moderate; includes measurements and calculations	Exhaustive; engineering simulation and verification
Data Collection	Utility bills, interviews, walkaround	Equipment inventories, spot measurements	Sub-metering, long-term monitoring, lab tests
Instrumentation	Minimal or none	Portable meters (kWmeter, lux, flue gas analyser)	Full suite + data loggers + simulation tools
Savings Accuracy	±30–50%	±20–30%	±5–10%
Cost of Audit	Low	Moderate	High
Suitable For	Initial screening; small facilities	Medium to large facilities; targeted areas	Major capital investment decisions; green financing
Deliverable	Short report listing key observations and opportunities	Detailed report with ECM analysis and SPP	Bankable report with IRR, NPV, M&V plan

Table 3.7: Comparison of Energy Audit Types

3.3.1 Type I — Walk-Through / Preliminary Audit

The walk-through audit is a rapid assessment conducted by an energy auditor walking through the facility with a checklist. It relies primarily on visual observation, review of existing records, and brief interviews with facility staff.

Key Characteristics:

- ☐ Duration: 1–2 days for typical industrial unit
- ☐ No sophisticated instruments required

- ❑ Focuses on obvious energy waste such as steam leaks, idle running equipment, poor insulation, lack of lighting controls
- ❑ Provides a rough estimate of energy savings potential (± 30 – 50%)
- ❑ Output: Short report (5–15 pages) with observations and priority recommendations

Typical Checklist Items:

- ≡ Compressed air leaks (audible hissing)
- ≡ Steam trap condition and steam leaks
- ≡ Motor loading (measured vs nameplate)
- ≡ Lighting levels and controls
- ≡ Boiler operating conditions and flue gas colour
- ≡ Thermal insulation condition on pipes and vessels
- ≡ Power factor reading from main panel

3.3.2 Type II — General / Standard Audit

The standard energy audit is the most commonly employed type for medium and large facilities. It builds upon the walk-through audit by incorporating quantitative measurements, detailed data collection, and engineering calculations.

Key Steps:

1. Detailed energy use profiling by end-use category and time period
2. Equipment-level measurements using portable instruments
3. Energy balance calculations for major systems (boilers, motors, HVAC, compressors)
4. Benchmarking against industry norms and best practices
5. Identification and quantification of ECMs with estimated savings
6. Financial analysis (SPP, NPV) and prioritisation of ECMs
7. Preparation of comprehensive audit report with action plan

NOTE: A Standard Energy Audit is mandatory for Designated Consumers (DCs) under the Energy Conservation Act, 2001. It must be conducted by a BEE-certified energy auditor once every three years.

3.3.3 Type III — Detailed / Investment-Grade Audit (IGA)

The Investment-Grade Audit (IGA) is the most rigorous and comprehensive audit type. It is typically commissioned when large capital expenditure is contemplated (e.g., >Rs. 50 lakhs) or when energy performance contracts (EnPC) with guaranteed savings are being structured.

Distinguishing Features of IGA:

- ☐ Sub-metering and long-term monitoring (typically 2–6 weeks of data logging)
- ☐ Dynamic engineering simulations (e.g., DOE-2, EnergyPlus for buildings; Aspen for chemical processes)
- ☐ Measurement and Verification (M&V) plan included (IPMVP Protocol)
- ☐ Bankable financial analysis including sensitivity analysis
- ☐ Applicable for ESCo (Energy Service Company) engagements where savings are guaranteed
- ☐ Report size: 50–150+ pages with technical appendices

3.3.4 Other Specialised Audit Types

In addition to the above, several specialised audits are conducted for specific purposes:

Audit Type	Focus and Purpose
Electrical Audit	Power quality, transformer losses, motor efficiency, harmonic distortion, PF correction
Thermal / Fuel Audit	Boiler efficiency, furnace performance, insulation, heat recovery from flue gases
Steam Audit	Steam generation, distribution, utilisation, condensate recovery, steam trap management
Water Energy Audit	Pumping energy, water treatment, cooling tower efficiency, water leakage
Compressed Air Audit	Compressor efficiency, leak detection, pressure optimisation, end-use pressure mapping
Retro-commissioning Audit	For existing buildings: ensures systems are functioning per design intent after retrofits
Carbon / GHG Audit	Quantifies GHG emissions linked to energy use; basis for carbon reduction targets and reporting

Table 3.8: Specialised Energy Audit Types

3.4 Energy Use Profiles

An energy use profile is a systematic description of how, when, and where energy is consumed within a facility. It provides the auditor with a clear picture of energy demand patterns and forms the analytical backbone of the audit.

3.4.1 Types of Energy Use Profiles

(a) Temporal Profile (Load Curves)

The temporal profile shows energy consumption variation over time — hourly, daily, weekly, monthly, or seasonal. It is typically derived from utility meter readings, demand controllers, or data loggers.

Key parameters derived from load curves:

- ☐ Peak Demand (kVA or kW) — determines maximum demand charges in the electricity tariff
- ☐ Load Factor = $\text{Average Load} / \text{Peak Load} \times 100\%$ (higher is better; target > 80%)
- ☐ Diversity Factor = $\text{Sum of Individual Peak Demands} / \text{System Peak Demand}$
- ☐ Demand Duration Curve — shows how many hours each demand level is sustained

Time Period	Mon–Fri kW (Avg)	Sat kW (Avg)	Sun kW (Avg)	Load Factor (%)
06:00 – 09:00	320	210	90	—
09:00 – 13:00	680	560	120	—
13:00 – 18:00	750 (Peak)	590	100	—
18:00 – 22:00	480	310	85	—
22:00 – 06:00	150	130	75	—
Average kW	476	360	94	—
Load Factor	63.5%	61.0%	78.3%	—

Table 3.9: Sample Temporal Energy Use Profile (Illustrative for a Medium Industry)

(b) End-Use Profile (Pie Chart / Sankey)

This profile categorises energy consumption by end use — motors, lighting, HVAC, process heating, etc. It identifies the major consumers on which the auditor should focus.

End-Use Category	Installed kW	Share of Consumption (%)	Priority for Savings
Electric Motors (pumps, fans, compressors)	820	38%	High — VFD retrofits, motor rewinding
Process Heating (furnaces, ovens, dryers)	480	26%	High — combustion optimisation, insulation
Compressed Air System	320	16%	High — leak repair, pressure reduction
HVAC / Cooling	180	9%	Medium — chiller COP improvement
Lighting	120	6%	Medium — LED retrofit, daylight controls
Steam Generation	88	3%	Medium — boiler efficiency, condensate return
Miscellaneous / Standby	48	2%	Low — housekeeping measures
TOTAL	2,056	100%	

Table 3.10: Sample End-Use Energy Profile (Illustrative for Large Industry)

(c) Source / Fuel-Mix Profile

This profile shows the breakdown of energy by source or carrier — electricity, coal, furnace oil, LPG, natural gas, biomass, etc. It is important for:

- ☐ Calculating energy costs and tariff optimisation
- ☐ Computing Greenhouse Gas (GHG) / carbon footprint
- ☐ Identifying opportunities for fuel switching (e.g., coal to gas; grid to solar)

Energy Source	Annual Quantity	GJ/year	Cost (Rs. Lakh)	Share (%)
Electricity (Grid)	4,200,000 kWh	15,120	462.0	41%
Furnace Oil	480 kL	17,280	336.0	47%
LPG	24 MT	1,152	32.4	3%
DG Set (HSD)	36 kL	1,296	39.6	4%
Solar PV (Captive)	180,000 kWh	648	0.0	2%*
Biomass	180 MT	2,700	9.0	7%
TOTAL	—	38,196 GJ	879.0	100%

Table 3.11: Sample Energy Source / Fuel-Mix Profile (* Solar reduces grid purchase; not separately billed)

3.4.2 Energy Performance Indices (EPIs)

EPIs (also called Key Performance Indicators for energy) allow comparative tracking of energy efficiency over time and across facilities. Common EPIs include:

EPI Name	Formula	Typical Unit	Applicable To
Specific Energy Consumption (SEC)	Energy / Production	GJ/tonne; kWh/unit	Industry
Energy Use Intensity (EUI)	Energy / Floor Area	kWh/m ² /year	Buildings
Energy Cost Ratio (ECR)	Energy Cost / Turnover	%	Industry / Commercial
Fuel Efficiency / Boiler Efficiency	Heat Output / Heat Input	% (typically 70–90%)	Boilers / Furnaces
Motor System Efficiency	Shaft Power / Input Power	% (IE2: 88–93%)	Electrical Systems

Table 3.12: Common Energy Performance Indices

3.5 Measurements in Energy Audits

Accurate measurements are the foundation of a credible energy audit. Measurement activities convert qualitative observations into quantitative data, enabling calculation of energy balances, efficiency parameters, and savings potential. The golden rule in energy auditing is:

"What cannot be measured, cannot be managed." — Peter Drucker

3.5.1 Electrical Measurements

Electrical measurements are essential for assessing the performance of motors, drives, transformers, power distribution systems, and lighting.

Parameter	Instrument	Unit	Purpose / Remarks
Voltage (V)	Clip-on / digital multimeter	Volts (V)	Check voltage unbalance; target $\leq 1\%$ unbalance
Current (I)	Clamp meter (CT clamp)	Amperes (A)	Motor loading; compare with nameplate FLA
Active Power (kW)	Power analyser / kWmeter	kW	True power consumed; basis for cost calculation
Reactive Power (kVAR)	Power analyser	kVAR	Excess VAR $\rightarrow$ poor PF; needs capacitor bank
Apparent Power (kVA)	Power analyser	kVA	$kVA = \sqrt{(kW^2 + kVAR^2)}$; basis of maximum demand tariff
Power Factor (PF)	Power analyser / power meter	dimensionless (0–1)	Target PF ≥ 0.95 ; penalty below 0.85 in most tariffs
Energy (kWh)	Energy meter / data logger	kWh	Integrate power over time; use for baseline and billing check
Frequency (Hz)	Power analyser	Hz	Standard 50 Hz; frequency sag affects motor speed
Total Harmonic Distortion	Harmonic analyser	THD (%)	Harmonic $> 5\%$ causes losses in cables, transformers
Illuminance	Lux meter	Lux (lx)	Compare with BIS/NBC standards; identify over/under-lit areas

Table 3.13: Electrical Parameters and Measurement Instruments

Motor Load Calculation from Electrical Measurements:

$$\text{Motor Load Factor (\%)} = \text{Measured kW} / \text{Rated kW} \times 100$$

$$\text{Rated kW} = \text{Rated HP} \times 0.746 / \text{Motor Efficiency}$$

Motor is under-loaded if Load Factor < 50% → Consider downsizing or VFD

3.5.2 Thermal Measurements

Thermal measurements quantify heat flows, temperatures, and combustion performance in boilers, furnaces, heat exchangers, and steam systems.

Parameter	Instrument	Unit	Purpose
Flue gas temperature	Thermocouple / pyrometer	°C	Boiler efficiency; target < 200°C for fuel oil
Flue gas O ₂ / CO ₂ %	Combustion / flue gas analyser	%	Excess air control; optimum O ₂ : 2–3% for oil
CO in flue gas	Flue gas analyser (electrochemical)	ppm	Incomplete combustion indicator; CO > 200 ppm → tune burner
Surface Temperature	Contact thermometer / IR gun	°C	Insulation assessment; surface > 50°C → insulation deficient
Steam pressure	Pressure gauge / transmitter	bar g / kPa	Boiler, line, and process pressure mapping
Steam flow	Orifice plate / ultrasonic FM	kg/h	Steam balance and condensate recovery
Thermal imaging	Infrared (IR) thermography camera	°C map	Hot spots on switchgear, refractory, pipes, rooftops
Fuel flow rate	Rotameter / turbine / Coriolis FM	L/h; m ³ /h; kg/h	Combustion input; basis for boiler efficiency test

Table 3.14: Thermal Parameters and Measurement Instruments

Boiler Efficiency by Indirect (Heat Loss) Method:

$$\text{Boiler Efficiency (\%)} = 100 - (\text{Sum of all Losses \%})$$

Key Losses: Flue gas sensible heat loss + Radiation loss + CO loss + Moisture loss in fuel

Typically 8–15% for coal-fired; 5–10% for oil-fired boilers

3.5.3 Flow Measurements

Flow measurements quantify the movement of air, gases, water, steam, and other fluids within the facility.

Fluid / Application	Instrument	Principle	Typical Range
Water / Condenser water	Electromagnetic FM	Faraday's law	0.1 – 10 m/s
Steam	Vortex FM; Annubar	Vortex shedding; DP	0.3 – 80 m/s
Fuel oil / HFO	Positive displacement FM	Gear / oval gear	1 – 500 L/min
Natural gas	Turbine / ultrasonic FM	Velocity / transit-time	5 – 5000 m ³ /h
Duct air velocity	Pitot tube + manometer	Differential pressure	2 – 30 m/s
Compressed air	Thermal mass FM	Mass / heat transfer	0.5 – 200 m ³ /min
Cooling water (non-intrusive)	Clamp-on ultrasonic FM	Transit-time (Doppler)	0.01 – 15 m/s

Table 3.15: Flow Measurement Instruments Used in Energy Audits

3.5.4 Compressed Air System Measurements

Compressed air is one of the costliest utilities (typically 7–8 times the cost of equivalent electrical energy at the point of use). Key measurements include:

- ☐ System pressure at compressor outlet and at point of use (pressure drop indicates distribution losses)
- ☐ Compressor input kW vs compressed air output (m³/min or CFM) → Specific Power (kW/m³/min)
- ☐ Leak rate quantification: using ultrasonic leak detector or by load/unload cycle timing
- ☐ Total air flow using mass flow meter at compressor outlet

Leak Quantification Formula:

$$\text{Leak Rate (\%)} = [T_{\text{on}} / (T_{\text{on}} + T_{\text{off}})] \times 100$$

Where: T_{on} = compressor loaded time; T_{off} = compressor unloaded time (no production running)

Typical target: < 10% leakage. Industry average is often 20–30% — a major savings opportunity.

3.5.5 Measurement and Verification (M&V)

After ECMs are implemented, savings must be verified through M&V. The International Performance Measurement and Verification Protocol (IPMVP) defines four M&V options:

Option	Name	Description	Suitable For
A	Partially Measured Retrofit Isolation	Measure one or more key parameters; stipulate others	Lighting, low-cost ECMs
B	Retrofit Isolation	Measure all parameters of isolated ECM	Chiller, boiler, motor upgrades
C	Whole-Facility	Measure entire facility energy use; regression-adjusted	Multiple ECMs; ESCo contracts
D	Calibrated Simulation	Energy simulation calibrated to measured data	New construction; complex facilities

Table 3.16: IPMVP M&V Options

3.6 Presentation of Energy Audit Results

The presentation of audit results is as important as the audit itself. A well-structured audit report and presentation converts technical findings into actionable information that management can understand, approve, and act upon.

3.6.1 Structure of the Energy Audit Report

A standard energy audit report follows a well-defined structure as outlined by BEE (India) and ASHRAE guidelines:

Sl.	Section	Key Contents
1	Executive Summary	Overview of facility; total energy cost; top ECMs; estimated savings; investment required — 2 to 3 pages for management reading
2	Facility Description	Location, processes, production capacity, utility connections, operating schedule
3	Energy Consumption Analysis	Historical energy data (12–36 months), energy cost breakdown, energy mix, seasonal trends
4	Energy Use Profile	Load curves, end-use pie charts, Sankey diagram, SEC vs industry benchmark
5	Energy System Assessments	Detailed findings for each system: electrical, thermal, HVAC, lighting, compressed air, steam, etc.
6	ECM Recommendations	Tabulated list with description, energy savings (GJ/year, kWh/year), cost savings (Rs/year), investment, SPP, priority
7	Implementation Plan	Short-term (< 6 months), medium-term (6–24 months), long-term (> 24 months) ECMs with responsibilities
8	Financial Analysis	Investment summary, NPV, IRR, sensitivity analysis, project cash flow projections
9	M&V Plan	Method to verify savings post-implementation (per IPMVP or BEE protocol)
10	Annexures	Raw data sheets, calibration certificates, instrument details, calculation sheets, photographs

Table 3.17: Standard Energy Audit Report Structure (BEE / ASHRAE Aligned)

3.6.2 ECM Summary Table (Master Recommendation Register)

The most critical deliverable within the report is the ECM Summary Table — a consolidated register of all energy conservation measures with financial metrics. A sample format is shown below:

No.	ECM Description	Energy Saved (GJ/yr)	Cost Saving (Rs. L/yr)	Invest. (Rs. L)	SPP (yr)	CO ₂ Red. (t/yr)	Priority	Category
1	VFD on cooling tower fans	252	27.7	12.5	0.45	58.6	High	Low-Cost
2	LED retrofit for factory lighting	180	19.8	8.4	0.42	41.9	High	Low-Cost
3	Insulate bare steam pipes (200m)	504	21.0	6.2	0.30	38.4	High	No-Cost
4	PF correction capacitor bank	—	14.4	5.5	0.38	—	High	Low-Cost
5	WHR from furnace flue gas	2,160	90.0	180.0	2.00	165.2	Medium	Capital
6	Compressed air leak repairs	360	39.6	2.5	0.06	83.8	High	No-Cost
7	IE3 motor for largest pump (185 kW)	216	23.8	28.0	1.18	50.2	Medium	Low-Cost
8	Solar rooftop PV (500 kWp)	5,400	150.0	350.0	2.33	—*	Low	Capital
TOTAL		9,072	386.3	593.1	0.06-2.33	438.1	--	--

Table 3.18: Sample ECM Master Register (Illustrative; * Solar avoids grid emission but renewable)

3.6.3 Presentation Techniques

For management presentations, findings should be communicated through clear visual tools:

Visual Tool	Application in Energy Audit Presentation
Sankey Diagram	Shows energy flows from input → processes → losses visually; immediately highlights largest losses
Pie Chart	End-use energy breakdown; quickly shows where the most energy is used
Bar / Column Chart	Monthly energy trends; comparison of actual vs benchmark SEC
Scatter / Regression Plot	Energy vs production correlation; used to create energy baseline models

Visual Tool	Application in Energy Audit Presentation
Thermographic Images	Colour-coded thermal images showing heat loss from walls, pipes, switchgear
ECM Priority Matrix	Plots savings potential vs investment; helps management prioritise ECMs visually
Cumulative Cash Flow Chart	Shows when investment recovers and net benefits accumulate — powerful for CFO presentations

Table 3.19: Presentation Visual Tools and Their Applications

3.6.4 Energy Audit Report Quality Checklist

Before submitting the audit report, verify the following:

Sl.	Checklist Item	Status
1	Energy balance accounts for $\geq 95\%$ of all energy inputs	☐
2	All measurements made with calibrated instruments (calibration certificates attached)	☐
3	SEC compared with BEE or national benchmarks; gap clearly stated	☐
4	Financial analysis (SPP, NPV, IRR) computed for each ECM	☐
5	Report reviewed for data consistency across sections (totals match)	☐
6	Photographs taken for key observations (steam leaks, faulty insulation, illuminated areas)	☐
7	Executive summary is self-contained and readable by non-technical audience	☐
8	Implementation plan includes responsible person, timeline, and resource requirements	☐
9	M&V plan included to verify savings after ECM implementation	☐
10	Report signed by BEE-certified energy auditor (for DCs)	☐

Table 3.20: Energy Audit Report Quality Checklist

Module 3 — Summary

This module has provided a comprehensive understanding of energy auditing — from its conceptual foundation to practical measurement techniques and professional report presentation. The key takeaways are:

8. Energy auditing is a systematic process to identify and quantify energy-saving opportunities; it is mandated by the Energy Conservation Act, 2001 for Designated Consumers.
9. The seven core elements of an energy audit — from pre-audit planning through cost-benefit analysis to report writing — form an interlocking framework for a credible audit.
10. Three principal audit types (Walk-Through, Standard, Investment-Grade) cater to different levels of depth, budget, and purpose; specialised audits target specific systems.
11. Energy use profiles — temporal, end-use, and fuel-mix — provide the analytical backbone to identify the largest consumers and prioritise savings opportunities.
12. Measurements using calibrated instruments are essential for converting qualitative observations into quantitative data; key parameters span electrical (V, I, kW, PF), thermal (temperature, flue gas, flow), and system-level domains.
13. Audit results must be communicated clearly through structured reports, ECM master registers, and visual tools (Sankey diagrams, pie charts, thermograms) to drive management decisions and investment approvals.

Module 3 — Review Questions

Short Answer Questions:

14. Define energy audit. State three objectives of conducting an energy audit.
15. List the seven elements of an energy audit and briefly explain any three.
16. Differentiate between Walk-Through Audit, Standard Audit, and Investment-Grade Audit.
17. What is Specific Energy Consumption (SEC)? How is it calculated and used in benchmarking?
18. List any five electrical parameters measured during an energy audit and name the instruments used.
19. Explain the significance of flue gas analysis in a thermal energy audit. What parameters are measured?
20. What is a load factor? How does it indicate energy efficiency?
21. Describe the structure of a standard energy audit report.

Long Answer / Numerical Questions:

22. A motor of 55 kW rating draws 48 kW at site. Calculate the motor load factor. If the motor efficiency at this load is 92%, calculate the shaft power delivered. What is the annual energy cost if it runs 6000 hours/year at Rs. 7.50/kWh?
23. For a boiler with flue gas temperature 250°C, ambient temperature 30°C, O₂ in flue gas 7%, calculate the approximate stack heat loss percentage. Use the appropriate formula and comment on the result.
24. Explain how an energy use profile is constructed for an industrial facility. What information is captured in temporal, end-use, and fuel-mix profiles?
25. A compressed air compressor of 90 kW runs for 8 hours with a load/unload cycle of T_{on} = 18 min, T_{off} = 12 min (no production). Calculate the leak rate percentage and the annual energy loss if the tariff is Rs. 8/kWh. Suggest corrective measures.
26. Draw the structure of an Energy Audit Report as recommended by BEE India, and explain the purpose of the Executive Summary and the ECM Master Register sections.

MCQ / Objective Questions:

27. An energy audit that includes long-term sub-metering and M&V plans is called: (a) Walk-Through Audit (b) Standard Audit (c) Investment-Grade Audit (d) Carbon Audit
28. The formula for Specific Energy Consumption is: (a) Energy × Production (b) Energy / Cost (c) Energy / Production (d) Cost / Production
29. Power Factor is defined as: (a) kW / kVA (b) kVAR / kVA (c) kV × A (d) kWh / kVAh
30. As per Energy Conservation Act 2001, Designated Consumers must conduct energy audits at least once every: (a) 1 year (b) 2 years (c) 3 years (d) 5 years
31. In the IPMVP M&V Protocol, Option C refers to: (a) Retrofit Isolation (b) Whole-Facility measurement (c) Calibrated Simulation (d) Stipulated Savings

NOTE: Answers to MCQs: 1-(c); 2-(c); 3-(a); 4-(c); 5-(b)