**Energy Audit**

1. Definition of Energy Audit • As per Indian Energy Conservation Act 2001, Energy Audit is defined as: “the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption “
2. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-4-638.jpg?cb=1489326404)Why the Need for Energy Audit • The three top operating expenses are energy (both electrical and thermal), labour and materials. • Energy would emerge as a top ranker for cost reduction • primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs • Energy Audit provides a “ bench-mark” (Reference point) for managing energy in the organization
3. Types of Energy Audits 1. Preliminary Energy Audit 2. Targeted Energy Audit 3. Detailed Energy Audit
4. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-6-638.jpg?cb=1489326404)Preliminary Energy Audit • Preliminary energy audit uses existing or easily obtained data • Find out the energy consumption area in the organization • Estimates the scope for saving • Identifies the most likely areas for attention • Identifies immediate(no cost or low cost) improvements • Sets a ‘reference point’ • Identifies areas for more detailed study/measurement
5. • Targeted energy audits are mostly based upon the outcome of the preliminary audit results. • They provide data and detailed analysis on specified target projects. • As an example, an organization may target its lighting system or boiler system or compressed air system with a view to bring about energy savings. • Targeted audits therefore involve detailed surveys of the target subjects/areas with analysis of the energy flows and costs associated with those targets. Targeted Energy Audits
6. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-8-638.jpg?cb=1489326404)Detailed Energy Audit Detailed Energy Audit evaluates all systems and equipment which consume energy and the audit comprises a detailed study on energy savings and costs. Detailed Energy Audit is carried out in 3 phases – The Pre-audit Phase – The Audit Phase – The Post-Audit Phase
7. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-9-638.jpg?cb=1489326404) Organize Instruments • Resource planning, Establish/organize a Energy audit team • Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.) • Informal Interview with Energy Manager, Production / Plant Manager • Walk through Audit • Plan and organise •The Ten Steps for Detailed Audit Step No PLAN OF ACTION PURPOSE / RESULTS Step 1 Step 2 Phase I –Pre Audit Phase & First hand observation • Familiarization of process/plant activities • Macro Data collection (suitable to type of industry.) •time frame & Orientation, awareness creation • Issue questionnaire for each department • Building up cooperation •Assessment of current level operation and practices
8. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-10-638.jpg?cb=1489326404) Primary data gathering, Process Flow Diagram, •Step 3 Step 4 Phase II –Audit Phase & All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air • Prepare process flow charts • Historic data analysis, Baseline data collection • Conduct survey and monitoring •Energy Utility Diagram & Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data. • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview) • Design, operating data and schedule of operation •steam distribution.
9. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-11-638.jpg?cb=1489326404) Reporting • Cost benefit analysis • Identification and development of Energy Conservation (ENCON) opportunities • Analysis of energy use • Conduct of detailed trials /experiments for selected energy guzzlers •Step 5 Step6 Step 7 Step 8 Step9 & Energy and Material balance • Trials/Experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc. - Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc •Presentation to the Top Management & Identification •energy loss/waste analysis & Review the ♣Conceive, develop, and refine ideas ♣Consolidation ENCON measures Prioritise by low, medium, long term measures Documentation, Report Presentation to the top Management. • Select the most promising projects • Assess technical feasibility, economic viability and prioritization of ENCON options for implementation •Contact vendors for new/efficient technology ♣Use brainstorming and value analysis techniques ♣Review the previous ideas suggested by energy audit if any ♣previous ideas suggested by unit personal
10. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-12-638.jpg?cb=1489326404)Follow-up and periodic review ♣Action plan, Schedule for implementation ♣ Implementation and Follow- up Assist and Implement ENCON recommendation measures and Monitor the performance •Step10 Phase III –Post Audit phase
11. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-13-638.jpg?cb=1489326404)Questions which an Energy Auditor should ask • What function does this system serve? • How does this system serve its function? • What is the energy consumption of this system? • What are the indications that this system is working properly ? • If this system is not working, how can it be restored to good working conditions/ • How can the energy cost of this system be reduced?
12. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-14-638.jpg?cb=1489326404)DETAILED ENERGY AUDIT A TYPICAL INDUSTRIAL FORMAT OF REPORT Energy Audit Team Executive Summary –Scope & Purpose Energy Audit Options & Recommendations 1.0 Introduction about the plant 1.1 General Plant details and descriptions 1.2 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others) 1.3 Major Energy use and Areas 2.0 Production Process Description 2.1 Brief description of manufacturing process 2.2 Process flow diagram and Major Unit operations 2.3 Major Raw material Inputs, Quantity and Costs 3.0 Energy and Utility System Description 3.1 List of Utilities 3.2 Brief Description of each utility 3.2.1 Electricity 3.2.2 Steam 3.2.3 Water 3.2.4 Compressed air 3.2.5 Chilled water 3.2.6 Cooling water
13. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-15-638.jpg?cb=1489326404)4.0 Detailed Process flow diagram and Energy& Material balance 4.1 Flow chart showing flow rate, temperature, pressures of all input- Output streams 4Water balance for entire industry 5.0 Energy efficiency in utility and process systems 5.1 Specific Energy consumption 5.2 Boiler efficiency assessment 5.3 Thermic Fluid Heater performance assessments 5.4 Furnace efficiency Analysis 5.5 Cooling water system performance assessment 5.6 DG set performance assessment 5.7 Refrigeration system performance 5.8 Compressed air system performance 5.9 Electric motor load analysis 5.10 Lighting system 6.0 Energy Conservation Options & Recommendations 6.1 List of options in terms of no cost, low cost, medium cost and high cost, annual energy savings and payback 6.2 Implementation plan for energy saving measures/Projects ANNEXURE Al. List of instruments A2. List of Vendors and Other Technical details
14. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-16-638.jpg?cb=1489326404)Energy Audit Instruments Electrical Measuring Instruments: These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kvar, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals. POWER ANALYSERS
15. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-17-638.jpg?cb=1489326404)Combustion analyzer: This instrument has in-built chemical cells which measure various gases such as CO2, CO, NOX, SOX etc Fuel Efficiency Monitor: This measures Oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency. Fyrite: A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. Percentage Oxygen or CO2 can be read from the scale. FLUE GAS ANALYSERS
16. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-18-638.jpg?cb=1489326404)Contact thermometer: These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature a leaf type probe is used with the same instrument. Infrared Pyrometer: This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. Can be useful for measuring hot jobs in furnaces, surface temperatures etc. TEMPERATURE MEASURMENTS
17. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-19-638.jpg?cb=1489326404)Pitot Tube and manometer: Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows. Ultrasonic flow meter: This a non contact flow measuring device using Doppler effect principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter. FLOW MEASURMENTS – AIR ,WATER
18. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-20-638.jpg?cb=1489326404)Tachometer Stroboscope Speed Measurements: In any audit exercise speed measurements are critical as thay may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes. Lux meters: Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.
19. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-21-638.jpg?cb=1489326404)Identification of Energy Conservation Factors & Areas Steps for conserving energy can be taken if we know the correct factors and areas to be studied and also details of fuels used. These can be: • Energy generation • Energy distribution • Energy usage by processes • Fuel substitution
20. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-22-638.jpg?cb=1489326404) Waste disposal Net Savings /Year (Rs./year) = (Annual savings-annual operating costs) Payback period in months = (Investment/net savings/year) x 12 Technology availability, space, skilled manpower, reliability, service,Impact of measure on safety, quality, production or process.Maintenance requirements and spares availability • Raw material • Electrical Energy • Thermal Energy • Depreciation 3. Annual savings • Energy • Manpower • Maintenance • Cost of capital •Technical and Economic feasibility- Factors Sample Worksheet for Economic Feasibility Name of Energy Efficiency Measure i. Investment a. Equipments b. Civil works c. Instrumentati on d. Auxiliaries 2. Annual operating costs
21. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-23-638.jpg?cb=1489326404)Energy Costs in Indian Scenario ? Common Fuels • Fuel oil,• Low Sulphur Heavy Stock (LSHS),• Light Diesel Oil (LDO),• Liquefied Petroleum Gas (LPG) • Coal,• Lignite,• Wood Fuels Cost Inputs & Factors • Price at source, transport charge, type of transport, • Quality of fuel • Contaminations, Moisture, Energy content (GCV) Power Costs In India Electricity costs vary substantially not only from State to State, but also from city to city and also within consumer to consumer – though power does the same work everywhere. Reason: •Tariff Structure
22. Energy conservation measures
23. Understanding energy costs Electricity (1 kWh) = 860 kcal/kWh (0.0036 GJ) Heavy fuel oil (calorific value, GCV) =10.000 kcal/litre ( 0.0411 GJ/litre) Coal (calorific value, GCV) =4000 kcal/kg ( 28 GJ/ton) An industrial energy bill summary Conversion to common unit of energy ENERGY BILL EXAMPLE Type of energy Original units Unit Cost Monthly Bill (Rs) Electricity 5,00,000 kWh Rs.4.00/kWh 20,00,000 Fuel oil 200,kL Rs.11,000 KL 22,00,000 Coal 1000 tons Rs.2,200/ton 22,00,000 Total 64,00,000
24. Benchmarking • Benchmarking can be a useful tool for understanding energy consumption patterns in the industrial sector and also to take requisite measures for improving energy efficiency. • FACTORS INVOLVED: – Scale of operation – use of technology – Raw material specifications and quality – Product specifications and quality
25. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-27-638.jpg?cb=1489326404) Across similar industries Scale of operation, use of technology, raw material specification and quality and product specification and quality− Historical and trend analysis • External Benchmarking −Benchmarking for Energy Performance • Internal Benchmarking
26. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-28-638.jpg?cb=1489326404)Bench Marking Energy Performance • Quantification of fixed and variable energy consumption trends vis-à-vis production levels • Comparison of the industry energy performance w.r.t. various production levels (capacity utilization) • Identification of best practices (based on the external benchmarking data) • Scope and margin available for energy consumption and cost reduction • Basis for monitoring and target setting exercises
27. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-29-638.jpg?cb=1489326404)Benchmarking parameters Production or Equipment Related •Gross production related e.g. kWh/MT clinker or cement produced (Cement plant) e.g. kWh/MT, kCal/kg, paper produced (Paper plant) •Equipment / utility related e.g. kWh/ton of refrigeration (on Air conditioning plant) e.g. kWh /litre in a diesel power generation plant.
28. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-30-638.jpg?cb=1489326404)Measuring Energy Performance Production Factor = Current year’s production Reference year’s production • Reference Year Equivalent Energy Use • The reference year’s equivalent energy use (or reference year equivalent) is the energy that would have been used to produce the current year’s production output. • The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above) • Reference year equivalent = Reference year energy use x Production factor • Plant Energy Performance is the improvement or deterioration from the reference year. It is a measure of plant’s energy progress. • Plant energy performance = Reference year equivalent – Current year’s energy x 100 Reference year equivalent
29. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-31-638.jpg?cb=1489326404)Maximizing System Efficiencies - Some Measures • Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy conservation equipment, wherever significant energy efficiency margins exist • Eliminate steam leakages by trap improvements • Maximize condensate recovery • Adopt combustion controls for maximizing combustion efficiency
30. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-32-638.jpg?cb=1489326404)Matching Energy Usage to Requirement • The mismatch between equipment capacity and user requirement often leads to inefficiencies due to part load operations, wastages etc. It is thus essential that proper energy matching studies are carried out & actions implemented. Examples : Eliminate throttling Eliminate damper operations Fan resizing for better efficiency. Moderation of chilled water temperature for process chilling needs
31. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-33-638.jpg?cb=1489326404) Identify potential for heat exchanger networking and process integration.} Periodic review of insulation thickness } Shuffling of compressors to match needs. } EXAMPLES: } In order to ensure that the energy given to the system is being put to optimal use, site specific measures and checks should be carried out regularly. }Optimising Energy Input Requirement
32. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-34-638.jpg?cb=1489326404)Identification of energy conservation opportunities Fuel substitution • Replacement of coal by coconut shells, rice husk etc • Replacement of LDO by LSHS Energy substitution • Replacement of electric heaters by steam heaters • Replacement of steam based hot water by solar systems Energy Generation • Captive power plant • Steam generation Energy usage by processes • Analyze which process gets high energy consumption
33. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-35-638.jpg?cb=1489326404)Energy monitoring & targeting Importance An effective monitoring & implementing system with adequate technical ability for analyzing energy saving options is key to ENERGY MANAGEMENT Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. These techniques covers all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed.----It Becomes the “Energy Cost Centers.”
34. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-36-638.jpg?cb=1489326404)Elements of Monitoring & Targeting System • Recording - Measuring and recording energy consumption • • Analyzing - Correlating energy consumption to a measured output, such as production quantity • • Comparing -Comparing energy consumption to an appropriate standard benchmark • • Setting Targets -Setting targets to reduce or control energy consumption • • Monitoring - Comparing energy consumption to the set target on a regular basis • • Reporting -Reporting the results including any variances from the targets which have been set • • Controlling - Implementing management measures to correct any variances, which may have been occurred. • Particularly M&T system will involve the following: • Checking the accuracy of energy invoices • Allocating energy costs to specific departments (Energy Accounting Centres) • Determining energy performance/efficiency • Recording energy use, so that projects intended to improve energy efficiency can bechecked \* Highlighting performance problems in equipment or systems
35. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-37-638.jpg?cb=1489326404)Data and Information Analysis • Plant level information can be derived from financial accounting systems-utilities cost centre • Plant department level information can be found in comparative energy consumption data for a group of similar facilities, service entrance meter readings etc. • System level (for example, boiler plant) performance data can be determined from sub metering data • Equipment level information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment
36. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-38-638.jpg?cb=1489326404)Relating Energy Consumption and Production • After collection of energy consumption, energy cost and production data, the next stage of the monitoring process is to study and analyze the data and represent it for day to day controls—so represent it graphically
37. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-39-638.jpg?cb=1489326404)Specific Energy Consumption(SEC) is energy consumption per unit of production
38. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-40-638.jpg?cb=1489326404)CUSUM -Cumulative Sum • Cumulative Sum (CUSUM) represents the difference between the base line and the actual consumption points over the base line period of time. • This useful technique not only provides a trend line, it also calculates savings/losses to date and shows when the performance changes.
39. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-41-638.jpg?cb=1489326404)CUSUM Technique CUSUM analysis 1 Plot the Energy - Production graph for the first 9 months 2. Draw the best fit straight line 3. Derive the equation of the line, y=mx+c 4. Calculate the expected energy consumption based on the equation 5. Calculate the difference between actual and calculated energy use 6. Compute CUSUM 7. Plot the CUSUM graph 8. Estimate the savings accumulated from use of the heat recovery system 1-Given 4-Analysis-TABLE 2-plot graph 3-fit equation
40. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-42-638.jpg?cb=1489326404)Case Study The CUSUM Technique Energy consumption and production data were collected for a plant over a period of 18 months. During month 9, a heat recovery system was installed. Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data is given in Table 8.3: \* toe = tonnes of oil equivalent.
41. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-43-638.jpg?cb=1489326404)Based on the graph 8.10 (see Table 8.4), savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.
42. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-44-638.jpg?cb=1489326404)5-CUSUM -Analysis
43. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-45-638.jpg?cb=1489326404)The Sankey Diagram and its Use The Sankey diagram is very useful tool to represent an entire input and output energy flow in any energy equipment or system such as boiler, fired heaters, furnaces after carrying out energy balance calculation. This diagram represents visually various outputs and losses so that energy managers can focus on finding improvements in a prioritized manner. Example: The Figure 4.2 shows a Sankey diagram for a reheating furnace. From the Figure 4.2, it is clear that exhaust flue gas losses are a key area for priority attention.
44. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-46-638.jpg?cb=1489326404)• We know, equation of slope, Y=mx+c Where, “y” is dependent variable(i.e energy consumption) “x” is independent variable(i.e production ) “c” is the value at which the straight line curve intersect the “y” axis. “m” is the gradient of straight line curve. Least Square Method Therefore, Energy consumed for the period=C+m\*production for the same period.
45. [.](https://image.slidesharecdn.com/energyaudit-170312134416/95/energy-audit-47-638.jpg?cb=1489326404)• Consider the sample points, (X1,y1).(x2,y2)……(xn,yn) Therefore, Equation of straight lines are, 1. cn+m∑x=∑y 2. c∑x+m∑X2 = ∑xy….(on the basis of production i.e independent variable) n= no. of data points These equations are known as normal equations of the problems and they can be used to establish the value of “c” and “m”.