BASIC PRINCIPLES OF ENERGY AUDIT

Syllabus: Energy audit- definitions - concept - types of Energy audit - energy index - cost index - pie charts - Sankey diagrams and load profiles - Energy conservation schemes- Energy audit of industries- energy saving potential - energy audit of process industry, thermal power station - building energy audit - Conservation of Energy Building Codes (ECBC-2017).

Energy audit: -

The main purpose energy audit is to increase energy efficiency and reduce energy related costs. Energy audit is not an exact science. It involves collection of detailed data and its analysis.

(or)

It is an official scientific study/ survey of energy consumption of a region/ organization/ process/ plant/ equipment aimed at the reduction of energy consumption and energy costs, without affecting productivity and comforts and suggesting methods for energy conservation and reduction in energy costs.

(or)

An energy audit is an inspection, survey and analysis of energy flows for energy conservation in a building, process (or) system to reduce the amount of energy input into the system without negatively affecting the output(s).

Energy audit is a fundamental part of an energy management program (EMP) in controlling energy costs. It will identify areas of wasteful and inefficient use of energy.

The aims of energy audit are as follows:

- To identify the main energy users and quantity their annual energy consumption
- To ascertain the optimized energy data
- To determine the availability or energy/production data
- To investigate the distribution systems for the site services and note any existing metering
- To prepare energy and process flow diagrams for the site

Need for Energy Audit:

- **Cost savings:** Energy is often one of the top three operating expenses in industries. An audit helps identify inefficiencies and areas where energy (and money) can be saved.
- **Improved efficiency:** It provides a detailed breakdown of energy consumption, helping organizations optimize systems and processes for better performance.
- **Environmental impact:** By reducing unnecessary energy use, audits contribute to lower carbon emissions and a smaller environmental footprint.
- **Regulatory compliance:** In many regions, energy audits are required under energy conservation laws or sustainability initiatives.
- **Strategic planning:** The audit report includes recommendations and action plans that support long-term energy management goals.

Energy Audit Definitions:-

1. Energy Accounting:-

Energy audit simply means an orderly month by month accounting of energy used in a building for comparison against a budget or another standard of performance.

2. Means To Achieve Conservation:-

Energy audit deals with specific ways and means to achieve energy conservation.

3. Systematic Approach to Decision Making:-

Energy Audit is the key to systematic approach for decision – making; in the areas of energy management it attempts to balance the total energy inputs with its use and serves to identify all the energy streams in a facility. It quantities energy usage according to its discrete functions.

4. Effective Tool for Energy Management:-

Industrial Energy Audit is an effective tool in defining and pursuing comprehensive energy management programmer. In this field also, the basic functions of management like planning, decision – making, organizing and controlling, apply equally as any other management subject.

5. Ways of usage of Energy:-

Energy Audit will help to understand more about the ways energy and fuel or used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.

6. Construction and Stream Lining:-

An energy audit promotes cost reduction, preventive maintenance, and quality control—crucial for efficient production and utility operations. It helps track energy cost fluctuations, assess supply reliability, determine optimal energy mix, and identify suitable conservation technologies and retrofits

7. Ideas and Feasible Solutions:-

An energy audit transforms conservation concepts into actionable solutions by integrating technical, economic, and organizational factors within a defined timeline. It offers a more effective approach than fragmented, short-term measures by promoting a structured, science-based strategy and reinforcing organizational infrastructure.

8. Use and Opportunities:-

An energy audit is a comprehensive analysis of energy use in a facility, aimed at identifying savings opportunities, assessing economic and technical feasibility, and recommending prioritized improvements for efficient energy management.

9. Definition as Per Bureau of Energy Efficiency Guidelines:-

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".

Types of Energy Audit:-

The type of Energy Audit to be performed depends on:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following two types.

i) Preliminary Audit (ii) Detailed Audit

i) <u>Preliminary Energy Audit Methodology:-</u>

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention)
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

ii) <u>Detailed Energy Audit Methodology:-</u>

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost. In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre Audit Phase
Phase II - Audit Phase
Phase III - Post Audit Phase

A Guide for Conducting Energy Audit at a Glance Industry-to-industry, the methodology of Energy Audits needs to be flexible. A comprehensive ten-step methodology for conduct of Energy Audit at field level is presented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types

Step No.	PLAN OF ACTION	PURPOSE / RESULTS
<u>Phase I –Pre Audit Phase</u>		
Step 1	· Plan and organise	· Resource planning, Establish/organize a Energy audit team
	· Walk through Audit	· Organize Instruments & time frame
	· Informal Interview with Energy Manager, Production / Plant Manager	· Macro Data collection (suitable to type of industry.)
		· Familiarization of process/plant activities
		· First hand observation & Assessment of current level operation and practices
Step 2	Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	· Building up cooperation
		· Issue questionnaire for each department
		· Orientation, awareness creation
<u>Phase II –Audit Phase</u>		
Step 3		· Historic data analysis, Baseline data collection
		· Prepare process flow charts

	Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	· All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution.
		· Design, operating data and schedule of operation
		· Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	Conduct survey and monitoring	Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	Conduct of detailed trials /experiments for selected energy guzzlers	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
Step 6	Analysis of energy use	· Energy and Material balance & energy loss/waste analysis
Step 7	Identification and development of Energy Conservation (ENCON) opportunities	· Identification & Consolidation ENCON measures
		. Conceive, develop, and refine ideas
		. Review the previous ideas suggested by unit personal
		. Review the previous ideas suggested by energy audit if any
		. Use brainstorming and value analysis techniques
		. Contact vendors for new/efficient technology
Step 8	Cost benefit analysis	· Assess technical feasibility, economic viability and prioritization of ENCON options for implementation
		· Select the most promising projects
		· Prioritise by low, medium, long term measures
Step 9	Reporting & Presentation to the Top Management	Documentation, Report Presentation to the top Management.
Phase III –Post Audit phase		
Step 10	Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance . Action plan, Schedule for implementation . Follow-up and periodic review

ENERGY INDEX:

It is a useful parameter to monitor and compare energy consumption whenever the industry/firm (or a facility in general) is producing a specified product.

$$Energy\ Index = \frac{\text{Energy used}}{\text{Production output}}$$

This may be calculated weekly/monthly/annually. For better monitoring, the total energy indices are calculated. If there is any increase or decrease in the Energy Index, with the implementation of any conservation scheme, the particular source can be identified and investigated immediately.

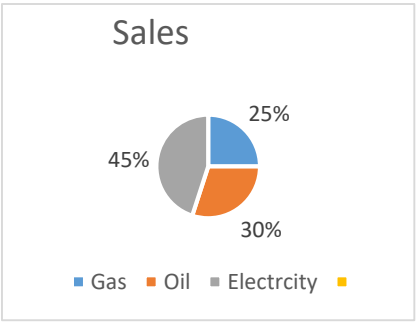
COST INDEX: Another parameter which is useful in monitoring and assessing energy use of a facility is cost index.

$$\text{cost index} = \frac{cost\ of\ energy}{production\ cost\ output}$$

It is defined as the ratio of the cost of energy to the production output. Any changes in energy consumption which can be investigated and remedied are indicated by comparison of cost indices. The trends and fluctuations are clearly visible with such comparisons.

PIE CHART:-

Energy usage is plotted on a circular chart where the quantity of a particular type is represented as a segment of a circle. The size of the segment will be depends upon the usages of the product.
For example, the company uses 25% of gas, 30% of the oil and 45% of the electricity



SANKEY DIAGRAM:-

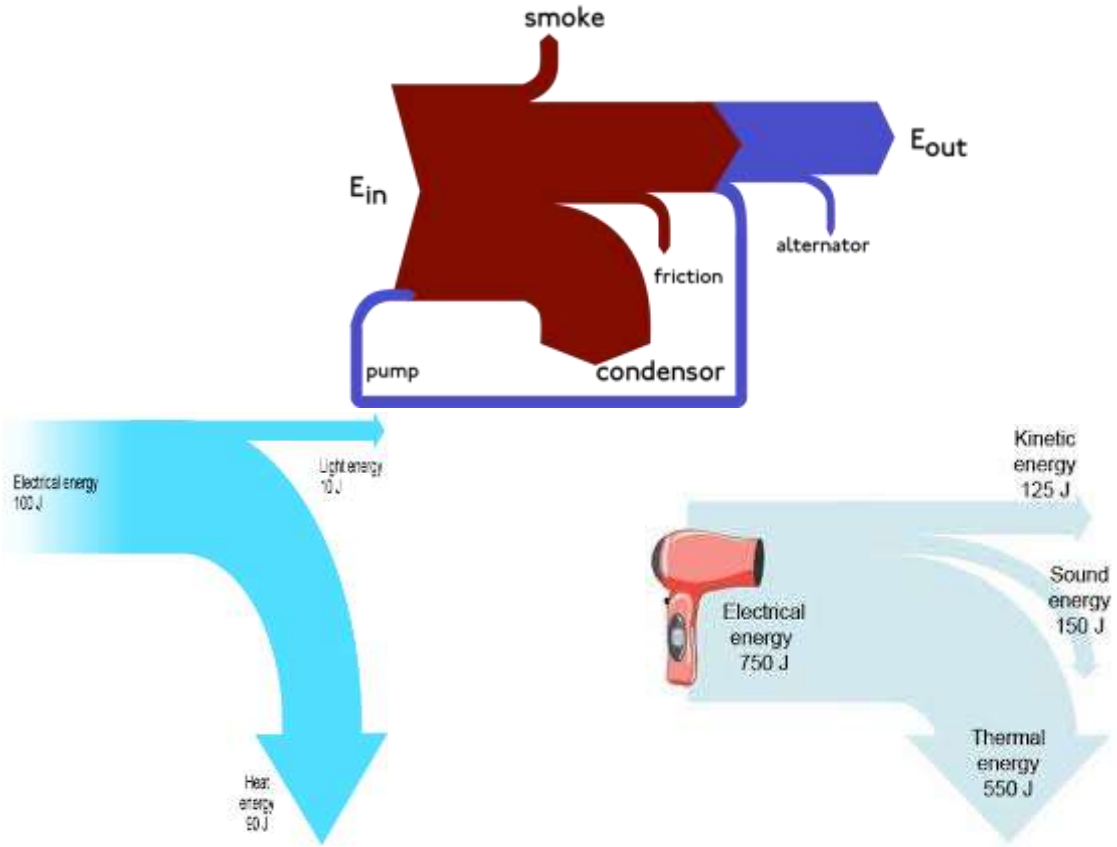
The sankey diagram represents all the primary energy flows in to a factory. The widths of the bands are directly proportional to energy production, utilization and losses.

(or)

Sankey diagrams are a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity. They are typically used to visualize energy or material or cost transfers between processes.

They are also commonly used to visualize the energy accounts or material flow accounts on a regional or national level. Sankey diagrams put a visual emphasis on the major transfers or flows within a system. They are helpful in locating dominant contributions to an overall flow. Often, Sankey diagrams show conserved quantities within defined system boundaries, typically energy or mass, but they can also be used to show flows of non- conserved quantities such as energy. Sankey Diagrams drop their arrows when energy is being used.

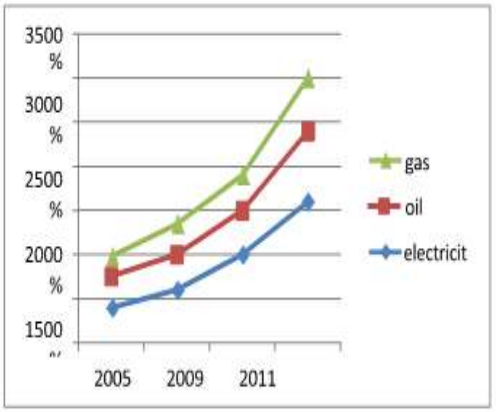
Examples of Sankey diagrams



LOAD PROFILES:-

For the purpose of monitoring and checking energy consumption on a time dependent basis is to use load profiles. In electrical engineering, a load profile is a graph of the variation in the electrical load versus time. A load profile will vary according to customer type (typical examples include residential, commercial and industrial), temperature and holiday seasons.

The below load profiles shows the day by day increases the usages the products is drawn the graph by taking the products with percentage**.**



Load profiles can be determined by direct metering but on smaller devices such as distribution network transformers this is not routinely done. Instead a load profile can be inferred from customer billing or other data. An example of a practical calculation used by utilities is using a transformer's maximum demand reading and taking into account the known number of each customer type supplied by these transformers. This process is called load research.

ENERGY CONSERVATION SCHEMES:

Development of an energy conservation program can provide savings by reduced energy use. The energy conservation measures may be classified on an economic basis and fall into the following three categories,

(a) Short term

(b) Medium term

(c) Long term

(a) **Short-term energy conservation schemes**:

This group consists of tasks of tightening of operational control and improved housekeeping.

(i) Furnace efficiencies:

For good combustion, minimum excess air over stoichiometric air is to be maintained. A continuous monitoring of oxygen level in flue gases is to be done. The oil burners should be cleaned regularly and well maintained.

(ii) Heal exchangers:

In case of heat exchangers where there is a transfer of useful heat from product streams to feed streams. The optimum cycles can be determined by continuous performance monitoring. An improved heat recovery can be achieved by frequent cleaning.

(iii) Good housekeeping:

When natural light is available and sufficient, artificial light should be avoided. During the heating season doors and windows should be closed as much as possible. Encouragement should be given to staff to wear suitable clothing in the working areas.

(iv) Electrical Power:

In most of the industries, electrical power is 'imported'. About 10 to 15% of electrical energy costs can be reduced by adopting conservation measures. At locations whcrc natural air cooling is sufficient, the usage of I.D. fans can

be avoided. Gravity flow application can minimize pumping costs of liquids.

(v) Steam usage—The majority of steam leaks should be repaired as soon as possible after they occur. The quality as well as quantity of steam required should be optimized and a careful control of the supply and distribution of steam is essential. The payback period for this type of schemes is less than or equal to one year.

(b) Medium-term energy conservation schemes:

Considering a payback period of less than two years, considerable savings in energy consumption are often available for quite modest outlays of capital. Some examples are given below:

(i) Insulation: Improving insulation prevents the leakage of cold air into the room and also thermal losses in the steam distribution system. Optimum thickness of insulation or critical radius of insulation is to be evaluated based on the study under consideration. Due consideration is to be given to economical thickness of insulation also.

(ii) The temperature control and operational time of cooling/heating systems.

(iii) Whenever necessary, the air compressors are to be replaced.

(iv) The reliable measurement and control of energy parameters can be achieved by providing adequate instrumentation at all places.

(v) Certain processes of the industry need modification. For example, the uncontaminated steam condensate may be used as boiler feed water. This results in heat recovery in the condensate as well as in reduction of raw water amount and its treatment costs.

(vi) Considerable savings can be obtained by suitably adjusting the electrical power factor correction.

(vii) The control and atomizing of steam in boilers and oil in furnaces is found to be in excess of the optimum designed value. This optimal value when used results in energy conservation.

(c) Long-term energy conservation schemes:

Further energy saving can be attained by adopting policies which require large amount of capital expenditure. The return on capital for the long-term investment may not be as good as that of the medium-term. Economical appraisal techniques are to be used to ensure the economical viability of such schemes, involving certain modifications to the existing systems or refurbishments. Some examples are:

(i) Heater modification: The installation of heating tubes, air pre-heaters or any other suitable heat exchangers results in extraction of more heat from furnace flue gases.

(ii) Additional lagging (improved insulation) for storage tanks minimizes thermal energy losses.

(iii) To obtain improved heat recovery, additional heat exchangers are to be provided in the processing areas

ENERGY AUDIT OF INDUSTRIES:-

An energy audit is a key to assessing the energy performance of an industrial plant and for developing an energy management program. The typical steps of an energy audit are:

i) Preparation and planning

ii) Data collection and review

iii) Plant surveys and system measurements

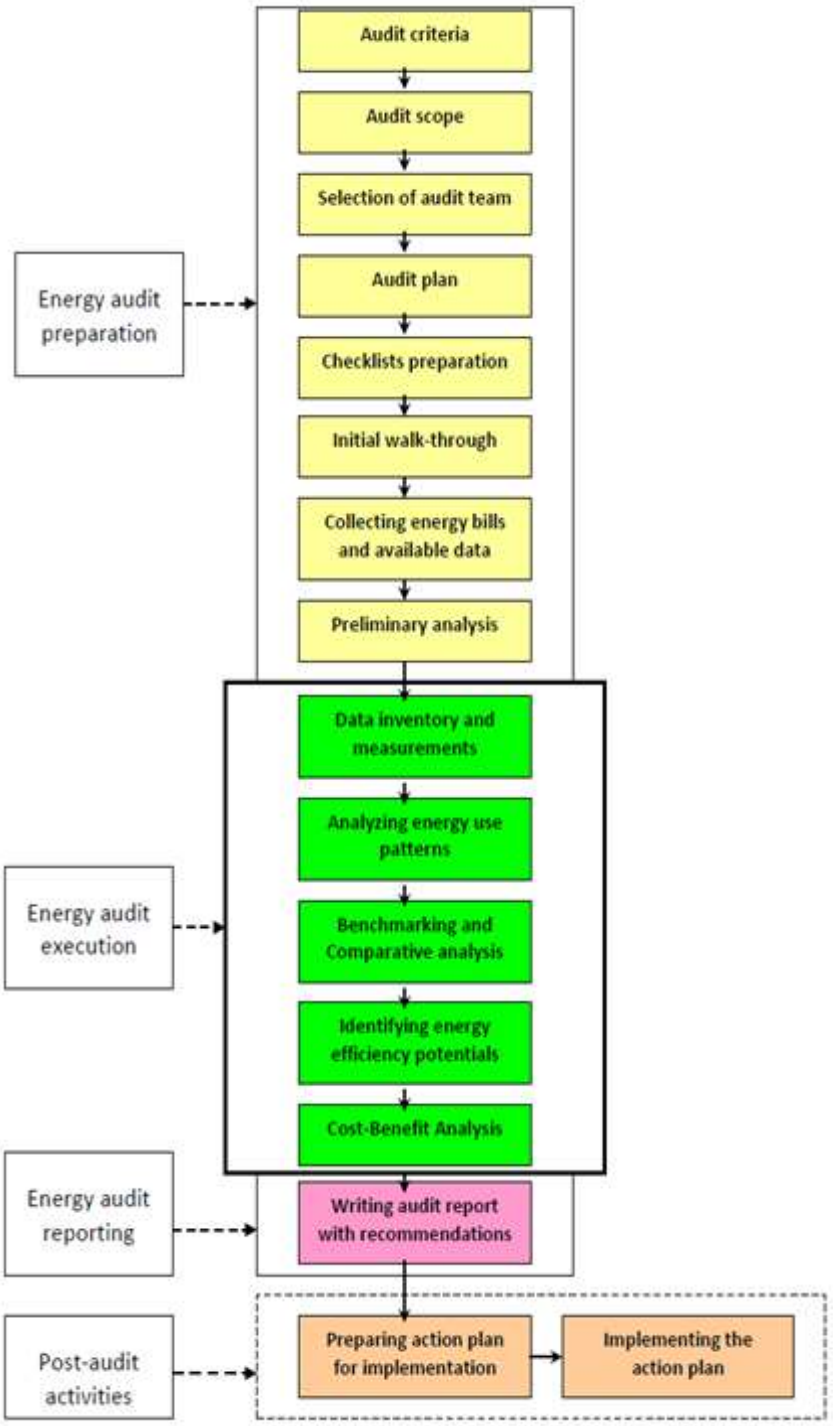
iv) Observation and review of operating practices

v) Data documentation and analysis

vi) Reporting of the results and recommendations.

An overview of the procedure for a detailed industrial energy audit is shown in Figure. A preliminary audit (walk-through audit) contains some of the same steps of the procedure shown, but the depth of the data collection and analysis might be different depending on the scope and objectives of the audit.

Overall, there are three main steps (excluding the post-audit activities) each of which has several sub-steps. These three main steps are energy audit preparation, execution, and reporting.



ENERGY SAVING POTENTIAL:-

Energy saving potential refers to the amount of energy that can be conserved through various measures, often by improving efficiency or reducing consumption. This potential exists across different sectors like industrial, buildings, and agriculture, with significant opportunities for energy savings through technological advancements and behavioural changes.

Key aspects of energy saving potential:

Energy Efficiency:

Improving the efficiency of energy use in appliances, equipment, and processes to reduce the amount of energy needed for a specific task. This can involve using energy-efficient appliances, optimizing industrial processes, or adopting better building designs.

Behavioural Changes:

Modifying daily habits to reduce energy consumption. Examples include switching off lights and appliances when not in use, adjusting thermostat settings, and using energy-efficient appliances.

Technological Advancements:

Developing and implementing new technologies that consume less energy. This includes advancements in renewable energy sources, energy storage, and smart grid technologies.

Government Policies and Regulations:

Implementing policies and regulations that incentivize energy efficiency and discourage wasteful practices. For example, the Energy Conservation Act in India formalizes the government's strategy to increase energy efficiency.

Economic Benefits:

Reducing energy consumption leads to lower energy bills for individuals and businesses, as well as reducing the overall cost of energy production and distribution.

Environmental Benefits:

Lowering energy consumption reduces reliance on fossil fuels, which in turn decreases greenhouse gas emissions and air pollution.

Factors Affecting Energy Saving Potential:

Current efficiency: The lower the current efficiency, the higher the potential savings.
Technology: Older equipment usually offers more opportunities.
Process control: Better control systems reduce waste.
Maintenance: Well-maintained equipment consumes less energy.
Operational practices: Training and awareness affect energy use.

How to Estimate Energy Saving Potential?

1. Conduct an energy audit.
2. Identify key energy consumers.
3. Evaluate inefficiencies and wastages.
4. Calculate savings for each energy conservation measure.
5. Prioritize measures based on payback and feasibility.

ENERGY AUDIT OF PROCESS INDUSTRY

Process industries—like cement, steel, chemicals, and textiles—are energy-intensive. Audits help:

- Lower **operating costs** by reducing energy waste.
- Improve **equipment performance** and **system reliability**.
- Ensure **compliance** with energy regulations and standards like ISO 50001.

Key Phases of an Energy Audit

1. **Preliminary Assessment**:
    - Review energy bills and plant layout.
    - Identify major energy-consuming systems.
2. **Detailed Audit**:
    - Measure actual energy use (electricity, steam, fuel).
    - Evaluate system efficiency (motors, boilers, HVAC).

    - Use tools like infrared thermography, flow meters, and power analyzers.
3. **Analysis & Recommendations**:
    - Suggest Energy Conservation Measures (ECMs).
    - Classify them into no-cost, low-capex, and high-capex options.
    - Develop an implementation roadmap with priorities.

Key Energy Systems in Process Industry to Audit:

- **Boilers and Steam Systems:** Efficiency, leaks, insulation, condensate recovery.
- **Motors and Drives:** Efficiency, load conditions, use of variable frequency drives.
- **Compressed Air Systems:** Leak detection, pressure optimization.
- **Heating and Cooling Equipment:** Furnaces, ovens, heat exchangers.
- **Lighting Systems:** Type of lamps, usage, controls.
- **Process Equipment:** Pumps, conveyors, mixers, dryers.
- **Electrical Distribution:** Transformer losses, power factor correction.

Energy Audit of Thermal Power Plant:

An energy audit of a thermal power plant is a comprehensive evaluation of energy flows, equipment performance, and operational practices to identify inefficiencies and recommend improvements. Given the scale and complexity of these plants, audits are essential for reducing Auxiliary Power Consumption (APC) and enhancing overall efficiency.

Key Components of the Audit

- **Segmentation of Operations**: The plant is divided into sub-areas like boiler, turbine, condenser, pumps, motors, and lighting systems.
- **Motor Audit**: Since motors range from fractional kW to several MW, they are a major focus due to their significant share in APC.
- **Boiler Efficiency Analysis**: Evaluates combustion efficiency, heat losses, and potential for waste heat recovery.
- **Transformer & Pump Audit**: Checks for load matching, losses, and scope for variable frequency drives.
- **Lighting Audit**: Assesses energy use and recommends efficient fixtures and controls.

Methodology

- **Data Collection**: Real-time measurements using analyzers, flow meters, and thermal cameras.
- **Benchmarking**: Compare performance against standards set by the Bureau of Energy Efficiency (BEE).
- **Reporting**: Structured reports highlight deficiencies and suggest remedial actions.

Benefits

- Reduction in APC (typically 7–10% of generation)
- Lower fuel consumption and emissions
- Improved reliability and lifespan of equipment
- Compliance with energy conservation regulations

BUILDING ENERGY AUDIT:-

A building energy audit is a systematic process to assess a building's energy consumption, identify areas of inefficiency, and recommend energy-saving measures. It involves a detailed analysis of how a building uses energy, the types of energy consumed, and the associated costs, with the goal of optimizing energy use and reducing consumption without compromising comfort or safety.

Key Aspects of a Building Energy Audit:

Inspection and Analysis:

Auditors examine various aspects of the building, including its envelope (walls, roof, windows, doors), heating, ventilation, and air conditioning (HVAC) systems, lighting, and other energy-consuming equipment.

Data Collection:

They gather data on energy consumption patterns, utility bills, and building characteristics to understand where energy is being used and how it's being used.

Identifying Inefficiencies:

The audit identifies areas where energy is being wasted or used inefficiently, such as air leaks, inadequate insulation, inefficient lighting, or poorly performing HVAC systems.

Developing Recommendations:

Based on the findings, the audit provides recommendations for energy-saving measures, which may include upgrades to equipment, operational changes, or adjustments to building systems.

Cost-Benefit Analysis:

The audit often includes a cost-benefit analysis of the recommended measures, outlining the potential energy savings, implementation costs, and payback periods.

Benefits of a Building Energy Audit:

Reduced Energy Costs:

By identifying and addressing inefficiencies, audits can lead to significant reductions in energy consumption and lower utility bills.

Improved Energy Efficiency:

Audits help optimize a building's energy performance, making it more sustainable and environmentally friendly.

Enhanced Comfort:

In some cases, addressing energy inefficiencies can also improve the comfort of the building's occupants by addressing issues like drafts or temperature imbalances.

Compliance with Regulations:

Some municipalities and regions have energy audit requirements for certain types of buildings, making audits a necessary step for compliance.

Informed Decision-Making:

The audit provides building owners and managers with valuable information to make informed decisions about energy management and investments in energy-saving technologies.

Conservation of Energy Building Codes (ECBC-2017):

The Energy Conservation Building Code (ECBC) 2017 in India sets minimum energy efficiency standards for commercial buildings, aiming to reduce energy consumption and promote sustainable design. It focuses on key building systems like the envelope, HVAC, lighting, and electrical power, and also encourages renewable energy integration. ECBC 2017 introduces different levels of compliance (ECBC, ECBC Plus, and Super ECBC) with increasing energy savings.

Key aspects of ECBC 2017:

Scope: Applies to new commercial buildings with a connected load of 100 kW or greater or a contract demand of 120 kVA or greater.

Building Systems: Covers building envelope (walls, roofs, windows), HVAC systems, lighting, and electrical power systems.

Energy Efficiency Levels: ECBC, ECBC Plus, and Super ECBC offer varying degrees of energy savings (25%, 35%, and 50% respectively).

Renewable Energy: Mandates provisions for renewable energy system installation, encouraging buildings to generate their own power.

Passive Design: Emphasizes passive design strategies like daylighting and shading to reduce reliance on mechanical systems.

Climate Zones: Recognizes India's five climate zones (Hot Dry, Warm Humid, Temperate, Composite, and Cold) and tailors requirements accordingly.

Compliance Methods: Allows for compliance through prescriptive methods or whole building performance methods.

Beyond Code Performance: ECBC 2017 is one of the first building energy codes to recognize and encourage performance beyond basic code requirements.

Implementation:

- The Bureau of Energy Efficiency (BEE) is the nodal agency for ECBC implementation in India.
- States are encouraged to adopt and enforce the code, with various partners like CPWD (Central Public Works Department), SDAs (State Designated Agencies), and State PWDs (Public Works Departments) involved in implementation.

- ECBC is a crucial step towards achieving energy neutrality in commercial buildings and reducing India's overall energy demand.

EXAMPLE PROBLEMS

1. There are three types of energy with energy consumption and also produces $100x10^3$ tons of a particular product. Calculate the energy index?

Energy type	Consumption	Energy (Wh)
Oil	$10x10^3$ gal	$0.520x10^9$
gas	$5x10^3$ therm	$0.146x10^9$
Electricity	$995x10^3$ kwh	$0.995x10^9$
	Total	$1.661x10^9$

ANS: - Oil energy index is $0.520x10^9$ wh/$100x10^3$ = $5.20x10^3$ wh/ton of product

Gas energy index is $0.146x10^9$ wh/$100x10^3$ = $1.46x10^3$ wh/ton of product

` Electricity energy index is $0.995x10^9$ wh/$100x10^3$ = $9.95x10^3$ wh/ton of product

Total energy index is $1.661x10^9$ wh/$100x10^3$ = $16.61x10^3$ wh/ton of product

2. The table given below shows the energy costs for a company using coke, gas and electricity. This company produces 15*10^3 tonnes per year , then claculate the cost indices.

Energy type	Consumption	Costs (Rs)
Coke	$1.5x10^3$ tonnes	108*10^6
Gas	$18x10^3$ therm	3.6*10^6
Electricity	$1x10^9$ kwh	22.5*10^6
	Total	134.1*10^6

Coke Cost index is 108*10^6/15*10^3 = Rs.$7.2x10^3$ /ton

Gas Cost index is 3.6*10^6/15*10^3 = Rs. $0.2x10^3$ /ton

Electricity Cost index is 22.5*10^6/15*10^3 = Rs. $1.5x10^3$ /ton

Total energy index is 134.1*10^6/15*10^3 = Rs. $8.9x10^3$ /ton

3. A company uses on an hourly basis, 4.32 x 10^9 J of oil, 11.72 x 10^3 therms of gas and 500 kW of electricity. Draw a Pie chart for this company's energy usage. (To convert 1 therm to J/s divide by 29.31 x 10^-3)

Sol: All the units are first converted into a particular unit, namely kW, thus

$$Oil = \frac{4.32\ X\ 10^9}{3600\ X\ 10^3} = 1200\ kW$$

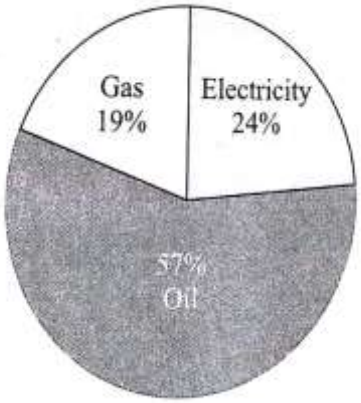
$$Gas = \frac{11.72\ X\ 10^3}{29.31\ X\ 10^{-3}} = 400\ kW$$

Electricty = 500kW

Total hourly energy consumption = 2100kWThen the segment angles of the pie chart are obtained and percentage of consumption are calculated as: $Oil = \frac{1200}{2100}\ X\ 360^0 = 206^0\ ;57.2\%$

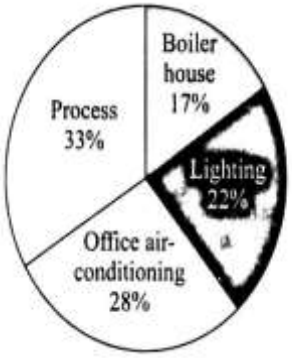
$$Gas = \frac{400}{2100} X\ 360^0 = \ 68^0\ ;18.9\%$$

$$Electricity = \frac{500}{2100} X\ 360^0 = \ 86^0\ ;23.9\%$$



Pie chart is shown as

The Pie charts may also be extended to indicate the consumption of a particular type of energy throughout an (Industry) facility. For example, consider the consumption of electricity of an industry. The consumption, angles and percentages are evaluated as follows:



Office air-conditioning	= 150 kW	= 100°	= 27.8 %
Lighting	= 120 kW	= 80°	= 22.2 %
Boiler house	= 90 kW	= 60°	= 16.7 %
Process	= 180 kW	= 120°	= 33.3 %

Total = 540 kW =360° =100%

The Pie charts enable the energy manager/energy auditor to identify the areas where energy conservation opportunities are to be identified, analyzed and evaluated in the order of priority. The technical feasibility and economical viability of such proposals are then considered for execution or implementation of them.

5.Find the cost index of an industry producing 15000 MT per year. Whose energy cost details are given as under:

Energy Type	Consumption	Energy costs/unit in Rupees	Total cost in Rupees
Coal	1500 MT	410/MT	615 x 10^3
Oil	18.000 litres	40.0/litre	720 x 10^3
Electricity	1.0 x 10^5 kWh	3.0/kWh	300 x 10^3
Total			1635 x 10^3

Coal cost index = $\frac{615 \text{ x } 10^3}{15\text{x}10^3} = \text{Rs } 41.0/\text{MT}$

Oil cost index = $\frac{720 \text{ x } 10^3}{15\text{x}10^3} = \text{Rs } 48.0/\text{MT}$

Electricity cost index = $\frac{300 \text{ x}10^3}{15\text{x}10^3} = \text{Rs } 20/\text{MT}$

Total cost index =Rs109 /MT