Energy Management
&
Energy Audit

WHAT IS ENERGY?

- **Definition:** Energy is the capacity of a physical system to perform work. Energy exists in several forms such as heat, kinetic or mechanical energy, light, potential energy, electrical or other forms.
- According to the law of conservation of energy, the total energy of a system remains constant, though energy may transform into another form.
- For example, two billiard balls colliding, may come to rest, with the resulting energy converting to sound and perhaps a little bit of heat, at the point of collision.

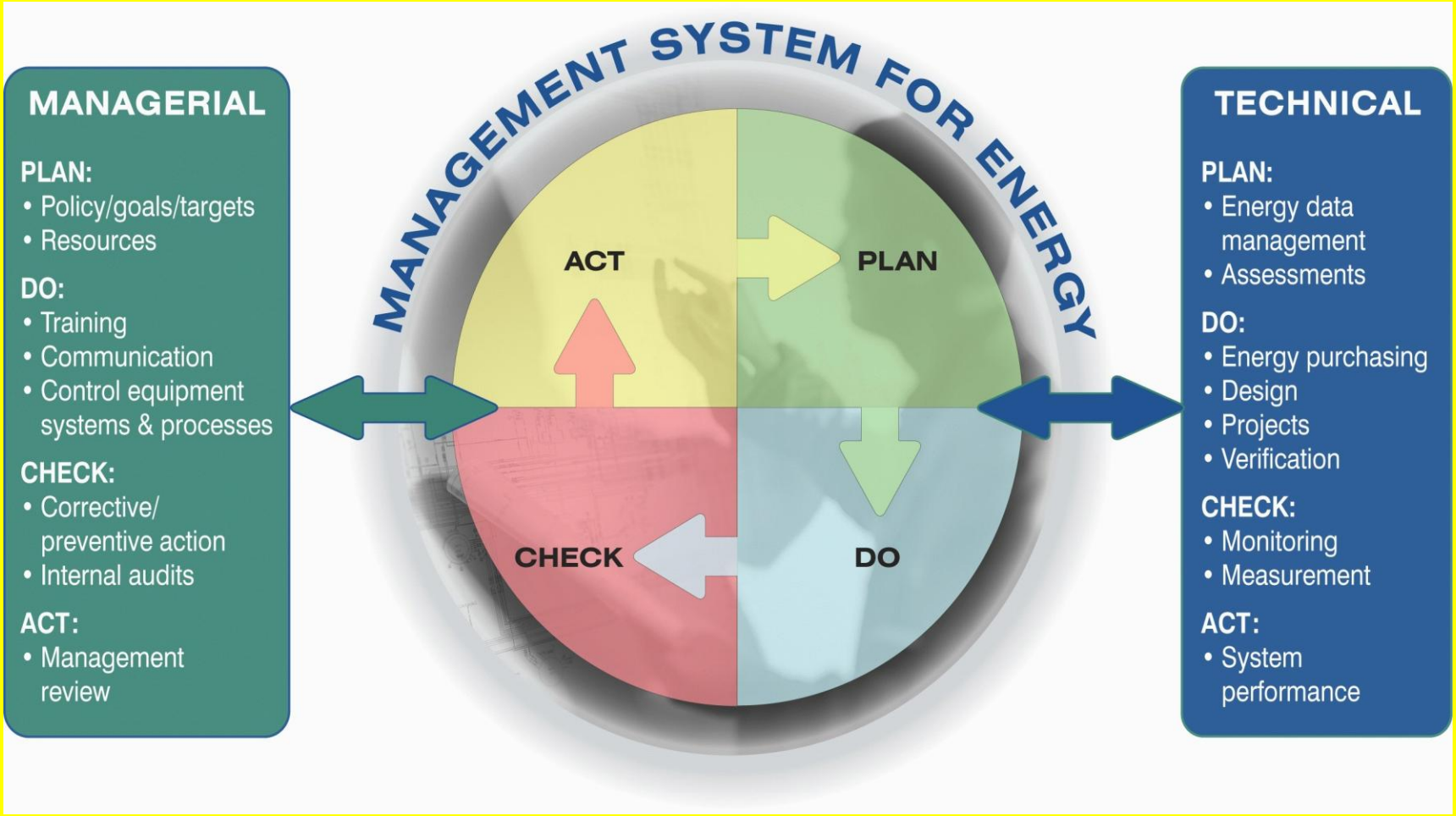
TYPES OF ENERGY

- **Mechanical energy**
  Mechanical energy is energy that results from movement or the location of an object. Mechanical energy is the sum of Kinetic and Potential Energy.
- **Thermal energy**
  Thermal energy or heat energy reflects the temperature difference between two systems.
- **Nuclear energy**
  Nuclear energy is energy resulting from changes in the atomic nuclei or from nuclear
- **Chemical energy**
  Chemical energy results from chemical reactions between atoms or molecules. There are different types of chemical energy, such as electrochemical energy etc.
- **Electromagnetic energy**
  Electromagnetic energy is energy from light or electromagnetic waves.

Definition of Energy Management

Energy Management is defined as "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 Energy Management System



The Objectives of Energy Management

1. To achieve and maintain optimum energy procurement and utilisation, throughout the organization

2. To minimise energy costs / waste without affecting production & quality

3. To minimise environmental effects.

Energy Management Objectives Clarified

The basic objective of any Energy Management System is to answer five simple questions:

- How much energy is consumed
- How is the energy consumed
- Where is the energy consumed
- When is the energy consumed
- What is the quality of the energy consumed

- **In order to address these queries Energy Audits are conducted. Lets understand audits -**

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"

Reference: Link
https://www.slideshare.net/o4el82/energy-audit-9860585

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

Types of Energy Audits

1. Preliminary Energy Audit
2. Targeted Energy Audit
3. Detailed Energy Audit

Preliminary Energy Audit

Preliminary energy audit uses existing or easily obtained data

Establishes the energy consumption 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

Targeted Energy Audits

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.

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

The Ten Steps for Detailed 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

Step 3	Phase II –Audit Phase ● 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.

Step10	Phase III –Post Audit phase ● Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance ♣ Action plan, Schedule for implementation ♣ Follow-up and periodic review

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?

DETAILED ENERGY AUDIT
A TYPICAL INDUSTRIAL FORMAT

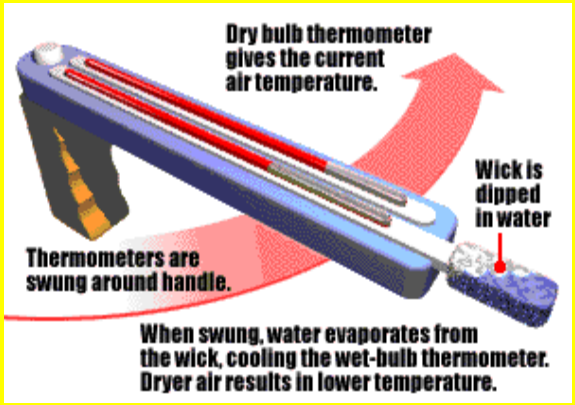
Energy Audit Team
Executive Summary –Scope & Purpose

Energy Audit Options & Recommendations

1. Introduction about the plant
2. General Plant details and descriptions
3. Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)
4. Major Energy use and Areas
5. Production Process Description
6. Brief description of manufacturing process
7. Process flow diagram and Major Unit operations
8. Major Raw material Inputs, Quantity and Costs
9. Energy and Utility System Description
10. List of Utilities
11. Brief Description of each utility
12. Electricity
    1. Steam
    2. Water
    3. Compressed air
    4. Chilled water
    5. Cooling water

1. Detailed Process flow diagram and Energy& Material balance
2. Flow chart showing flow rate, temperature, pressures of all input- Output stream
3. Water balance for entire industry
4. Energy efficiency in utility and process systems
5. Specific Energy consumption
6. Boiler efficiency assessment
7. Thermic Fluid Heater performance assessments
8. Furnace efficiency Analysis
9. Cooling water system performance assessment
10. DG set performance assessment
11. Refrigeration system performance
12. Compressed air system performance
13. Electric motor load analysis
14. Lighting system
15. Energy Conservation Options & Recommendations
16. List of options in terms of no cost, low cost, medium cost and high cost, annual energy savings and payback
17. Implementation plan for energy saving measures/Projects

ANNEXURE
Al. List of instruments
A2. List of Vendors and Other Technical details



All Energy Audits require many measurements. Some common Instruments used are shown above

Some more Energy Audit Instruments

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

Case Study

Energy Audit at Mother Dairy (Milk Plant)

BASE LINE DATA

Product	**Bulk Processed Milk (Toned, Double Toned & Full Cream)**
Capacity of the plant	**8 Lac liters of Milk per day**
Annual Fuel / Energy Consumption	PNG: 17,76,000 SCM Worth: Rs 3.7 Crores Electricity: 134.6 Lac kVAh Worth: Rs 6.68 Crores
Annual Energy Bill	Rs 10.38 Crores
Compressed Air generation	180 cfm
Steam Consumption	65,000 kg/month for Milk Plant 15,000 kg/month for Ice Cream Plant

Summary of Savings Identified & Realized (Year 2003 & 2004)

Total Savings projected by PCRA	Electricity: 21,43,360 kVAh Worth: Rs 78.24 Lac LDO: 184.31 KL Worth: 85.8 Lac
Total Savings Realised till date	Electricity: 5,21,017 kVAh Worth: Rs 19.02 Lac LDO: 130.06 KL Worth: Rs 60.55 Lac
% Savings Realised of total energy consumption	Electricity: 3.7% LDO: 20.3%

- **Major recommendations implemented:**
  1. Boiler fuel switched over to PNG from LDO
  2. Steam supplied to ICP from this boiler
  3. Improvement of Power Factor from 0.9 to 0.996
  4. New air compressor installed lowering SEC
  5. Installation of Auto Blow Down system for Boiler

Summary of Savings Identified (Year 2025)

Total savings identified	Electricity: 7,17,004 kVAh PNG: 1,36,042 SCM Worth: Rs 59.18 Lac
No cost savings with immediate payback	Electricity: 95,308 kVAh Worth: Rs 4.1 Lac
Low cost savings with payback < 1 year	Electricity: 5,41,796 kVAh Worth: Rs 23.3 Lac
High cost savings with payback between 1-2 years	Electricity: 79,900 kVAh Worth: Rs 3.44 Lac Gas: 1,36,042 SCM Worth: Rs 28.34 Lac
% savings identified of total energy consumption	Electricity: 5.32% Gas: 7.66%

BOILERS

Observations:

1. Condensate recovery is not being done.
2. Feed water temperature presently is 50°C.

Recommendations:

1. Recover condensate to raise feed water temperature to upto 85°C
2. Install de-aerator head on feed water tank and recover condensate.
3. Install steam operated condensate recovery pump

Savings Estimated / year	Investment	Payback Period
Rs 28.34 Lac	Rs 25 Lac	11 Months

Air Compressors

Observations:

1. Air leakage are about 26%.

Recommendations:

1. Plugging of air leakages

Savings Estimated / year	Investment	Payback Period
Rs 4.0 Lac	Nominal	Immediate

illumination

Observations:

1. HPMV lamps are used for street lighting.
2. 36 Watt Tube lights with copper chokes are used.

Recommendations:

1. Replace HPMV lamps by HPSV lamps
2. Replace 36 Watt Tube lights with T-5 28 Watt with electronic choke in a phased manner.

Savings Estimated / year	Investment	Payback Period
Rs 3.34 Lac	Rs 4.0 Lac	16 Months

Conclusion

The gaps may exist in design & actual operations for large complexes due to integration of :

- ✓ **Steam thermal systems.**
- ✓ **Electrical systems**
- ✓ **Process systems (Motive/ Thermal loads) due to variation in efficiencies/ actual requirements**
- ✓ **Continuous monitoring and analysis of integrated systems is essential for improvements.**
- ✓ **Energy Audits will identify such gaps.**
- ✓ **Implementation of recommendations will result into considerable energy savings.**

Technical and Economic feasibility- Factors

Technology availability, space, skilled manpower, reliability, service,Impact of measure on safety, quality, production or process.Maintenance requirements and spares availability

Sample Worksheet for Economic Feasibility

Name of Energy Efficiency Measure

i. Investment

a. Equipments
b. Civil works
c. Instrumentation
d. Auxiliaries

2. Annual operating costs

- Cost of capital
- Maintenance
- Manpower
- Energy
- Depreciation

3. Annual savings

- Thermal Energy
- Electrical Energy
- Raw material
- Waste disposal

Net Savings /Year (Rs./year)
= (Annual savings-annual operating costs)

Payback period in months
= (Investment/net savings/year) x 12

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

Understanding energy costs

An industrial energy bill summary

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

Conversion to common unit of energy

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)

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

Benchmarking for Energy Performance

- **Internal Benchmarking**
  - **Historical and trend analysis**
- **External Benchmarking**
  - **Across similar industries**

    Scale of operation, vintage of technology, raw material specification and quality and product specification and quality

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

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.

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) / Reference year equivalent x 100**

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

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

Optimising Energy Input Requirement

- **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.**

- EXAMPLES:
- Shuffling of compressors to match needs.
- Periodic review of insulation thickness
- Identify potential for heat exchanger networking and process integration.

Fuel and Energy Substitution – key steps towards conservation

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 Auditor Exam Information

https://beeindia.gov.in/content/energy-auditors

https://targetstudy.com/exams/bee/

Reference Links

Walk through Energy Audit
https://www.youtube.com/watch?v=8eKpfjnT0ro
Old home energy Audit
https://www.youtube.com/watch?v=seSlAAB9aTo
https://www.youtube.com/watch?v=YolBP0-vkBU
https://www.youtube.com/watch?v=0DfGthBP_BY
Industry Energy Audit
https://verdesolutions.com/industrial-energy-audits-a-responsible-approach-towards-energy-savings/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