3. ENERGY MANAGEMENT AND AUDIT

Syllabus
Energy Management & Audit: Definition, Energy audit- need, Types of energy audit, Energy management (audit) approach-understanding energy costs, Bench marking, Energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments

3.1 Definition & Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

The term energy management means many things to many people. One definition of energy management is:

> *"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"*
>
> (Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press inc. 1997)

Another comprehensive definition is

> "The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilisation, throughout the organization and:

- To minimise energy costs / waste without affecting production & quality
- To minimise environmental effects.

3.2 Energy Audit: Types And Methodology

Energy Audit is the key to a systematic approach for decision-making in the area 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 quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programme.

As per the 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".

3.2.1 Need for Energy Audit

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The 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 and also provides the basis for planning a more effective use of energy throughout the organization.

3.2.2 Type 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

3.2.3 Preliminary Energy Audit Methodology

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

3.2.4 Detailed Energy Audit Methodology

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.

Ten Steps Methodology for Detailed Energy Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	Phase I –Pre Audit Phase	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • 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
	Phase II –Audit Phase	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • 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	• 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.
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
Step6	• 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
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
	<u>Phase III –Post Audit phase</u>	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance ▪ Action plan, Schedule for implementation ▪ Follow-up and periodic review

Phase I –Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyse the major energy consumption data with the relevant personnel.
- Obtain site drawings where available – building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are: -

- To finalise Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit eg. kWh, steam, oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame
- To collect macro data on plant energy resources, major energy consuming centers
- To create awareness through meetings/ programme

Phase II- Detailed Energy Audit Activities

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equipment, by end-use

2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
3. Energy cost and tariff data
4. Process and material flow diagrams
5. Generation and distribution of site services (eg.compressed air, steam).
6. Sources of energy supply (e.g. electricity from the grid or self-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).
8. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilisation
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies / yield

DATA COLLECTION HINTS

It is important to plan additional data gathering carefully. Here are some basic tips to avoid wasting time and effort:

- measurement systems should be easy to use and provide the information to the accuracy that is needed, not the accuracy that is technically possible
- measurement equipment can be inexpensive (flow rates using a bucket and stopwatch)
- the quality of the data must be such that the correct conclusions are drawn (what grade of product is on, is the production normal etc)
- define how frequent data collection should be to account for process variations.
- measurement exercises over abnormal workload periods (such as startup and shutdowns)
- design values can be taken where measurements are difficult (cooling water through heat exchanger)

DO NOT ESTIMATE WHEN YOU CAN CALCULATE
DO NOT CALCULATE WHEN YOU CAN MEASURE

Draw process flow diagram and list process steps; identify waste streams and obvious energy wastage

An overview of unit operations, important process steps, areas of material and energy use and sources of waste generation should be gathered and should be represented in a flowchart as shown in the figure below. Existing drawings, records and shop floor walk through will help in making this flow chart. Simultaneously the team should identify the various inputs & output streams at each process step.

Example: A flowchart of Penicillin-G manufacturing is given in the figure3.1 below. Note that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart

The audit focus area depends on several issues like consumption of input resources, energy efficiency potential, impact of process step on entire process or intensity of waste generation / energy consumption. In the above process, the unit operations such as germinator, pre-fermentor, fermentor, and extraction are the major conservation potential areas identified.

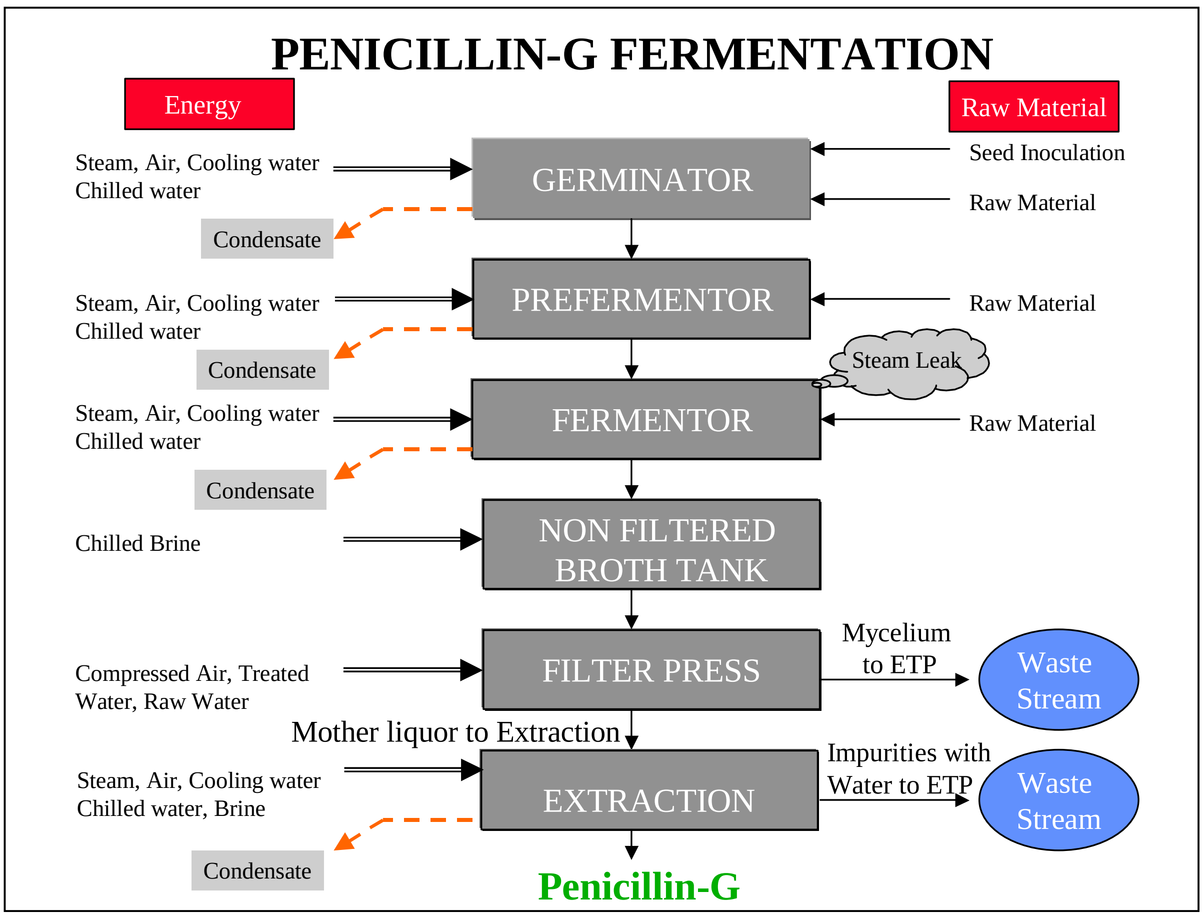


Figure 3.1

Identification of Energy Conservation Opportunities

Fuel substitution: Identifying the appropriate fuel for efficient energy conversion

Energy generation : Identifying Efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/thermic fluid heating, optimising existing efficiencies, efficienct energy conversion equipment, biomass gasifiers, Cogeneration, high efficiency DG sets, etc.

Energy distribution: Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, Etc.

Energy usage by processes: This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

Technical and Economic feasibility

The technical feasibility should address the following issues

- Technology availability, space, skilled manpower, reliability, service etc
- The impact of energy efficiency measure on safety, quality, production or process.
- The maintenance requirements and spares availability

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using a variety of methods. Example: Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient. A sample worksheet for assessing economic feasibility is provided below:

Sample Worksheet for Economic Feasibility

Name of Energy Efficiency Measure

1. Investment	2. Annual operating costs	3. Annual savings
• Equipments • Civil works • Instrumentation • Auxiliaries	• Cost of capital • Maintenance • Manpower • Energy • Depreciation	• Thermal Energy • Electrical Energy • Raw material • Waste disposal

Net Savings /Year (Rs./year)	Payback period in months
= (Annual savings-annual operating costs)	= (Investment/net savings/year) x 12

Classification of Energy Conservation Measures

Based on energy audit and analyses of the plant, a number of potential energy saving projects may be identified. These may be classified into three categories:

1. Low cost – high return;
2. Medium cost – medium return;
3. High cost – high return

Normally the low cost – high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. Refer Table 3.1 for project priority guidelines.

TABLE 3.1 PROJECT PRIORITY GUIDELINE

Priority	Economical Feasibility	Technical Feasibility	Risk / Feasibility
A - Good	Well defined and attractive	Existing technology adequate	No Risk/ Highly feasible
B -May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk/May be feasible
C -Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D -No	Clearly not attractive	Need major breakthrough	Not feasible

3.3 Energy Audit Reporting Format

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation. A typical energy audit reporting contents and format are given below. The following format is applicable for most of the industries. However the format can be suitably modified for specific requirement applicable for a particular type of industry.

Report on

DETAILED ENERGY AUDIT

TABLE OF CONTENTS

The following Worksheets (refer Table 3.2 & Table 3.3) can be used as guidance for energy audit assessment and reporting.

TABLE 3.2 SUMMARY OF ENERGY SAVING RECOMMENDATIONS

S.No.	Energy Saving Recommendations	Annual Energy (Fuel & Electricity) Savings (kWh/MT (or) kl/MT)	Annual Savings (Rs.Lakhs)	Capital Investment (Rs.Lakhs)	Simple Payback period
1					
2					
3					
4					
Total					

TABLE 3.3 TYPES AND PRIORITY OF ENERGY SAVING MEASURES

	Type of Energy Saving Options	Annual Electricity /Fuel savings	Annual Savings	Priority
		kWh/MT (or) kl /MT	(Rs. Lakhs)	
A	No Investment (Immediate) - Operational Improvement - Housekeeping			
B	Low Investment (Short to Medium Term) - Controls - Equipment Modification - Process change			
C	High Investment (Long Term) - Energy efficient Devices - Product modification - Technology Change			

Reporting Format for Energy Conservation Recommendations		
A: Title of Recommendation	**:**	**Combine DG set cooling tower with main cooling tower**
B: Description of Existing System and its operation	**:**	Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m^3/hr.Two cooling water pumps are in operation continuously with 50% of its rated capacity. A separate cooling tower is also operating for DG set operation continuously.
C: Description of Proposed system and its operation	**:**	The DG Set cooling water flow is only 240 m^3/h. By adding this flow into the main cooling tower, will eliminate the need for a separate cooling tower operation for DG set, besides improving the %loading of main cooling tower. It is suggested to stop the DG set cooling tower operation.
D: Energy Saving Calculations		
Capacity of main cooling tower	=	5000 m^3/ hr
Temp across cooling tower (design)	=	8 ^oC
Present capacity	=	3000 m^3/hr
Temperature across cooling tower(operating)	=	4 ^oC
% loading of main cooling tower	=	(3000 x 4)/(5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m^3/hr
Temp across the tower	=	5^oC
Heat Load (240x1000 x 1x 5)	=	1200,000 K.Cal/hr
Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m^3/h (66.67 l/s) with 6 kg/cm^2	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential	=	40kWx 8400hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 xRs.4.00 = Rs.13.4 Lakh per year
Investment (Only cost of piping)	=	Rs 1.5Lakhs
Simple Pay back Period	=	**Less than 2 months**

3.4 Understanding Energy Costs

Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year, which gives a base-line for future reference
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc.
- When electricity is purchased on the basis of maximum demand tariff
- They can suggest where savings are most likely to be made.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures

Fuel Costs

A wide variety of fuels are available for thermal energy supply. Few are listed below:

- Fuel oil
- Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- COAL
- LIGNITE
- WOOD ETC.

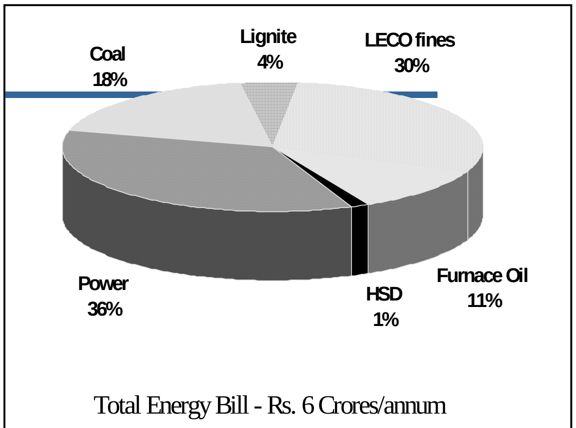


Figure 3.2:Annual energy bill

Understanding fuel cost is fairly simple and it is purchased in Tons or Kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- Energy content (calorific value)

Power Costs

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges, kVA
  (i.e. **How fast** the electricity is used?)

- Energy Charges, kWh
  (i.e., **How much** electricity is consumed?)
- TOD Charges, Peak/Non-peak period
  (i.e. **When** electricity is utilized ?)
- Power factor Charge, P.F
  (i.e., **Real power use versus Apparent power use factor**)
- Other incentives and penalties applied from time to time
- High tension tariff and low tension tariff rate changes
- Slab rate cost and its variation
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, Government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/States
- Tax holiday for new projects

Example: Purchased energy Bill

A typical summary of energy purchased in an industry based on the invoices

Table 3.4			
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.10,000/ kL	20,00,000
Coal	1000 tons	Rs.2,000/ton	20,00,000
Total			60,00,000

Unfortunately the different forms of energy are sold in different units e.g. kWh of electricity, liters of fuel oil, tonne of coal. To allow comparison of energy quantities these must be converted to a common unit of energy such as kWh, Giga joules, kCals etc.

Electricity(1 kWh)	= 860 kCal/kWh	(0.0036 GJ)
Heavy fuel oil (Gross calorific value, GCV)	=10000 kCal/litre	(0.0411 GJ/litre)
Coal (Gross calorific value, GCV)	=4000 kCal/kg	(28 GJ/ton)

3.5 Benchmarking and Energy Performance

Benchmarking of energy consumption internally (historical / trend analysis) and externally (across similar industries) are two powerful tools for performance assessment and logical evolution of avenues for improvement. Historical data well documented helps to bring out energy consumption and cost trends month-wise / day-wise. Trend analysis of energy consumption, cost, relevant production features, specific energy consumption, help to understand effects of capacity utilization on energy use efficiency and costs on a broader scale.

External benchmarking relates to inter-unit comparison across a group of similar units. However, it would be important to ascertain similarities, as otherwise findings can be grossly misleading. Few comparative factors, which need to be looked into while benchmarking externally are:

- Scale of operation
- Vintage of technology
- Raw material specifications and quality
- Product specifications and quality

Benchmarking energy performance permits

- Quantification of fixed and variable energy consumption trends vis-à-vis production levels
- Comparison of the industry energy performance with respect to 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.

The benchmark parameters can be:

- Gross production related
  - e.g. kWh/MT clinker or cement produced (cement plant)
  - e.g. kWh/kg yarn produced (Textile unit)
  - e.g. kWh/MT, kCal/kg, paper produced (Paper plant)
  - e.g. kCal/kWh Power produced (Heat rate of a power plant)
  - e.g. Million kilocals/MT Urea or Ammonia (Fertilizer plant)
  - e.g. kWh/MT of liquid metal output (in a foundry)

- Equipment / utility related
  - e.g. kW/ton of refrigeration (on Air conditioning plant)
  - e.g. % thermal efficiency of a boiler plant
  - e.g. % cooling tower effectiveness in a cooling tower
  - e.g. kWh/NM^3 of compressed air generated
  - e.g. kWh /litre in a diesel power generation plant.

While such benchmarks are referred to, related crucial process parameters need mentioning for meaningful comparison among peers. For instance, in the above case:

- For a cement plant – type of cement, blaine number (fineness) i.e. Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit – average count, type of yarn i.e. polyester/cotton, is to be reported along side kWh/square meter.
- For a paper plant – paper type, raw material (recycling extent), GSM quality is some important factors to be reported along with kWh/MT, kCal/Kg figures.
- For a power plant / cogeneration plant – plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kCal/kWh).
- For a fertilizer plant – capacity utilization(%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption

- For a foundry unit – melt output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number or power trips could be some useful operating parameters to be reported while mentioning specific energy consumption data.
- For an Air conditioning (A/c) plant – Chilled water temperature level and refrigeration load (TR) are crucial for comparing kW/TR.
- For a boiler plant – fuel quality, type, steam pressure, temperature, flow, are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, may mean a lot in benchmarking exercise for meaningful comparison.
- Cooling tower effectiveness – ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- Compressed air specific power consumption – is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance – is to be compared at similar loading %, steady run condition etc.

Plant Energy Performance

Plant energy performance (PEP) is the measure of whether a plant is now using more or less energy to manufacture its products than it did in the past: a measure of how well the energy management programme is doing. It compares the change in energy consumption from one year to the other considering production output. Plant energy performance monitoring compares plant energy use at a reference year with the subsequent years to determine the improvement that has been made.

However, a plant production output may vary from year to year and the output has a significant bearing on plant energy use. For a meaningful comparison, it is necessary to determine the energy that would have been required to produce this year production output, if the plant had operated in the same way as it did during the reference year. This calculated value can then be compared with the actual value to determine the improvement or deterioration that has taken place since the reference year.

Production factor

Production factor is used to determine the energy that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year. It is the ratio of production in the current year to that in the reference year.

$$\text{Pr}\,oduction\ factor = \frac{Current\ \ year's\ \ production}{\text{Re}\,ference\ year's\ \ production}$$

Reference Year Equivalent Energy Use

The reference year's energy use that would have been used to produce the current year's production output may be called the "reference year energy use equivalent" or "reference year equivalent" for short. 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

The improvement or deterioration from the reference year is called "energy performance" and is a measure of the plant's energy management progress. It is the reduction or increase in the current year's energy use over the reference, and is calculated by subtracting the current year's energy use from the reference years equivalent. The result is divided by the reference year equivalent and multiplied by 100 to obtain a percentage.

$$\text{Plant energy performance} = \frac{\text{Reference year equivalent - Current year's energy}}{\text{Reference year equivalent}} \times 100$$

The energy performance is the percentage of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.

Monthly Energy Performance

Experience however, has shown that once a plant has started measuring yearly energy performance, management wants more frequent performance information in order to monitor and control energy use on an on-going basis. PEP can just as easily be used for monthly reporting as yearly reporting.

3.6 Matching Energy Usage to Requirement

Mismatch between equipment capacity and user requirement often leads to inefficiencies due to part load operations, wastages etc. Worst case design, is a designer's characteristic, while optimization is the energy manager's mandate and many situations present themselves towards an exercise involving graceful matching of energy equipment capacity to end-use needs. Some examples being:

- Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speed drives
- Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.
- Moderation of chilled water temperature for process chilling needs
- Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption
- Adoption of task lighting in place of less effective area lighting

3.7 Maximising System Efficiency

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best practices in operation and maintenance as well as judicious technology adoption. Some illustrations in this context are:

- Eliminate steam leakages by trap improvements
- Maximise condensate recovery
- Adopt combustion controls for maximizing combustion efficiency
- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist.

Optimising the Input Energy Requirements

Consequent upon fine-tuning the energy use practices, attention is accorded to considerations for minimizing energy input requirements. The range of measures could include:

- Shuffling of compressors to match needs.
- Periodic review of insulation thickness
- Identify potential for heat exchanger networking and process integration.
- Optimisation of transformer operation with respect to load.

3.8 Fuel and Energy Substitution

Fuel substitution: Substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.

Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution.

Fuel substitution has taken place in all the major sectors of the Indian economy. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.

Few examples of fuel substitution

- Natural gas is increasingly the fuel of choice as fuel and feedstock in the fertilizer, petrochemicals, power and sponge iron industries.
- Replacement of coal by coconut shells, rice husk etc.
- Replacement of LDO by LSHS

Few examples of energy substitution

- ✓ Replacement of electric heaters by steam heaters
- ✓ Replacement of steam based hotwater by solar systems

Case Study : Example on Fuel Substitution

A textile process industry replaced old fuel oil fired thermic fluid heater with agro fuel fired heater. The economics of the project are given below:

A: Title of Recommendation	:	**Use of Agro Fuel (coconut chips) in place of Furnace oil in a Boiler**
B: Description of Existing System and its operation	:	A thermic fluid heater with furnace oil currently. In the same plant a coconut chip fired boiler is operating continuously with good performance.
C: Description of Proposed system and its operation	:	It was suggested to replace the oil fired thermic fluid heater with coconut chip fired boiler as the company has the facilities for handling coconut chip fired system.

D: Energy Saving Calculations

Old System

Type of fuel Firing	**: Furnace Oil fired heater**
GCV	: 10,200 kCal/kg
Avg. Thermal Efficiency	: 82%
Heat Duty	: 15 lakh kCal / hour
Operating Hours	: 25 days x 12 month x 24 hours = 7,200 hrs.
Annual Fuel Cost	: Rs.130 lakh (7200 x 1800 Rs./hr.)

Modified System

Type of fuel saving	**= Coconut chips fired Heater**
GCV	= 4200 kCal/kg
Average Thermal Efficiency	= 72 %
Heat Duty	= 15 lakh kCal / hour
Annual Operating Cost	= 7200 x 700 Rs./hr = 50 lakh
Annual Savings	= 130 - 50 = Rs.80 lakh .
Additional Auxiliary Power + Manpower Cost	= Rs. 10 lakh
Net Annual Saving	= Rs. 70lakh
Investment for New Coconut Fired heater	= Rs.35 lakh
Simple pay back period	**= 6 months**

3.9 Energy Audit Instruments

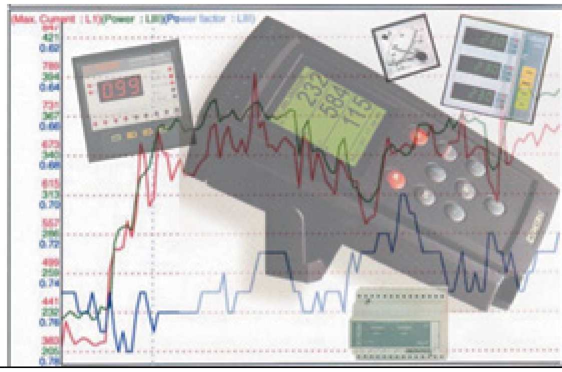
The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following:

Basic Electrical Parameters in AC &DC systems – Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

Parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis – CO_2, O_2, CO, SO_x, NO_x, combustion efficiency etc.

Key instruments for energy audit are listed below.

The operating instructions for all instruments must be understood and staff should familiarize themselves with the instruments and their operation prior to actual audit use.

 	**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.
	**Combustion analyzer:** This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_X and SO_X.
	**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. A separate fyrite can be used for O_2 and CO_2 measurement.

	**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 Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Water flow meter:** This **non-contact** flow measuring device using Doppler effect / Ultra sonic 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.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as they 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.
		**Leak Detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities**.**
		**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.

QUESTIONS

1.	List down the objective of energy management..
2.	What are the managerial functions involved in energy management?
3.	Explain why managerial skills are as important as technical skills in energy management?
4.	What are the various steps in the implementation of energy management in an organization?
5.	State the importance of energy policy for industries.
6.	Explain the role of training and awareness in energy management programme?
7.	What is an energy audit?
8.	Explain briefly the difference between preliminary and detailed energy audits?
9.	What is the significance of knowing the energy costs?
10.	What are the benefits of benchmarking energy consumption?
11.	Explain the implications of part load operation of energy equipment with examples?
12.	What do you understand by the term fuel substitution? Give examples.
13.	What are the parameters that can be measured by on line power analyser?
14.	Name the one instrument used to measure CO_2 from boilers stack is (a) Infrared thermometer (b) Fyrite (c) Anemometer (d) Pitot tube
15.	Non contact flow measurement can be carried out by (a) Orifice meter (b) Turbine flow meter (c) Ultrasonic flow meter (d) Magnetic flow meter
16.	Non contact speed measurements can be carried out by (a) Tachometer (b) Stroboscope (c) Oscilloscope (d) Odometer

REFERENCES

1. NPC energy audit manual and reports
2. Energy management handbook, John Wiley and Sons - Wayne C. Turner
3. Guide to Energy Management, Cape Hart, Turner and Kennedy
4. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council

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