

UNIT-5

Energy Economics

In the process of energy management, at some stage, investment would be required for reducing the energy consumption of a process or utility. Investment would be required for modifications/retrofitting and for incorporating new technology. It would be prudent to adopt a systematic approach for merit rating of the different investment options vis-à-vis the anticipated savings.

It is essential to identify the benefits of the proposed measure with reference to not only energy savings but also other associated benefits such as increased productivity, improved product quality etc.

The cost involved in the proposed measure should be captured in totality viz.

- Direct project cost
- Additional operations and maintenance cost
- Training of personnel on new technology etc.

Based on the above, the energy economics can be carried out by the energy management team. Energy manager has to identify how cost savings arising from energy management could be redeployed within his organization to the maximum effect. To do this, he has to work out how benefits of increased energy efficiency can be best sold to top management as,

- Reducing operating /production costs
- Increasing employee comfort and well-being
- Improving cost-effectiveness and/or profits
- Protecting under-funded core activities
- Enhancing the quality of service or customer care delivered
- Protecting the environment

Cost-Benefit Analysis

Within any organization there are many worthy causes, each of which requires funding and it is the job of senior management to invest in capital where it is going to obtain the greatest return. In order to make a decision about any course of action, management needs to be able to appraise all the costs involved in a project and determine the potential benefits.

This however, is not quite as simple as it might first appear. The capital value of plant or equipment usually decreases with time and it often requires more maintenance as it gets older. If money is borrowed from a bank to finance a project, then interest will have to be paid on the loan. Inflation too will influence the value of any future energy savings that might be achieved. It is therefore important that

the cost-benefit analysis allows for all these factors, with the aim of determining which investments should be undertaken, and of optimizing the benefits achieved. To this end a number of accounting and financial appraisal techniques have been developed which help energy managers and auditors make correct and objective decisions.

When appraising the cost-benefit involved in a project it is important to understand the difference between fixed and variable costs. Variable costs are those which vary directly with the output of a particular plant or production process, such as fuel costs. Fixed costs are those costs, which are not dependent on plant or process output, such as site-rent and insurance. The total cost of any project is therefore the sum of the fixed and variable costs.

Discount Rate or Rate of Return

The rate of return is the amount you receive after the cost of an initial investment, calculated in the form of a percentage. The percentage can be reflected as a positive, which is considered a gain or profit. When the percentage is negative, it reflects a loss. This information is very useful in determining whether or not the initial investment you made was a good one.

6.3.1 The Rate of Return Formula

There are two major numbers needed to calculate the rate of return: Current value

= the current value of the item.

Original value = the price at which you purchased the item.

Then, apply these values to the

Rate of return formula = ((Current value - original value) / original value) x 100

Example 6.1

Let's say that in 2002 you purchased a home for Rs 2,000,000. In the next few years, homes in your neighborhood have been selling well due to the new shopping plaza a couple of miles away, which increased the market value of your home. So in 2007, you decided to downsize and sell your home. Based on the current market value during this time, you were able to sell your home for Rs 2,500,000. Using the formula, let's calculate the rate of return on your investment:

Current value = 2500,000

Original value = 2,000,000

Then
of return

$$\text{rate of return} = ((\text{Current value} - \text{original value}) / \text{original value}) \times 100 = \text{rate}$$
$$= ((2,500,000 - 2,000,000) / 2,000,000) \times 100 = 25\%$$

rate
Of

Here the positive percentage indicates the business is profitable.

Simple Pay-Back Period

Simple Payback Period (SPP) is defined as the time (number of years) required to recover the initial investment (First Cost), considering only the Net Annual Saving:

The simple payback period is usually calculated as follows:

$$\text{Simple payback period} = \frac{\text{First cost}}{\text{Yearly benefits} - \text{Yearly costs}}$$

Advantages

A widely used investment criterion, the payback period seems to offer the following advantages:

- It is simple, both in concept and application. Obviously a shorter payback generally indicates a more attractive investment. It does not use tedious calculations.
- It favours projects, which generate substantial cash inflows in earlier years, and discriminates against projects, which bring substantial cash inflows in later years but not in earlier years.

Limitations

- It fails to consider the time value of money
- It ignores cash flows beyond the payback period.

Example 6.2

A new small cogeneration plant installation is expected to reduce a company's annual energy bill by Rs.4,86,000. If the capital cost of the new boiler installation is Rs.22,20,000 and the annual maintenance and operating costs are Rs. 42,000, the expected payback period for the project can be worked out as.

Solution

$$PB = 22,20,000 / (4,86,000 - 42,000) = 5.0 \text{ years}$$

Internal Rate of Return

This method calculates the rate of return that the investment is expected to yield. The internal rate of return (IRR) method expresses each investment alternative in terms of a rate of return (a compound interest rate). The expected rate of return is the interest rate for which total discounted benefits become

just equal to total discounted costs (i.e net present benefits or net annual benefits are equal to zero, or for which the benefit / cost ratio equals one). The criterion for selection among alternatives is to choose the investment with the highest rate of return.

The rate of return is usually calculated by a process of trial and error, whereby the net cash flow is computed for various discount rates until its value is reduced to zero.

The internal rate of return (IRR) of a project is the discount rate, which makes its net present value (NPV) equal to zero. It is the discount rate in the equation:

$$0 = \frac{CF_0}{(1+k)^0} + \frac{CF_1}{(1+k)^1} + \dots + \frac{CF_n}{(1+k)^n} = \sum_{t=0}^n \frac{CF_t}{(1+k)^t}$$

where CF_t = cash flow at the end of year "t"

k = discount rate

n = life of the project.

Net Present Value

The *net present value* method calculates the *present value* of all the yearly cash flows (i.e. capital costs and net savings) incurred or accrued throughout the life of a project, and summates them.

The net present value (NPV) of a project is equal to the sum of the present values of all the cash flows associated with it. Symbolically,

$$NPV = \frac{CF_0}{(1+k)^0} + \frac{CF_1}{(1+k)^1} + \dots + \frac{CF_n}{(1+k)^n} = \sum_{t=0}^n \frac{CF_t}{(1+k)^t}$$

Where NPV = Net Present Value

CF_t = Cash flow occurring at the end of year 't' ($t=0,1,\dots,n$)

n = life of the project

k = Discount rate

The discount rate (k) employed for evaluating the present value of the expected future cash flows should reflect the risk of the project.

Advantages

The net present value criterion has considerable merits.

- It takes into account the time value of money.
- It considers the cash flow stream in its project life.

Life Cycle Costing (LCC)

Life cycle costing, or whole-life costing, is the process of estimating how much money you will spend on an asset over the course of its useful life. Whole-life costing covers an asset's costs from the time you purchase it to the time you get rid of it including the costs of acquisition, maintenance, repair, replacement, energy, and any other monetary costs (less any income amounts, such as salvage value) that are affected by the investment decision. The time value of money must be taken into account for all amounts, and the amounts must be considered over the relevant period.

To calculate an asset's life cycle cost, estimate the following expenses:

1. Purchase
2. Installation
3. Operating
4. Maintenance
5. Financing (example interest...)
6. Depreciation
7. Disposal

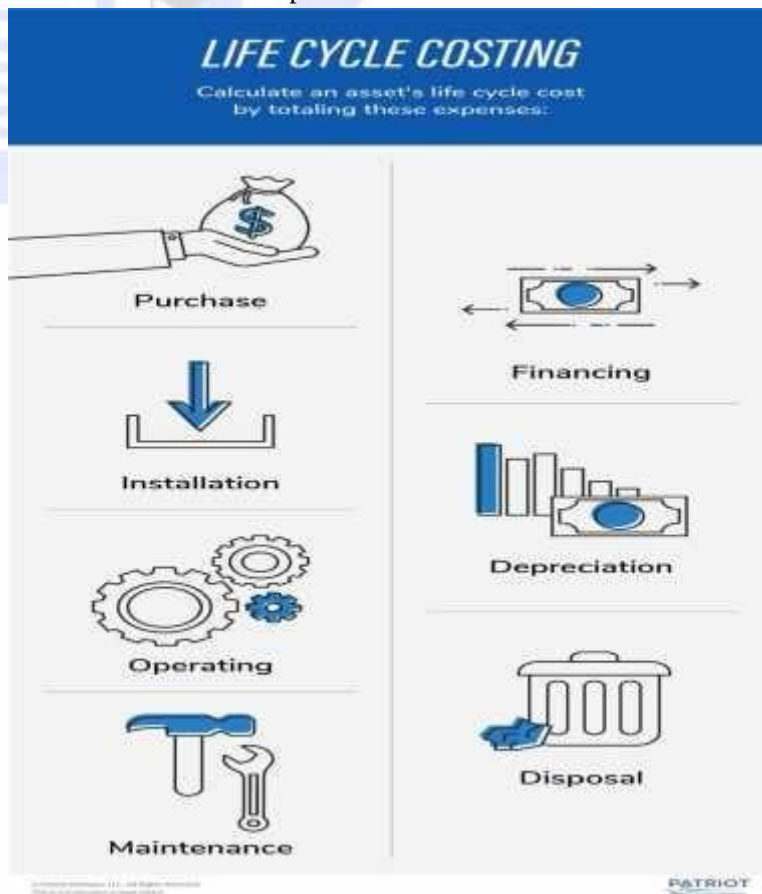


Figure 6.1 Stages of LCC

ESCO (Energy Saving Company) Concept

ESCOs are usually companies that provide a complete energy project service, from assessment to design to construction or installation, along with engineering and project management services, and financing. In one way or another, the contract involves the capitalization of all of the services and goods purchased, and repayment out of the energy savings that result from the project.

In performance contracting, an end-user (such as an industry, institution, or utility) seeking to improve its energy efficiency, contracts with ESCO for energy efficiency services and financing.

In some contracts, the ESCOs provide a guarantee for the savings that will be realized, and absorbs the cost if real savings fall short of this level. Typically, there will be a risk management cost involved in the contract in these situations. Insurance is sometimes attached, at a cost, to protect the ESCO in the event of a savings shortfall.

Energy efficiency projects generate incremental cost savings as opposed to incremental revenues from the sale of outputs. The energy cost savings can be turned into incremental cash flows to the lender or ESCO based on the commitment of the energy user (and in some cases, a utility) to pay for the savings.

ESCOs are not “bankers” in the narrow sense. Their strength is in putting together a package of services that can provide guaranteed and measurable energy savings that serve as the basis for guaranteed cost savings. But, the energy savings must be measurable. The figure shows ESCOs role.

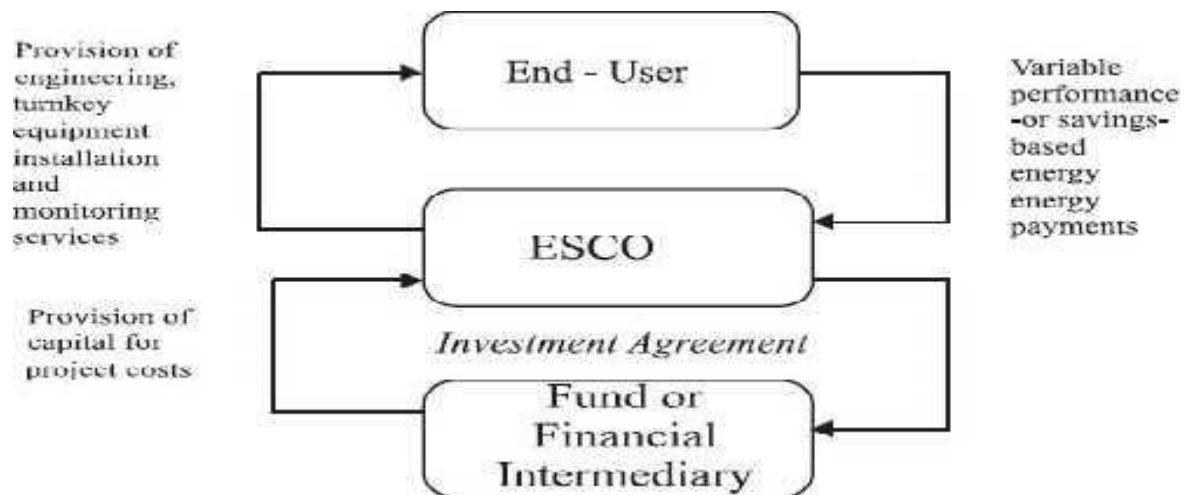


Figure 6.2 Role of ESCO

UNIVERSITY QUESTIONS

UNIT-1

1. Compare the objectives and deliverables of preliminary, detailed and specific energy audit
2. What are the barriers for energy audit?
3. Discuss the typical functions of an energy manager?
4. What is global warming? List the gases that cause it?
5. What the term CO₂ equivalent mean?
6. Compare the energy scenario of India with any one of the developed countries with respect to per capita energy generation, conservation and T&D loss?
7. What is energy audit? Detail the methodology and outcomes of preliminary, detailed and specific energy audit?
8. Mention the role of energy managers in an industry?
9. How energy efficiency and energy conservation are defined and differentiated? Explain with an example?
10. Name 5 energy consuming sectors in India?
11. How energy consumption and “Acid rain & Ozone layer depletion” are related? Explain.
12. What do the following instruments measure.

(i) Fyrite(ii) Pitot tube(iii) Psychrometer(iv) Luxmeter
13. How energy conservation and environment are related?
14. What are the role of BEE (Bureau of Energy Efficiency) in India

UNIT-2

1. List at least 8 options for energy conservation in transformers and illumination systems?
2. A 50 kW induction motor with 86% present full load efficiency is being considered for replacement by a 89% efficiency motor. What will be the savings in energy if the motor works for 6000 hours per year and cost of energy is Rs 4.50 per kWh?
3. Classify the various losses encountered in a motor and detail the techniques adopted for curtailing system?
4. List 5 losses taking place in motor operation. Indicate the values of these losses in % and show by a sankey diagram. (Assume total loss = 100%)
5. Define the concept of “All day efficiency of a transformer”?
6. List the merits and limitation of GLS (General Lighting Service) lamps
7. A 3Φ , 50Hz, 500HP, 11kV star connected induction motor has a full load efficiency of 85% with lagging power factor of 0.75. If it is desired to correct the PF to 0.92 lagging, determine the size/rating of capacitor bank to be added ?
8. Define two laws of illumination (Inverse square law & Lambert’s cosine law)
9. Name two methods employed for speed control in a motor and brief?
10. State the criteria at which the efficiency of a transformer will be maximum?
11. List the advantages of LED lighting over the commonly used lamps?
12. The average power factor of an industry is 0.70 with an average kW of 650. How much kVAR is required to improve the PF to 0.90?
13. Differentiate Lux & Lumens?
14. A transformer (315 kVA) has a no-load loss of 1.2 kW and a full load loss of 6.2 kW . Estimate the maximum efficiency achievable in the transformer and the corresponding load?
15. The name plate details of a 3Φ squirrel cage induction motor as follows.

415 V	15 A	7.5kW	4pole	50hZ	0.8 PF
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The data measured when the motor was in operation as follows.

410 V	9.3 A	7.5kW	4pole	49.8Hz	0.78 PF	1470rpm
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No-load test Data: **410 V, 5 A, 0.2PF,**

Ω stator of 30°C = **0.24 Ω**

Stator temperature = **100°C,**

Stray loss = **4% of rated output**

16. Estimate the slip and full load efficiency of the motor?
17. Write working principle of LED lamp?
18. Write short note on capacitors
19. In a 25 kVA transformer, the iron and full load losses are 350 kW& 400 W respectively. Establish the efficiency of operation of the transformer at full load & unity power factor and half full load & 0.8 PF. Also determine the transformer load at which the efficiency will be maximum
20. Write on any 3 types of lamps commonly used in commercial establishments indicating their merits and limitations?
21. Write short note on power factor correction and losses taking place in a motor?

UNIT-3

1. Write down three functions of a steam trap and three mostly widely used types of steam traps
2. State the need for “Blow down” in a boiler?
3. Saturated steam flows at a rate of **5 tph** at **7 ksc** with a velocity of **25 m/s**. Determine the pipesize
4. Estimate the boiler efficiency by indirect method using the following:

Fuel Firing Rate	=	7000 kg/h
Calorific Value	=	40000 kJ / kg
Steam Parameters	=	7 kg/cm ² (abs): Saturated
Boiler feed water temp	=	60°C
Fuel Analysis (wt%)	=	C=84, H = 12, S =3% O ₂ = 1 %
Flue Gas Analysis	=	CO ₂ = 115, CO = 1000 ppm, O ₂ = 7%
Ambient Humidity	=	0.02 kg H ₂ O / kg Dry Air
Loss due to Ash Heat and Unburnts	=	0.8% of fuel CV
CO Heat of conversion	=	23630 kJ /kg

5. Write short note on flash steam utilization and condensate heat recovery with respect to boiler?
6. A process plant needs 10tph of saturated steam at 7 ksc pressure from boiler. Feed water inlet temperature is 40°C. Find the boiler rating F & A 100°C
7. State the advantages of condensate recovery in a process plant
8. Name two major losses occurring in fuel combustion in a boiler and elaborate?
9. Write on following:
 - (i) Boiler Derating
 - (ii) Method to find “excess air” used in combustion
 - (iii) Blow down – need for it

(iv) Economizer and air pre-heater : State their functions and which of these two will be bigger in size and why?

(v) Functions of a steam trap

10. Why indirect method is preferred for computing boiler efficiency

11. During the test of an oil fired water tube boiler, the following observation were noted:

Steam Pressure	=	16 bar (abs)
Water evaporated per minute	=	282.85kg
Feed water temperature	=	76°C
Steam quality	=	99%
Fuel oil consumption rate	=	44966 kJ /kg

find actual evaporation per kg of fuel oil, factor of evaporation and boiler efficiency?

12. Name 6 major losses that occur in a boiler operation and indicate the methods to control them

13. Write down the factors “blow down” and “superheated steam” in a boiler

14. Write on flash steam generation in a boiler

15. Elaborate the following with reference to boiler operation :

- (i) Advantages of steam as a heat transfer medium
- (ii) Indirect method of boiler efficiency determination
- (iii) Blow down in boiler operation
- (iv) types and functions of steam trap

16. Explain the concept of economic thickness of insulation in steam distribution systems

17. Write on pinch analysis

18. The ER (evaporation ratio) of a coal fired boiler is 4.2 Estimate boiler efficiency. Steam

enthalpy	=	2670 kJ / kg
Feed water temperature	=	55°C
Coal calorific Value	=	16700 kJ / kg

19. With a neat sketch, compare the working principle, advantages and drawbacks of float coupled thermostatic and thermodynamic steam traps?

20. List at least 8 guidelines for proper drainage and layout of steam supply network?

UNIT-4

1. Compare the characteristics of Forward curved, Backward curved and Radial fans?
2. Compare PD pumps vis-à-vis rotodynamic pumps with respect to flow rate versus pressure and flow rate versus velocity?
3. Following were the observations during compressor trial in a textile plant:

Receiver capacity	:	10m ³		
Initial pressure	:	0.2 bar	final pressure :	6.0 bar
Additional hold-up volume	:	1.2 m ³		
Compressor pump-up time	:	4.26 minutes		
Motor power consumption	:	98.6kW		

Calculate the operational capacity of compressor & specific power consumption (neglect temperature correction)

4. Name the 2 most important parameters to be considered in the selection of a pump and explain?
5. Show by a worked example that operating cost of a blower far exceeds its investment cost on life cycle cost analysis basis.
6. Show with a neat sketch the working principle of a heat pump?
7. Write down the equation for air flow measurement in a duct using pitot tube?
8. Explain technically why higher temperature at evaporator and low temperature at condenser are preferred in a vapour compression refrigeration (VCR) system from energy conservation point of view?
9. How Heat Wheel & Recuperator are differentiated in their basic principle of operation?
10. What are the possible causes for a higher power consumption in pumps. Explain?
11. Draw the characteristics curve of a blower?
12. Write the equation for estimating "Air leakage" in an air compressor system and explain?
13. In a A/C system of 10 TR capacity, air enters the cooling coil at 25°C (19.5°C WBT) and leaves at 15°C (WBT = 10°C). Estimate the air quantity supplied, CoP, EER and specific power

consumption if the motor power input is 15kW (motor efficiency = 88%) . Evolve a procedure for estimating Free Air Delivery (FAD) of an air compressor using pump-up method?

14. List Energy opportunities available in a pumping system?

15. A centrifugal fan has a circular inlet duct (450mm dia) and rectangular outlet duct (450*375 mm). static pressure at fan inlet is 12.5 mm WC and that at fan outlet is 25mm WC and that at fan outlet is 25mm WC. Airflow is 115 m³/min. Estimate the total pressure developed by the fan and the overall efficiency?

16. What are the tools used for energy audit? Briefly explain the functionality of the instruments?

17. What are the benchmarks of energy consumption?

18. Explain the need for energy auditing?

19. Define energy audit? Give its importance. Which are the steps involved in energy audit?

UNIT-5

1. Write note on simple pay back period and net present value method
2. Explain net present value method of financial analysis. What are the advantages and limitation of this method?
3. Define depreciation. The capital cost of a road laying machine is Rs 30 lakhs. Its salvage value after 5 years is Rs 50,000. The length of the road that the machine can lay its lifetime is 75,000 km. The length of the road during third year of operation is 3000km. Find the depreciation of the equipment for the third year?
4. What are the advantages of discounted cash flow method
5. What is the role of ESCO's
6. Compare the project acceptance criteria, merits and demerits of the following financial appraisal techniques
 - a) simple payback period
 - b) net present value method
 - c) Average rate of return
 - d) Internal rate of return
7. Three mutually exclusive projects A, B & C have been proposed. Each project requires an investment worth Rs 2,00,000 and have an estimated 5 years, 4 years & 3 years respectively. After its life cycle, the salvage value of the projects is to be nil. The company's required rate of return is 10%. The anticipated cash flows after taxes (CFAT) for the three projects are as follows

Year	CFAT for Projects		
	A	B	C
	50,000	80,000	1,00,000
	50,000	80,000	1,00,000
	50,000	80,000	10,000
	50,000	30,000	----
	1,90,000	---	----

Rank each project applying the methods of SPB, ARR, NPV & IRR

8. Analyze the merits and demerits of IRR over SPB, NPV & ARR

9. What is the role of ESCO (Energy Saving Company) in the implementation of ENCON schemes in an industry?

10. A factory has plans of recovering waste heat from a thermal source. There are 2 options available to the factory termed option 1 and option 2. The economics of options are as below. Suggest the better option. (Life time of each option is 6 years) [hint: use IRR method]

Option	Initial Invest Rs lakhs	Annual Income lakhs Rs/y
1	5	1.8
2	8	2.6

11. Calculate the NPV of the investment, if discount rate is 12% and capital investment is 25 lakh rupees and comment on the feasibility of the project. The return from the project is as follows

Year	1	2	3	4	5	6
CASH	1 lakh	3 lakh	3 lakh	4.5 lakh	4.5 lakh	5 lakh

12. A small windmill for water pumping costs Rs 10,000 to purchase and install. If Rs. 800 is the annual savings after replacing diesel engine, calculate the internal rate of return of the investment, if life of wind mill is assumed as 15 Years

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.

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***".

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

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

Energy Audit: Needs

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.

Energy Audit: Types

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

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

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

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.
- Analyze 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 finalize 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 pay- back 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

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

i. Acknowledgement

ii. Executive Summary

Energy Audit Options at a glance & Recommendations

1.0 Introduction about the plant

1.1 General Plant details and descriptions

1.2 Energy Audit Team

1.3 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)

1.4 Major Energy use and Areas

2.0 Production Process Description

2.1 Brief description of manufacturing process

2.2 Process flow diagram and Major Unit operations

2.3 Major Raw material Inputs, Quantity and Costs

3.0 Energy and Utility System Description

3.1 List of Utilities

3.2 Brief Description of each utility

3.2.1 Electricity

3.2.2 Steam

3.2.3 Water

3.2.4 Compressed air

3.2.5 Chilled water

3.2.6 Cooling water

4.0 Detailed Process flow diagram and Energy& Material balance

4.1 Flow chart showing flow rate, temperature, pressures of all input-output streams

4.2 Water balance for entire industry

5.0 Energy efficiency in utility and process systems

5.1 Specific Energy consumption

5.2 Boiler efficiency assessment

5.3 Thermic Fluid Heater performance assessment

5.4 Furnace efficiency Analysis

5.5 Cooling water system performance assessment

5.6 DG set performance assessment

5.7 Refrigeration system performance

5.8 Compressed air system performance

5.9 Electric motor load analysis

5.10 Lighting system

6.0 Energy Conservation Options & Recommendations

6.1 List of options in terms of No cost/ Low Cost, Medium cost and high investment Cost, Annual Energy & Cost savings, and payback

6.2 Implementation plan for energy saving measures/Projects

ANNEXURE

A1. List of Energy Audit Worksheets

A2. List of instruments

A3. List of Vendors and Other Technical details

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.

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
- Energy Charges, kWh
- TOD Charges, Peak/Non-peak period
- Power factor Charge, P.F
- 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

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 kilocal/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/NM³ of compressed air generated
 - e.g. kWh /litre in a diesel power generation plant.

Energy Performance

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.

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

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

Maximizing 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. Maximize 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.

Optimizing 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.

Fuel and Energy Substitution

Substituting existing fossil fuel with more efficient and less cost/less polluting fuels such as natural gas, biogas and locally available agro-residues. 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 hot water by solar systems

Energy Audit Instruments



Electrical Measuring Instruments:

These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics.

These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.

	Combustion analyzer: This instrument has in-built chemical cells which measure various gases such as O₂, 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 bellows 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 O₂ and CO₂ measurement.
	Contact thermometer: These are thermocouples which measure 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.