# UNIT-4

## 4.1.Energy Efficiency / Saving Measures in Pumps

Pump efficiency $= \dfrac{\text{Hydraulic power, } P_h}{\text{Power input to the pump shaft}} \times 100$

Where,

Hydraulic power $P_h(kW) = Q \times (h_d - h_s) \times \rho \times g / 1000$

$Q$ = Volume flow rate $(m^3 / s)$, $\rho$ = density of the fluid $(kg/m^3)$, $g$ = acceleration due to gravity $(m/s^2)$, $(h_d - h_s)$ = Total head in metres

- Ensure adequate NPSH at site of installation

- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.

- Operate pumps near best efficiency point.

- Modify pumping system and pumps losses to minimize throttling.

- Adapt to wide load variation with variable speed drives or sequenced control of multiple units.

- Stop running multiple pumps - add an auto-start for an on-line spare or add a boosterpump in the problem area.

- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates in case ofheat exchangers.

- Repair seals and packing to minimize water loss by dripping.
- Balance the system to minimize flows and reduce pump power requirements.
- Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage:
- Conduct water balance to minimize water consumption
- Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.

- In multiple pump operations, carefully combine the operation of pumps to avoid throttling

- Provide booster pump for few areas of higher head

- Replace old pumps by energy efficient pumps
- In the case of over designed pump, provide variable speed drive, or downsize /replace impeller or replace with correct sized pump for efficient operation.

- Optimize number of stages in multi-stage pump in case of head margins

- Reduce system resistance by pressure drop assessment and pipe size optimization.

## 4.2.Energy Efficiency / Saving Measures in Fans & Blowers

1. Minimizing excess air level in combustion systems to reduce FD fan and ID fan load.

2. Minimizing air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc. Cold air in-leaks increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself.

3. In-leaks / out-leaks in air conditioning systems also have a major impact on energy Efficiency and fan power consumption and need to be minimized.

The findings of performance assessment trials will automatically indicate potential areasfor improvement, which could be one or a more of the following:

1. Change of impeller by a high efficiency impeller along with cone.

2. Change of fan assembly as a whole, by a higher efficiency fan

3. Impeller de-rating (by a smaller dia impeller)

4. Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy Efficient hollow FRP impeller with aerofoil design, in case of axial flow fans, wheresignificant savings have been reported

5. Fan speed reduction by pulley dia modifications for derating

6. Option of two speed motors or variable speed drives for variable duty conditions

7. Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses.

8. Adopting inlet guide vanes in place of discharge damper control

9. Minimizing system resistance and pressure drops by improvements in duct system

## 4.3.Energy Efficiency / Saving Measures in Compressed Air System

• Ensure air intake to compressor is not warm and humid by locating compressors in well ventilatedarea or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase powerconsumption by1 percent.

• Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter.

• Keep compressor valves in good condition by removing and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50 percent.

• Install manometers across the filter and monitor the pressure drop as a guide to replacement of element.

• Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors.

• Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.

• Fouled inter-coolers reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must be ensured.

• Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken if required.

• If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at full load.

• The possibility of heat recovery from hot compressed air to generate hot air or water for process application must be economically analyzed in case of large compressors.

• Consideration should be given to two-stage or multistage compressor as it consumes less power for the same air output than a single stage compressor.

• If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed air systems.

• Reduce compressor delivery pressure, wherever possible, to save energy.
• Provide extra air receivers at points of high cyclic-air demand which permits operation without extra compressor capacity.

• Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminate the `unloaded' running condition altogether.

• Keep the minimum possible range between load and unload pressure settings.

• Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should be optimized.

• Check air compressor logs regularly for abnormal readings, especially motor current cooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressor load-cycle.

• Compressed air leakage of 40 – 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity of leakage.

• Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not in use.
• Present energy prices justify liberal designs of pipeline sizes to reduce pressure drops.

• Compressed air piping layout should be made preferably as a ring main to provide desired pressures for all users.

• A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthy pipelines.

• All pneumatic equipment should be properly lubricated, which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption or leakage.

• Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air and energy.

• Pneumatic equipment should not be operated above the recommended operating pressure as this not only wastes energy bus can also lead to excessive wear of equipment's components which leads to further energy wastage.

• Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy. Highest possibility of energy savings is by reducing compressed air use.

• Pneumatic tools such as drill and grinders consume about 20 times more energy than motor driven tools. Hence they have to be used efficiently. Wherever possible, they should be replaced with electricallyoperated tools.

• Where possible welding is a good practice and should be preferred over threaded connections.

• On account of high pressure drop, ball or plug or gate valves are preferable over globe valves in compressed air lines.

## 4 .4 Energy Efficiency / Saving Measures in Refrigeration System
### a) Cold Insulation

Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; andchoose appropriate (correct) insulation.

### b) Building Envelope

Optimize air conditioning volumes by measures such as use of false ceiling and segregation ofcritical areas for air conditioning by air curtains.

### c) Building Heat Loads Minimization

Minimize the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, optimal Thermo static setting of temperature of air conditioned spaces, sun film applications, etc.

### e) Process Heat Loads Minimization

Minimize process heat loads in terms of TR capacity as well as refrigeration level, i.e., temperaturerequired, by way of:

i) Flow optimization

ii) Heat transfer area increase to accept higher temperature coolant

iii) Avoiding wastages like heat gains, loss of chilled water, idle flows.

iv) Frequent cleaning / de-scaling of all heat exchangers

**f) At the Refrigeration A/C Plant Area**

i) Ensure regular maintenance of all A/C plant components as per manufacturer guidelines.

ii) Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flowsby closing valves of idle equipment.

iii) Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying process load.

iv) Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity.

v) Adopt VAR system where economics permit as a non-CFC solution.

## 4.5.Energy Efficiency / Saving Measures in A/C

- Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1 percent.

- Keep compressor valves in good condition by removingClean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter. and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50 percent.

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- Where possible welding is a good practice and should be preferred over threadedconnections.

- On account of high pressure drop, ball or plug or gate valves are preferable over globevalves in compressed air lines.

## 4.6. Energy Saving Opportunities in Cooling Towers

- Follow manufacturer's recommended clearances around cooling towers and relocate ormodify structures that interfere with the air intake or exhaust.
- Optimize cooling tower fan blade angle on a seasonal and/or load basis.
- Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
- On old counter-flow cooling towers, replace old spray type nozzles with new square sprayABS practically non-clogging nozzles.
- Replace splash bars with self-extinguishing PVC cellular film fill.
- Install new nozzles to obtain a more uniform water pattern
- Periodically clean plugged cooling tower distribution nozzles.
- Balance flow to cooling tower hot water basins.
- Cover hot water basins to minimize algae growth that contributes to fouling.
- Optimize blow down flow rate, as per COC limit.

- Replace slat type drift eliminators with low pressure drop, self extinguishing, PVC cellularunits. Restrict flows through large loads to design values.

- Segregate high heat loads like furnaces, air compressors, DG sets, and isolate cooling towers for sensitive applications like A/C plants, condensers of captive power plant etc. A 1°C cooling water temperature increase may increase A/C compressor kW by 2.7%. A 1°C drop in cooling water temperature can give a heat rate saving of kCal/kWh in a thermal power plant.

- Monitor L/G ratio, CW flow rates w.r.t. design as well as seasonal variations. It would help to increase water load during summer and times when approachis high and increase air flow during

monsoon times and when approach is narrow.

- Monitor approach, effectiveness and cooling capacity for continuous optimization efforts, as per seasonal variations as well as load side variations.

- Consider COC improvement measures for water savings.

- Consider energy efficient FRP blade adoption for fan energy savings.

- Consider possible improvements on CW pumps with respect to efficiency improvement.

- Control cooling tower fans based on leaving water temperatures especially in case of small units.
- Optimize process CW flow requirements, to save on pumping energy, cooling load, evaporation losses (directly proportional to circulation rate) and blow down losses.

### 4.7.Energy Saving Measures in DG Set

a) Ensure steady load conditions on the DG set, and provide cold, dust free air at intake(use of air washers for large sets, in case of dry, hot weather, can be considered).

b) Improve air filtration.

c) Ensure fuel oil storage, handling and preparation as per manufacturers' guidelines/oil company data.

d) Consider fuel oil additives in case they benefit fuel oil properties for DG set usage.

e) Calibrate fuel injection pumps frequently.

f) Ensure compliance with maintenance checklist.

g) Ensure steady load conditions, avoiding fluctuations, imbalance in phases, harmonicloads.

h) In case of a base load operation, consider waste heat recovery system adoption for steam generation or refrigeration chiller unit incorporation. Even the Jacket CoolingWater is amenable for heat recovery, vapour absorption system adoption.

i) In terms of fuel cost economy, consider partial use of biomass gas for generation. Ensure tar removal from the gas for improving availability of the engine in the longrun.

j) Consider parallel operation among the DG sets for improved loading and fuel economy therefore.

k) Carryout regular field trials to monitor DG set performance, and maintenance planningas per requirements.

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

## 4.8.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  makecorrect 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.

## 4.9.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.

**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**

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          return formula = ((Current value - original value) / original value) x 100          =rate
of return          = ((2,500,000 – 2,000,000)/ 2,000,000) *100
= 25%

rate
Of

Here the positive percentage indicates the business is profitable.

### 4.10.Simple Pay-Back Period

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

The simple payback period is usually calculated as follows:

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

### 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 inflowsin 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 .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 theproject can be worked out as.

### Solution

PB = 22,20,000 / (4,86,000 – 42,000) = 5.0 years

## 4.11.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 netcash 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 netpresent value (NPV) equal to zero. It is the discount rate in the equation:

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

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

$k$ = discount rate

$n$ = life of the project.

## 4.13.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 allthe cash flows associated with it. Symbolically,

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

Where NPV = Net Present Value

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

life of the project

$k$ = Discount rate

The discount rate (k) employed for evaluating the present value of the expected futurecash 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.

**4.14.Life Cycle Costing (LCC)**

Life cycle costing, or whole-life costing, is the process of estimating how much money you willspend 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
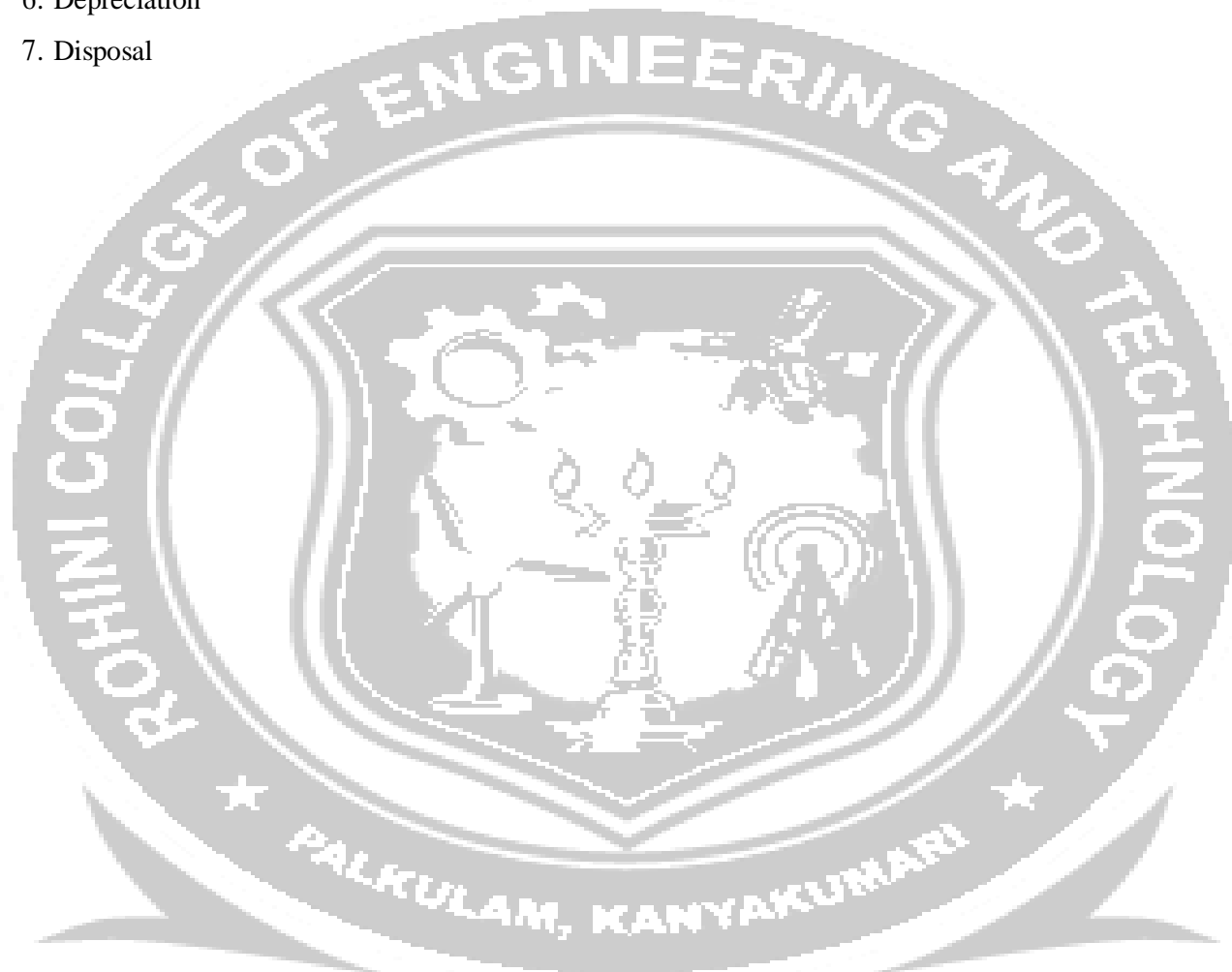5. Financing (example interest…)
6. Depreciation
7. Disposal

**Figure 6.1 Stages of LCC**

**4.15.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 fromthe 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.
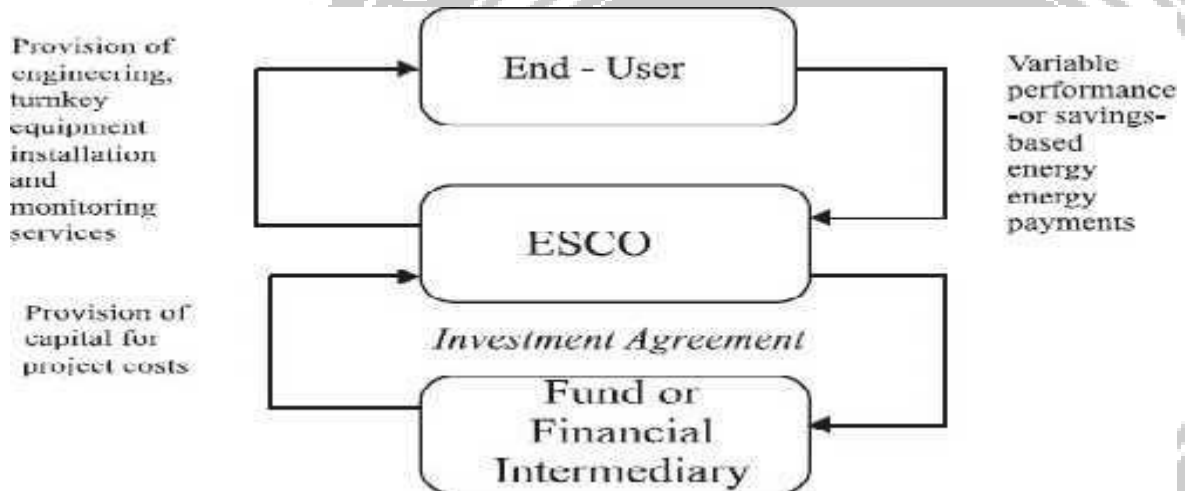


**Figure 6.2 Role of ESCO**

## 4.16.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.

## 4.17.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.

## 4.18.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 per- formed to justify the implementation of those conservation measures that require investments.

**4.19.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

## 4.20.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.

## 4.21.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.

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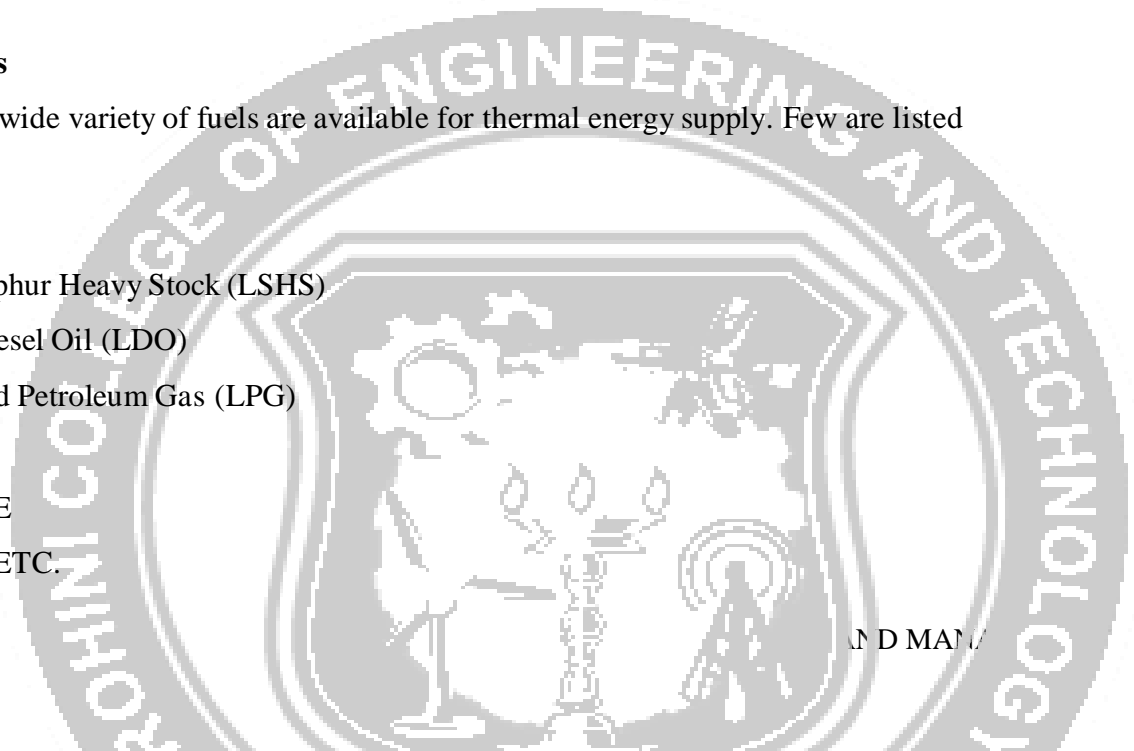
Understanding fuel cost is fairly simple and it is purchased in Tons or Kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- nergy 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

## 4.22.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 productionlevels (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.

## 4.23 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.

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

## 4.24.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.

## 4.25.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, petro chemicals, 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