MODULE – I

ENERGY AUDITING

ENERGY SITUATION:-

Introduction:-

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them. With the present situation of increasing energy demand, rising energy prices, and reinforcement of countermeasures for global warming, renewable energy sources have taken the spotlight. Bio fuels are one form of renewable energy that has become more widespread. Also, bio-fuels have been introduced and expanded as alternative fuel for the transportation sector and as a form of liquid renewable energy that can be blended with petroleum.

However, since the source material of bio-fuels is sometimes the same as for food, an increase in grocery prices has drawn attention to the next generation of bio-fuels being non-food sourced. This report will discuss the demand perspective derived from the IEA (International Energy Agency) world energy forecast, basic energy price trends, and bio-fuel trends.

Energy can be classified into several types based on the following criteria:

- Primary and Secondary energy
- Commercial and Non commercial energy
- Renewable and Non-Renewable energy

Primary and Secondary Energy:-

Primary energy sources are those that are either found or stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass (such as wood). Other primary energy sources available include nuclear energy from radioactive substances, thermal energy stored in earth‘s interior, and potential energy due to earth‘s gravity.

The major primary and secondary energy sources are shown in Figure 1.1 Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity.

Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can be used as a feedstock in fertilizer plants.

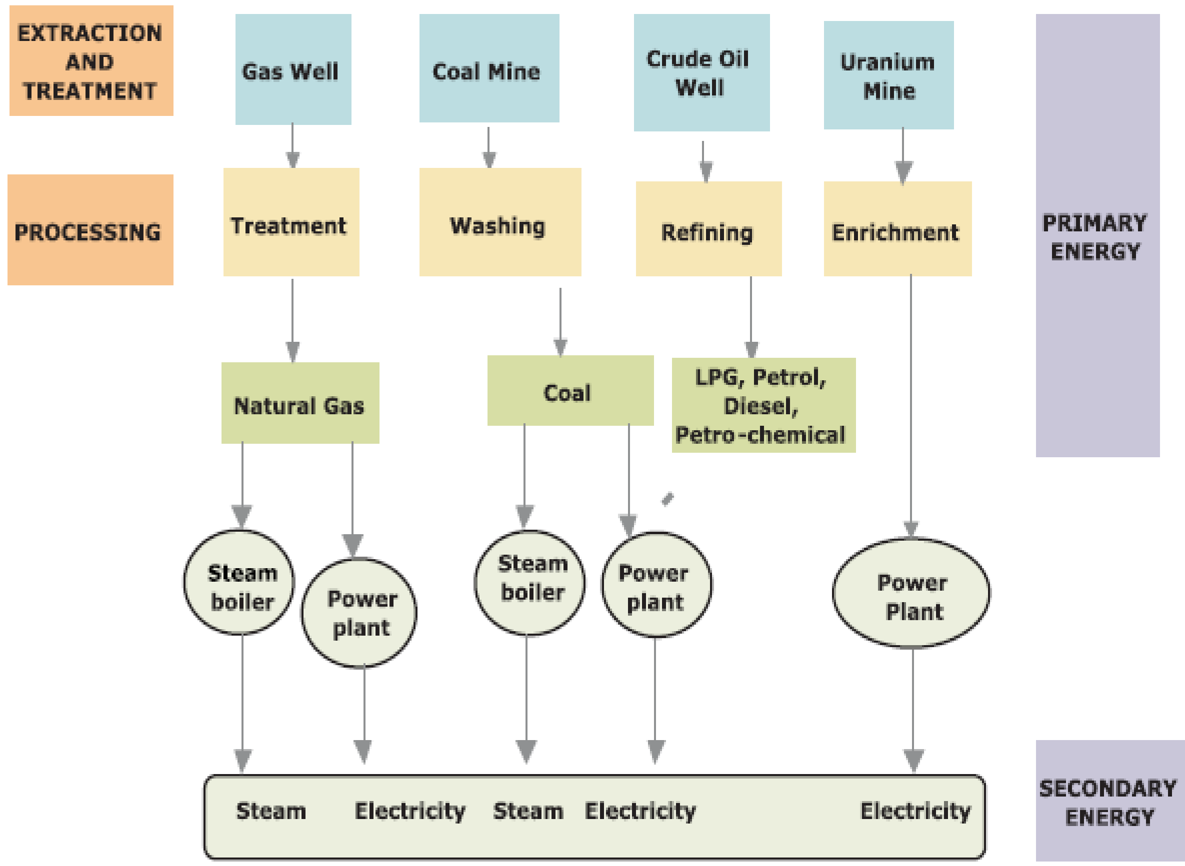


Fig 1.1 major primary and secondary energy sources

Commercial Energy and Non Commercial Energy:-

Commercial Energy:-

The energy sources that are available in the market for a definite price are known as commercial energy. By far the most important forms of commercial energy are electricity, coal and refined petroleum products. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world.

In the industrialized countries, commercialized fuels are predominant source not only for economic production, but also for many household tasks of general population.

Examples: - Electricity, lignite, coal, oil, natural gas etc.

Non-Commercial Energy:-

The energy sources that are not available in the commercial market for a price are classified as non-commercial energy. Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and not bought at a price used especially in rural households.

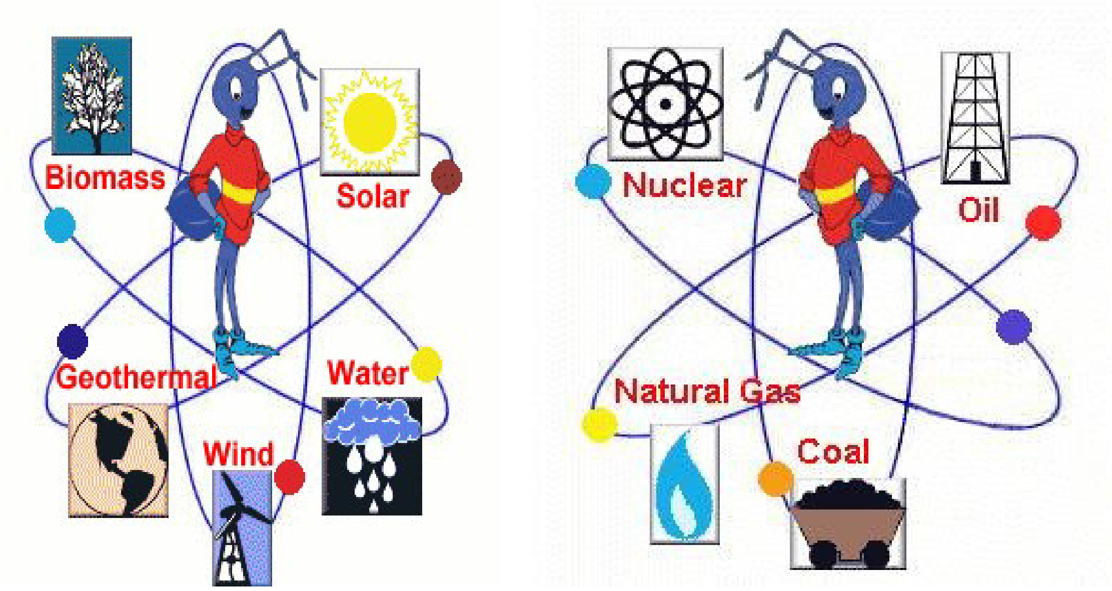
These are also called traditional fuels. Non-commercial energy is often ignored in energy accounting.

Example:- Firewood, agro waste in rural areas; solar energy for water heating, electricity generation, for drying grain, fish and fruits; animal power for transport, threshing, lifting water for irrigation, crushing sugarcane; wind energy for lifting water and electricity generation.

Renewable and Non-Renewable Energy:-

Renewable energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (See Figure 1.2). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time.



Renewable Non-Renewable

Figure 1.2 Renewable and Non-Renewable Energy

ENERGY CONSUMPTION:-

The global primary energy consumption at the end of 2008 was equivalent to 11295 Million tones oil equivalent. The share of oil is the largest at 35% followed by coal and natural gas with 29% and 24% respectively.

The demand for natural gas in future will increase as industrialized countries take strong action to cut CO2 emissions.

The Figure 1.3 shows the breakup of various constituents of primary energy consumption (Million Tonnes of Oil Equivalent, Mtoe) worldwide.

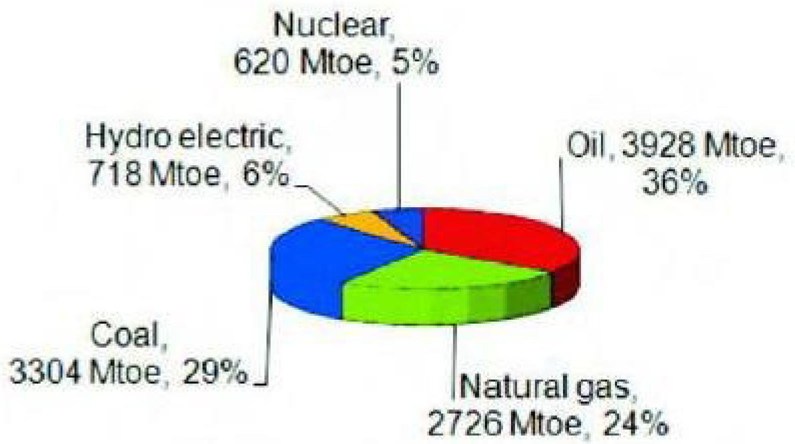


Fig 1.3 global primary energy consumption by energy source

The primary energy consumption for few of the developed and developing countries are shown in Table 1.1. It may be seen that India's absolute primary energy consumption is only 1/29th of the world, 1/7th of USA, 1/1.6th time of Japan but 1.1, 1.3, 1.5 times that of Canada, France and U.K respectively.

Table 1.1

Country	Million tones of oil equivalent (Mtoe)						
	Oil	Coal	Natural Gas	Nuclear	Hydro	Total	%
USA	884.5	565	600.7	192	56.7	2298.9	20.4
Canada	102	33	90	21.1	83.6	329.7	2.92
France	92.2	11.9	39.8	99.6	14.3	257.8	2.28
Russian Federation	130.4	101.3	378.2	36.9	37.8	684.6	6.06
UK	78.7	35.4	84.5	11.9	1.1	211.6	1.87
China	375.7	1406.3	2.3	15.5	132.4	1932.2	17.1
India	135	231.4	37.2	3.5	26.2	433.3	3.84
Japan	221.8	128.7	84.4	57	15.7	507.6	4.49
Malaysia	21.8	5	27.6	0	1.5	55.9	0.49
Pakistan	19.3	6.7	33.8	0	6.3	66.1	0.59
Singapore	49.9	66.1	8.3	34.2	0.9	159.4	1.41
Total World	**3927.9**	**3303.7**	**2726.1**	**619.7**	**717.5**	**11294.9**	**100**

Primary energy consumption at the end of 2008

Final energy consumption is the actual energy demand at the user end. This is the difference between primary energy consumption and the losses that takes place in transport, transmission & distribution and refinement. The actual final energy consumption (past and projected) is given in Table 1.2.

Table 1.2

Energy consumption by country during 2007

Country	Mtoe	% of Total Final Energy Consumption		
	Total Final Energy Consumption	Industry	Transport	Residential
China	1248.2	45.9	11.1	25.3
Japan	341.7	29.0	24.1	14.4
Republic of Korea	146.8	28.1	20.6	12.6
Indonesia	145.1	32.6	16.8	39.0
Malaysia	43.4	44.3	31.2	9.3
Philippines	22.9	23.6	37.9	27.7
Singapore	13.2	9.8	18.5	5.1
Thailand	69.6	33.3	26.1	15.2
Vietnam	48.5	21.3	16.2	56.6
Bangladesh	19.9	15.0	8.2	58.1
India	392.9	29.0	10.4	41.4
Iran	144.7	23.7	24.4	32.7
Nepal	9.5	4.6	3.1	89.6
Pakistan	68.9	27.5	16.1	47.3
Sri Lanka	8.3	25.4	25.7	41.5
Russian Federation	429.8	29.7	21.5	26.1
Europe	1394.8	26.0	26.3	23.5
North America	17,92.8	19.5	38.7	16.7
World	**8286.1**	**27.5**	**27.7**	**23.4**

The major commercial energy consuming sectors in the country are classified as shown in the Figure 1.4. As seen from the figure, industry remains the biggest consumer of commercial energy and its share in the overall consumption is 49%. (Reference year: 1999/2000) The per capita energy consumption (see Figure 1.7) is too low for India as compared to developed countries. It is just 4% of USA and 20% of the world average. The per capita consumption is likely to grow in India with growth in economy thus increasing the energy demand.

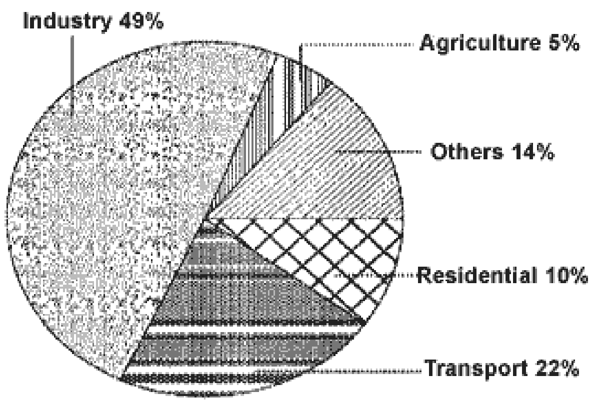


Figure 1.4 Sector Wise Energy Consumption (1999-2000)

ENERGY CONSERVATION:-

Energy conservation refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. For example, driving less is an example of energy conservation. Driving the same amount with a higher mileage vehicle is an example of energy efficiency.

Energy conservation and efficiency are both energy reduction techniques. Coal and other fossil fuels, which have taken three million years to form, are likely to deplete soon. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures. Today, 85% of primary energy comes from non-renewable and fossil sources (coal, oil, etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generations.

Energy Conservation and Energy Efficiency are separate, but related concepts. Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms. Energy Conservation can, therefore, is the result of several processes or developments, such as productivity increase or technological progress.

On the other hand Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

Energy efficiency is often viewed as a resource option like coal, oil or natural gas. It provides additional economic value by preserving the resource base and reducing pollution. For example, replacing traditional light bulbs with Compact Fluorescent Lamps (CFLs)

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means you will use only 1/4 of the energy to light a room. Pollution levels also reduce by the same amount. Energy Efficient Equipment uses less energy for same output and reduces CO_2emissions is shown in figure,

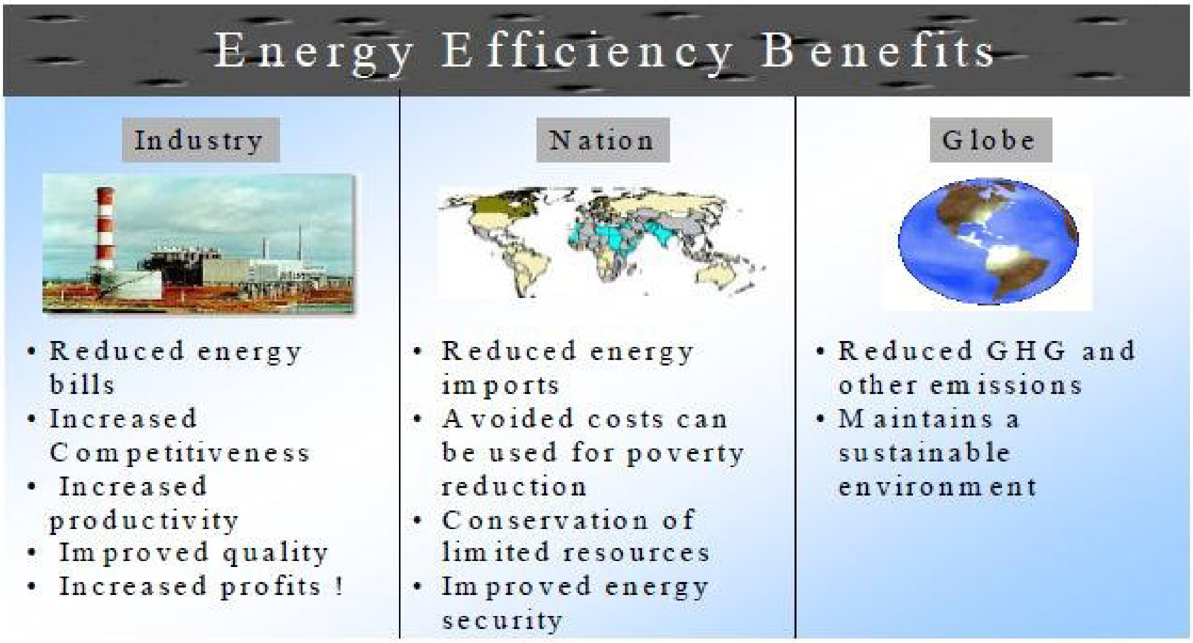
Incandescent Lamp 60W

CO2Emission –65 g/hr

Compact fluorescent Lamp 15W

CO2Emission –16 g/hr

The benefits of Energy conservation for various players are given in Figure,



The Energy Conservation Act, 2001 and its Features:-

Policy Framework – Energy Conservation Act – 2001

With the background of high energy saving potential and its benefits, bridging the gap between demand and supply, reducing environmental emissions through energy saving, and to effectively overcome the barrier, the Government of India has enacted the Energy Conservation Act – 2001.

The Act provides the much-needed legal framework and institutional arrangement for embarking on an energy efficiency drive. Under the provisions of the Act, Bureau of Energy Efficiency has been established with effect from 1st March 2002 by merging erstwhile Energy Management Centre of Ministry of Power. The Bureau would be responsible for implementation of policy programmers and coordination of implementation of energy conservation activities.

Important features of the Energy Conservation Act are:

Standards and Labeling:-

Standards and Labeling (S & L) has been identified as a key activity for energy efficiency improvement. The S & L program, when in place would ensure that only energy efficient equipment and appliance would be made available to the consumers.

The main provision of EC act on Standards and Labeling are:

- Evolve minimum energy consumption and performance standards for notified equipment and appliances.

- Prohibit manufacture, sale and import of such equipment, which does not conform to the standards.
- Introduce a mandatory labeling scheme for notified equipment appliances to enable consumers to make informed choices
- Disseminate information on the benefits to consumers

Designated Consumers:-

The main provisions of the EC Act on designated consumers are:

- The government would notify energy intensive industries and other establishments as designated consumers;
- Schedule to the Act provides list of designated consumers which covered basically energy intensive industries, Railways, Port Trust, Transport Sector, Power Stations, Transmission & Distribution Companies and Commercial buildings or establishments;
- The designated consumer to get an energy audit conducted by an accredited energy auditor;
- Energy managers with prescribed qualification are required to be appointed or designated by the designated consumers;
- Designated consumers would comply with norms and standards of energy consumption as prescribed by the central government.

Certification of Energy Managers and Accreditation of Energy Auditing Firms:-

The main activities in this regard as envisaged in the Act are:

A cadre of professionally qualified energy managers and auditors with expertise in policy analysis, project management, financing and implementation of energy efficiency projects would be developed through Certification and Accreditation programmed.

BEE to design training modules, and conduct a National level examination for certification of energy managers and energy auditors.

Energy Conservation Building Codes:-

The main provisions of the EC Act on Energy Conservation Building Codes are:

- The BEE would prepare guidelines for Energy Conservation Building Codes (ECBC);
- These would be notified to suit local climate conditions or other compelling factors by the respective states for commercial buildings erected after the rules relating to energy conservation building codes have been notified. In addition, these buildings should have a connected load of 500 kW or contract demand of 600 kVA and above and are intended to be used for commercial purposes;

- Energy audit of specific designated commercial building consumers would also be prescribed.

Central Energy Conservation Fund:-

The EC Act provisions in this case are:

- The fund would be set up at the centre to develop the delivery mechanism for large-scale adoption of energy efficiency services such as performance contracting and promotion of energy service companies. The fund is expected to give a thrust to R & D and demonstration in order to boost market penetration of efficient equipment and appliances. It would support the creation of facilities for testing and development and to promote consumer awareness.

Bureau of Energy Efficiency (BEE):-

- The mission of Bureau of Energy Efficiency is to institutionalize energy efficiency services, enable delivery mechanisms in the country and provide leadership to energy efficiency in all sectors of economy. The primary objective would be to reduce energy intensity in the Indian Economy.
- The general superintendence, directions and management of the affairs of the Bureau is vested in the Governing Council with 26 members. The Council is headed by Union Minister of Power and consists of members represented by Secretaries of various line Ministries, the CEOs of technical agencies under the Ministries, members representing equipment and appliance manufacturers, industry, architects, consumers and five power regions representing the states. The Director General of the Bureau shall be the ex-officio member-secretary of the Council.
- The BEE will be initially supported by the Central Government by way of grants through budget, it will, however, in a period of 5-7 years become self-sufficient. It would be authorized to collect appropriate fee in discharge of its functions assigned to it. The BEE will also use the Central Energy Conservation Fund and other funds raised from various sources for innovative financing of energy efficiency projects in order to promote energy efficient investment.

Role of Bureau of Energy Efficiency:-

- The role of BEE would be to prepare standards and labels of appliances and equipment, develop a list of designated consumers, specify certification and accreditation procedure, prepare building codes, maintain Central EC fund and undertake promotional activities in co-ordination with center and state level agencies.

The role would include development of Energy service companies (ESCOs), transforming the market for energy efficiency and create awareness through measures including clearing house.

Role of Central and State Governments:-

The following role of Central and State Government is envisaged in the Act

- **Central** - to notify rules and regulations under various provisions of the Act, provide initial financial assistance to BEE and EC fund, Coordinate with various State Governments for notification, enforcement, penalties and adjudication.
- **State** - to amend energy conservation building codes to suit the regional and local climatic condition, to designate state level agency to coordinate, regulate and enforce provisions of the Act and constitute a State Energy Conservation Fund for promotion of energy efficiency.

Enforcement through Self-Regulation:-

E.C. Act would require inspection of only two items. The following procedure of self-regulation is proposed to be adopted for verifying areas that require inspection of only two items that require inspection.

- The certification of energy consumption norms and standards of production process by the Accredited Energy Auditors is a way to enforce effective energy efficiency in Designated Consumers.
- For energy performance and standards, manufacturer‘s declared values would be checked in Accredited Laboratories by drawing sample from market. Any manufacturer or consumer or consumer association can challenge the values of the other manufacturer and bring to the notice of BEE. BEE can recognize for challenge testing in disputed cases as a measure for self-regulation.

Penalties and Adjudication:-

- Penalty for each offence under the Act would be in monetary terms i.e. Rs.10,000 for each offence and Rs.1,000 for each day for continued non Compliance.
- The initial phase of 5 years would be promotional and creating infrastructure for implementation of Act. No penalties would be effective during this phase.
- The power to adjudicate has been vested with state Electricity Regulatory Commission which shall appoint any one of its member to be an adjudicating officer for holding an enquiry in connection with the penalty imposed.

CODES, STANDARDS & LEGISLATION:-

It presents an historical perspective on key codes, standards, and regulations which have impacted energy policy and are still playing a major role in shaping energy usage. The Energy Policy Act of 1992 is far reaching and its implementation is impacting electric power deregulation, building codes and new energy efficient products.

Sometimes policy makers do not see the far reaching impact of their legislation. The Energy Policy Act for example has created an environment for retail competition. Electric utilities will drastically change the way they operate in order to provide power and lowest cost. This in turn will drastically reduce utility sponsored incentive and rebate programs which have influenced energy conservation adoption.

THE ENERGY POLICY ACT OF 1992:-

This comprehensive legislation is far reaching and impacts energy conservation, power generation, and Alternative fuel vehicles as well as energy production. The federal as well as private sectors are impacted by this comprehensive energy act. Highlights are described below:

Energy Efficiency Provisions:-

Buildings

- Requires states to establish minimum commercial building energy codes and to consider minimum residential codes based on current voluntary codes.

Utilities

- Requires states to consider new regulatory standards that would: require utilities to undertake integrated resource planning; allow efficiency programs to be at least as profitable as new supply options; and encourage improvements in supply system efficiency.

Equipment Standards

- Establishes efficiency standards for: commercial heating and air-conditioning equipment; electric motors; and lamps.
- Gives the private sector an opportunity to establish voluntary efficiency information/labeling programs for windows, office equipment and luminaries, or the Dept. of Energy will establish such programs.

Renewable Energy

- Establishes a program for providing federal support on a competitive basis for renewable energy technologies. Expands program to promote export of these renewable energy technologies to emerging markets in developing countries.

Alternative Fuels

- Gives Dept. of Energy authority to require a private and municipal alternative fuel fleet program starting in 1998. Provides a federal alternative fuel fleet program with phased-in acquisition schedule; also provides state fleet program for large fleets in large cities.

Electric Vehicles

- Establishes comprehensive program for the research and development, infrastructure promotion, and vehicle demonstration for electric motor vehicles.

Electricity

- Removes obstacles to wholesale power competition in the Public Utilities Holding Company Act by allowing both utilities and non-utilities to form exempt wholesale generators without triggering the PUHCA restrictions.

Global Climate Change

- Directs the Energy Information Administration to establish a baseline inventory of greenhouse gas emissions and establishes a program for the voluntary reporting of those emissions. Directs the Dept. of Energy to prepare a report analyzing the strategies for mitigating global climate change and to develop a least-cost energy strategy for reducing the generation of greenhouse gases.

Research and Development

- Directs the Dept. of Energy to undertake research and development on a wide range of energy technologies, including: energy efficiency technologies, natural gas end-use products, renewable energy resources, heating and cooling products, and electric vehicles.

STATE CODE:-

- American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE).

MODEL ENERGY CODE:-

The nation's model code organizations are,

- Council of American Building Officials (CABO),
- Building Officials and Code Administrators International (BOCA),
- International Conference of Building Officials (ICBO),
- Southern Building Codes Congress International (SBCCI),

- International Code Council (ICC).
- International Energy Conservation Code (IECC)

Others:-

- Federal Energy Management Implementation Act (FEMIA 1988)
- Occupational Safety and Health Administration (OSHA)
- United Nations Environment Program (UNEP)
- Federal Power Act
- Public Utility Regulatory Policies Act (PURPA)
- Natural Gas Policy Act (NGPA)
- Resource Conservation and Recovery Act of 1976 (RCRA)
- Public Utility Holding Company Act of 1935.

ENERGY AUDIT:-

The manufacturing industry in India, accounts for over 50% of total commercial energy used in the country. Across the world, industry consumes about 1/3 of all natural energy sources (Murphy & McKay, Energy Management, Butterworth Heinemann, London, 1982). The high levels of energy used in Indian Industry compared to similar industries in advanced countries, the increasing problems of availability of energy sources and their ever escalating costs, strongly point to the immediate need for effective control on the use of energy.

It is believed and often proved by actual studies that a reduction in energy consumption by as much as 10-30% is a realizable goal in a large number of industries, by better and effective energy management at unit level. And these savings can generally be achieved with little or no additional investment.

Any savings that can be achieved in energy costs, directly add to the profit figures. While this is also true, in respect of other direct costs as well, i.e. labour and material costs, it is much harder and more difficult to achieve reduction in their costs.

Another area by which profitability of an enterprise can be improved is by increasing production and market share; but these obviously require additional investments on expansion of manufacturing facilities and man-power and involve added management and marketing effort; and a small portion of increased sales volume contributes to profits.

While the situation from industry to industry may vary, it may be pertinent to state that energy cost savings to the extent of 15-20% is definitely feasible, at least in those industries (besides commercial buildings) where serious study has not yet been attempted. One can visualize the improvement in profitability besides improvement in the competitiveness of Indian manufactured goods in world market, which reduction in energy costs could result in, without any major investment.

DEFINITIONS:-

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

(or)

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

(or)

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

(or)

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".

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

CONCEPTS:-

The successful implementation of individual energy conservation programmed depends on a proper organizational framework and baseline data for identifying and evaluating energy conservation opportunities. The determination of the baseline data requires a comprehensive and detailed survey of energy uses, material-energy balances, and energy loss. This survey is generally referred to as the Energy Audit.

To save energy, it is necessary to know where, how and how much energy is being consumed. The objective of energy audits is to characterize and quantify the use of energy within the plant at various levels in departments, sections, major processes, and major equipment. The plant energy study provides a comprehensive and detailed picture not only of the type and quantity of energy being used but also how efficiently it is being utilized, and where it is wasted or lost.

The energy audit process include description of energy inputs and product outputs by major departments or by major processing functions, and will evaluate the energy; efficiency of each step of the manufacturing process.

Means of improving these will be listed, and a preliminary assessment of the cost of these improvements will be made to indicate the expected payback on any capital investment needed.

The aims of energy audit are as follows:

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

The Energy Audits are normally carried out in two phases, i.e., Preliminary Energy Audit (PEA) and Detailed Energy Audit (DEA).

TYPES OF ENERGY AUDIT:-

The type of Energy Audit to be performed depends on:

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

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

1.4.1) Preliminary Energy Audit (PEA)

1.4.2) Detailed Energy Audit (DEA)

Preliminary Energy Audit (PEA) / House Keeping Practices:-

Considerable savings are possible through small improvements in the –housekeeping‖ practices, and the cumulative effect of many such small efficiency improvements could be quite significant. These can identify by a short survey, observation and measurements. Many energy conscious industries have already achieved considerable progress in this area.

Approach to Preliminary Energy Audit (PEA)

This essentially involves preliminary data collection and analyses. The PEA is based on collection of available data, analysis, observation, and inference based on experience and judgment is carried out within a short time.

The PEA is the first step in implementing an energy conservation programmed, and consists of essentially collecting and analyzing data without the use of sophisticated instruments. The ability and experience on the part of Energy Auditor will influence the degree of its success.

Normally the results of the audit would depend on:-

Experience of the auditor	Availability and completeness of data
Physical size of the facility	Depth of analysis of available data
Complexity of operations within the facility	Awareness of energy matters within the facility

Broadly, the audit is carried out in six steps:-

1. **Organize resources**
    - ♥ Manpower / time frame
    - ♥ Instrumentation
2. **Identify data requirements**
    - ♥ Data forms
3. **Collect data**
    A. Conduct informal interviews
    - ♥ Senior management
    - ♥ Energy manager/coordinator
    - ♥ Plant engineer
    - ♥ Operators and production management and personnel
    - ♥ Administrative personnel
    - ♥ Financial manager

    B. Conduct plant walkthrough/visual inspection
    - ♥ Material/energy flow through plant
    - ♥ Major functional departments
    - ♥ Any installed instrumentation, including utility meters
    - ♥ Energy report procedures

- ♥ Production and operational reporting procedures
- ♥ Conservation opportunities

4. Analyze data

A. Develop data base

- ♥ Historical data for all energy suppliers
- ♥ Time frame basis
- ♥ Other related data
- ♥ Process flow sheets
- ♥ Energy consuming equipment inventory

B. Evaluate data

- ♥ Energy use consumption, cost, and schedules
- ♥ Energy consumption indices
- ♥ Plant operations
- ♥ Energy savings potential
- ♥ Plant energy management program
- ♥ Preliminary energy audit

5. Develop action plan

- ♥ Conservation opportunities for immediate implementation
- ♥ Projects for further study
- ♥ Resources for detailed energy audit
  - ➢ Systems for test
  - ➢ Instrumentation; portable and fixed
  - ➢ Manpower requirements
  - ➢ Time frame
- ♥ Refinement of corporate energy management programmed

6. Implementation

- ♥ Implement identified low cost/no cost projects
- ♥ Perform detailed audit

The preliminary energy audit is essentially, as the name implies a preliminary data collection and its analysis process. Readily available data on the plants energy systems and energy-using processes or equipment are obtained and studied. The operation and condition of equipment are observed by going around the plant. These provide basis to develop recommendations for immediate short term measures and to provide quick and rough estimates of savings that are possible and achievable.

A preliminary study usually identifies and assesses obvious areas for energy savings such as stream leaks, compressed air leaks, poor or missing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment etc. and serves to identify specific areas for the detailed plant energy study.

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 (DEA):-

This would be a comprehensive energy efficiency study using portable energy monitoring instruments. The essential part of this audit is carrying out various measurements and analyses covering individually every significant energy consuming plant item/processes, to determine their efficiencies and loss of energy at that point, and potential energy savings are explored and crystallized, and every recommendation for investment is supported by criteria such as pay-back analysis.

The detailed plant energy study is a comprehensive analyses evaluation of all aspects of energy generation, distribution and utilization within the plant. At the plant level, the analyses require time series data on a daily, monthly, or yearly basis, on the quantities of all forms of primary energy flowing into the plant, e.g. coal, fuel oil, electricity, etc. and production figures of major products, by products and waste products, at the department or section level.

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

Ten steps methodology for DEA:-

STEP No	PLAN OF ACTION	PURPOSE / RESULTS
Step-1	*Phase-I: Pre Phase Audit* ♥ Plan and Organize ♥ Walk through Audit ♥ Informal Interview with Energy Manager, Production / Plant Manager	♥ Resource planning, Establish/organize an 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 programmed 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: ♥ 24hours power monitoring (MD, PF, kWh etc.). ♥ Load variations trends in pumps, fan compressors etc. ♥ Boiler/Efficiency trials for (4-8 hours) ♥ Furnace Efficiency trials Equipments Performance experiments etc.,
Step-6	Analysis of energy use	♥ Energy and Material balance & energy loss/waste analysis.
Step-7	Identification and development of Energy Conservation (ENCON) opportunities.	♥ Identification & Consolidation ENCON measures. ♥ Conceive, develop, and refine ideas ♥ Review the previous ideas suggested by unit personal ♥ Review the previous ideas suggested by energy audit if any ♥ Use brainstorming and value analysis techniques ♥ Contact vendors for new/efficient technology.
Step-8	Cost benefit analysis	♥ Assess technical feasibility, economic viability and prioritization of ENCON (Energy Conservation) options for implementation.
Step-9	Reporting & Presentation to the Top Management	♥ Documentation, Report Presentation to the top Management.
Step-10	*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

The duration of DEA studies depends on plant size and complexity. Whereas the preliminary energy study can be carried out in a few days, the detailed study would require anywhere from few weeks to months to years of effort.

Plant energy studies can be carried out in house if adequate resources and expertise exist for doing so. Alternatively or additionally, external assistance may be sought from energy consultants, equipment suppliers, and engineering and design firms, in either case, intense interaction between plant personnel and the study team is essential for a proper understanding and a meaningful analysis of the plants energy options.

Too often, the plant energy study is considered to be the consultant‘s problem, resulting in minimal inputs and involvement from plant personnel. This attitude is counter-productive. Without the active participation of all levels, full benefits cannot be expected to be accomplished.

ENERGY CONSUMPTION MONITORING:-

Energy Consumption is to monitor, assess by a company/industry and compared with a specific products manufactured by the industry can be done by two parameters as follows.

They are,

Energy Index

Cost Index

ENERGY INDEX:-

Energy index is the figure obtained by dividing energy consumption by production output.

$$\text{Energy index} = \frac{\text{energy use}}{\text{Production output}}$$

The index may be calculated weekly, monthly or annually.

Energy index is a useful parameter to –monitor and compare energy consumption of specific products manufactured by the industry‖.

Although the total energy indices are sufficient for monitoring purposes, a record of the individual energy indices should be maintained. In the event of an increase or decrease (due to perhaps a conservation measure) in energy index, the particular source can be investigated immediately.

Energy may be purchased in various units, for example, coal in tons; gas in ft^3,m^3, therms; oil in gallons, liters, tons, barrels etc. the relevant conversion units from one system to the other are given below:

EXAMPLE: - To find the energy index we shown below example, here three types of energy with energy consumption and also produces $100x10^3$ tons of a particular product. Calculate the energy index?

Energy type	Consumption	Energy (Wh)
Oil	$10x10^3$ gal	$0520x10^9$
gas	$5x10^3$ therm	$0.146x10^9$
Electricity	$995x10^3$ kwh	$0.995x10^9$
	Total	$1.661x10^9$

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

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

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

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

COST INDEX:-

The cost index is defined as the cost of energy divided by the production output.

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

The cost index is another parameter which can be used to –monitor and assess energy consumption by a company‖.

An individual cost index can be determined for each energy form and for the total energy consumption by the company.

Same example for calculate the cost index in place of total energy, the cost will be used.

REPRESENTATION OF CONSUMPTION:-

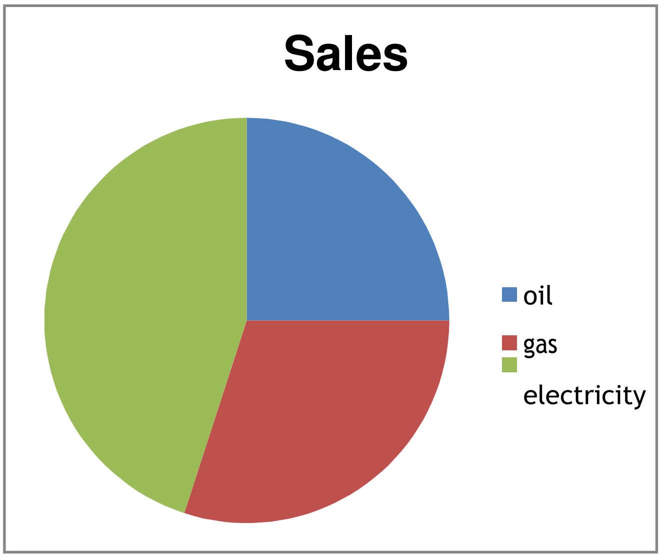
Several methods of representing energy flows and energy consumption are available and these may be graphical or tabular. Most among them are the

pie chart

sankey diagram

PIE CHART:-

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



SANKEY DIAGRAM:-

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

(or)

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

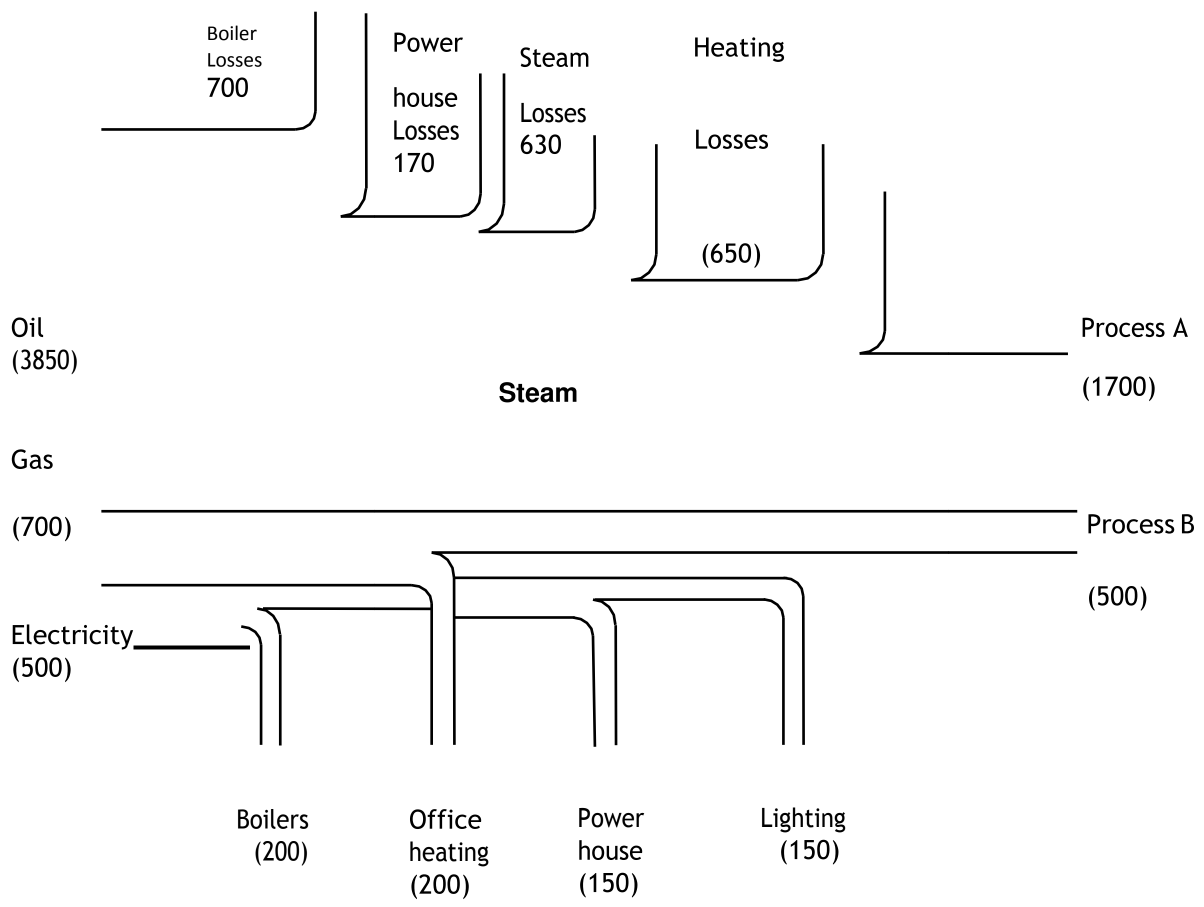
They are also commonly used to visualize the energy accounts or material flow accounts on a regional or national level. Sankey diagrams put a visual emphasis on the major transfers or flows within a system.

They are helpful in locating dominant contributions to an overall flow. Often, Sankey diagrams show conserved quantities within defined system boundaries, typically energy or mass, but they can also be used to show flows of non-conserved quantities such as energy. Sankey Diagrams drop their arrows when energy is being used.

Following Figure shows a Sankey diagram which represents all the primary energy flows into a factory. The widths of the bands are directly proportional to energy production (source), utilization and losses.

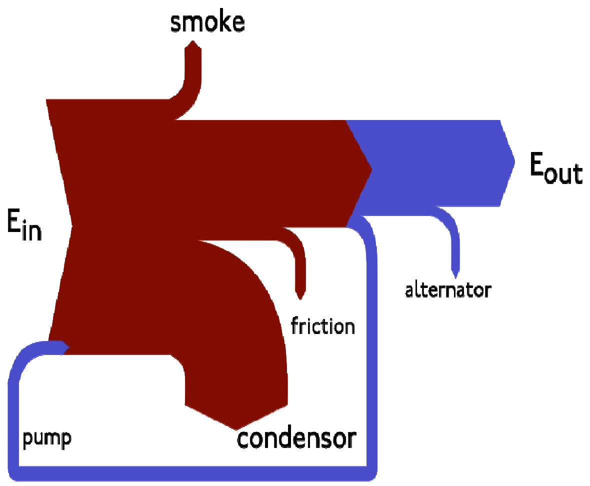
The primary energy sources are gas, electricity and coal/oil (say, for steam generation) and represent energy inputs at the left-hand side of the Sankey diagram.

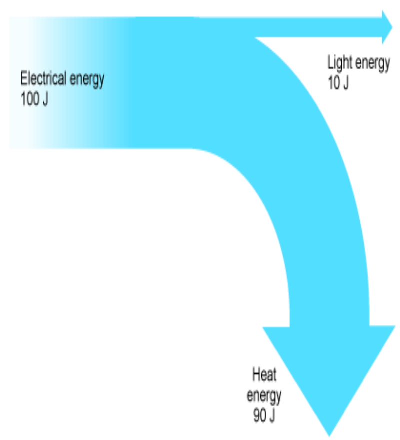
For example the steam flows from input to output and also the electrical energy uses by showing the sankey diagram is shown in below figure,



Energy Inputs: Oil, Gas, Electricity are represented in left

Sankey diagram representing energy usage (10^6 Joule per hour) by a company





For the purpose of monitoring and checking energy consumption and usage on a weekly or monthly basis, pie charts and Sankey diagram are relatively difficult. An alternative method of monitoring energy consumption on a time-dependent basis is to use load profiles.

LOAD PROFILES (HISTOGRAM):-

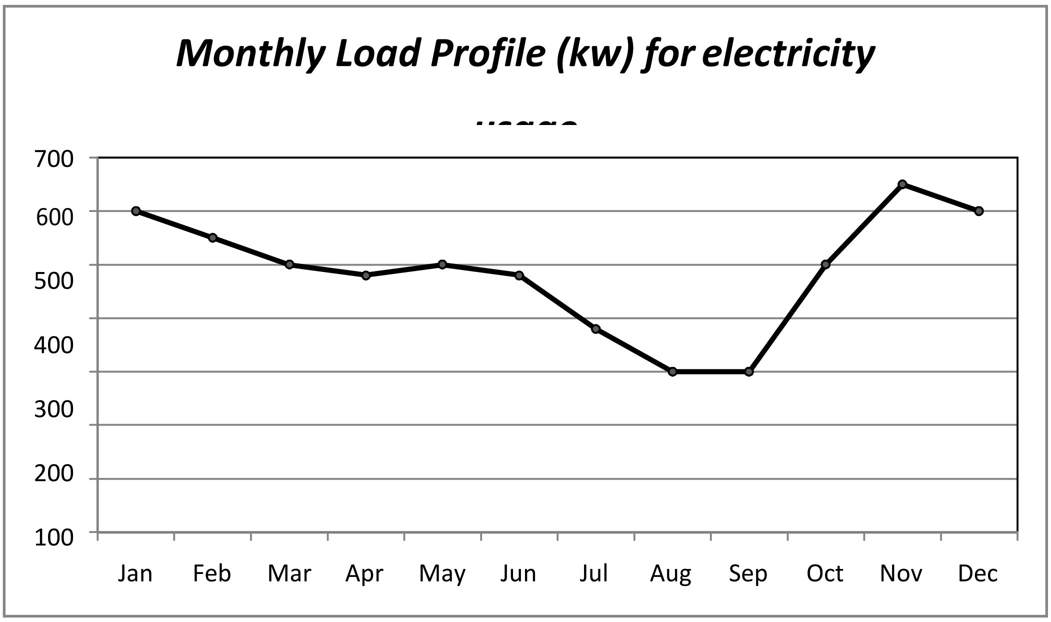
For the purpose of monitoring and checking energy consumption on a time dependent basis is to use load profiles. In electrical engineering, a load profile is a graph of the variation in the electrical load versus time.

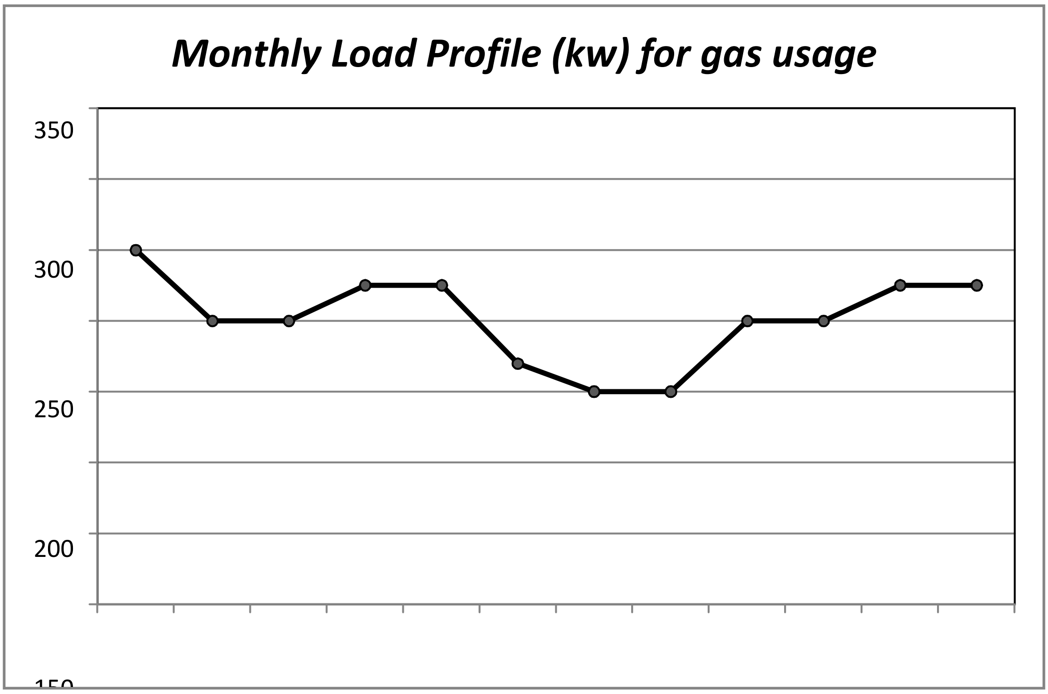
A load profile will vary according to customer type (typical examples include residential, commercial and industrial), temperature and holiday seasons.

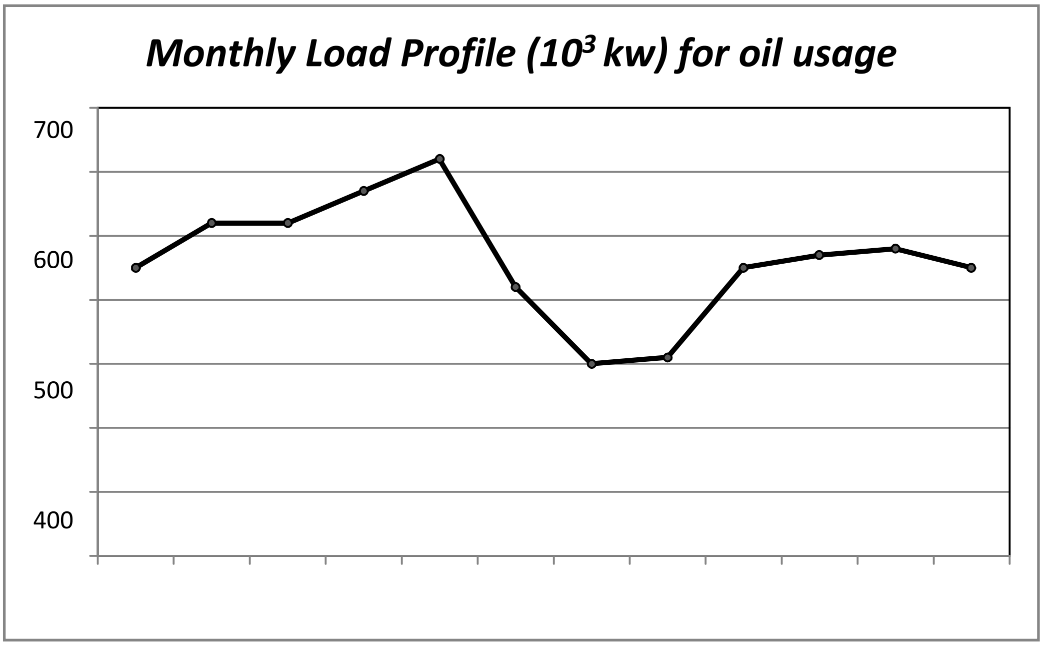
The usages of oil, gas and electricity in a plant can be plotted on a graph as shown in following Figure. The results illustrate seasonal variations and perhaps variations in production schedules.

This technique has the major advantage that after a period of time, energy consumption patterns emerge and it is possible to tell at a glance if an area is exceeding its predicted value. An overall load profile equivalent to several pie charts and sankey diagrams can be obtained by plotting the previous profiles can be also drawn.

Load factor — the ratio of the average load over the peak load. Peak load is normally the maximum demand but may be the instantaneous peak. The load factor is between zero and one. A load factor close to 1.0 indicates that the load runs almost constantly. A low load factor indicates a more widely varying load. From the utility point of view, it is better to have high load-factor loads. Load factor is normally found from the total energy used kilowatt-hours.







Load profiles can be determined by direct metering but on smaller devices such as distribution network transformers this is not routinely done. Instead a load profile can be inferred from customer billing or other data.

An example of a practical calculation used by utilities is using a transformer's maximum demand reading and taking into account the known number of each customer type supplied by these transformers. This process is called load research.

ENERGY CONSERVATION SCHEMES:-

Development of an energy conservation programmed can provide savings by reduced energy use. However, it is economical to implement an energy conservation program only when savings can offset implementation cost over a period of time.

Potential areas of conserving energy and a logical analysis of the methods or techniques of conservation would provide a systematic and disciplined approach to the entire conservation strategy as a sequel to the energy audit. Some established conservation trends are replacement, retrofit, process innovation, fuel conversion and co-generation.

It is generally considered that investment for energy conservation should be judged by exactly the same criteria as for any other form of capital investment. Energy conservation measures may be classified on an economic basis and fall into the following three categories:

Short term: These measures usually involve changes in operating practices resulting in little or no capital expenditure.

Medium term: Low-cost modifications and improvements to existing equipment where the pay-back period is less than two years and often under one year.

Long term: Modifications involving high capital costs and which frequently involve the implementation of new techniques and new technologies.

While the first two categories together can achieve savings of the order of 5-10%, capital expenditure using existing and new technology may achieve a further 10-15%. It is impossible to give a comprehensive list of all items in each category but selected examples are given for each section.

Short-term energy conservation schemes:-

Items in this group can be considered as a tightening of operational control and improved housekeeping.

a) **Furnace efficiencies:** greater emphasis should be placed on minimum excess combustion air. Oxygen levels of flue gases should be continually monitored and compared with target values. Oil burners must be cleaned and maintained regularly.

b) **Heat exchangers:** in the case of heat exchangers where useful heat is transferred form product streams to feed streams, careful monitoring of performance should be carried out to determine optimum cleaning cycles. Frequency of cleaning will generally increase as a result, with consequent improved heat recovery.

c) **Good housekeeping:** doors and windows should be kept closed as much as possible during the heating season. Wear natural light is sufficient, do not use artificial light. Avoid excessive ventilation during the heating season. Encourage staff to wear clothing appropriate to the temperature of the working areas.

d) **Use of steam:** major steam leaks should be repaired as soon as possible after they occur: often a firm specializing in ‗on stream' maintenance can be used. One crude distillation columns where live steam is used for stripping purposes, the amount required should be optimized and carefully controlled.

e) **Electrical power:** in industries where all the electrical power is ‗imported', conservation measures can reduce the annual electricity costs by 10-15%. Steam driven turbines may prove more economical as prime movers. Natural air cooling may be sufficient and therefore induced-draught fans may be taken out of commission. Pumping costs can sometimes be saved by utilizing gravity to move products from one tank to another. Where possible, use off-peak electricity.

Medium-term energy conservation schemes:-

Significant savings in energy consumption are often available for quite modest outlays of capital based on a pay-back period of less than two years.

a) **Insulation:** Improving insulation to prevent cold air leaking into the building and also, improving insulation of the steam distribution system. Many optimum insulation thicknesses were determined at a time when fuel oil was £6 per tone and, consequently, at present fuel oil prices, optimum thicknesses have increased appreciable. In addition, in older plants lagging may have deteriorated to varying degrees.

In one company, additional insulation was added to four boiler casing after calculation had showed the structures could accept the increase in temperature. For an outlay of £25000, savings of £60000 per annum were achieved.

In an oil refinery the lagging on the process steam system was up rated to new optimum thicknesses and the £20000 invested in the project was recouped within a year.

b) **Heating systems:** Improving the time and temperature control of the heating systems in buildings should result in substantial energy savings.

c) Replacing air compressors

d) **Instrumentation:** to measure and control the energy conservation parameters, adequate instrumentation must be provided or operators will soon lose interest in maintaining efficiencies if they are working with inadequate and unreliable instruments.

e) **Process modifications:** Many of these schemes will depend on the nature of the industry concerned, however, one general scheme will be considered. Steam condensate, if uncontaminated, may be used as boiler feed water. Improved condensate return systems can increase the amount recovered. The effect will be to increase the heat recovered in the condensate and at the same time reduce raw water and treatment costs.

In one instance 10000 kg h^{-1} of condensate was recovered for an investment of £10000; the pay-back time was less than six months.

f) **Burners:** the control and amount of atomizing steam is important and often in furnaces and boilers the amount of atomizing steam is far in excess of design.

In a hospital two fuel oil-fired boilers were examined and in some instances it was found that 1 kg steam/kg fuel oil was being utilized. The oil burners were replaced and the atomizing steam requirements are now 0.1 kg steam/kg fuel oil. The pay-back for an outlay of £12000 was ten months.

g) **Electrical Power Savings:** considerable savings may be made by adjusting the electrical power factor correction.

Capacitors were installed in one particular company at a cost of £10000. The power factor was increased from 0.84 to 0.97 reducing the maximum demand level by over 14 per cent. The pay-back time was nine months.

To increase plant capacity two feed pumps may be run in parallel to achieve the required feed rate. When replacement, for mechanical reasons, becomes necessary it is more economical to replace the pumps by a single pump having a higher capacity.

Long-term energy conservation schemes:-

To obtain further economics in energy consumption required the spending of significant amounts of capital, although, in many cases, the return on capital for the long-term investment may not be as good as that of the medium term.

Full financial evaluation is needed, using the appraisal techniques discussed in unit-V, to ensure that investment is economically viable.

a) **Heater modifications:** the installation of heating tubes and air pre-heaters to extract more heat from furnace flue gases.

b) **Improved Insulation:** Additional lagging of heated storage tanks. This type of project often comes within the medium-term group.

c) **Heat recovery:** Improved heat recovery in the processing areas by additional heat exchange schemes.

Many of the energy projects that have been outlined may be adopted by a wide variety of companies. However, some are more specific in their application and it is necessary to consider the contribution of energy costs to companies and energy usage by different industries.

ENERGY AUDIT OF INDUSTRIES:-

The manufacturing industry in India, accounts for over 50% of total commercial energy used in the country. Across the world, industry consumes about 1/3 of all natural energy sources. Hence, it is very important to concentrate on conserving energy in the industrial sector.

Normally electricity and HSD are the main energy sources to any industry. Electricity is used for driving motors of air compressors, refrigeration compressors, pumps, fans, blowers, machinery, welding sets and lighting.

HSD is used for running DG sets, which are used in case of power failure from the grid. Electricity may also be used for heating and drying ovens etc. and for other applications. Some industries use coal, bagasse, rice husk etc. mainly for steam generation.

The major energy consuming equipment/systems in a typical industry are listed below:

- ♥ Electrical systems
- ♥ Electric drives
- ♥ Steams system
- ♥ Furnaces
- ♥ Compressed Air System
- ♥ Air Conditioning & Refrigeration
- ♥ Pumping systems
- ♥ Cooling Towers
- ♥ Fans and Blowers
- ♥ Lighting System
- ♥ Diesel Generating Sets

Brief scope of energy conservation in the above equipment/system is given below

Electrical Systems

The scope in Electrical System comprises of transformer loading practices, Power Factor Management, analysis/optimizing Voltage levels, Distribution losses and Harmonic levels. A specific observation on daily load curve for possibility of further suppression of demand especially during peak load hours will be looked into.

Electric Drives

Following recommendations could be made based on actual measurements and analysis

- ♥ Proper sizing of motor
- ♥ Use of energy efficient motor by replacing oversized and less efficient motors
- ♥ Retrofitting inverters or soft-starters
- ♥ Re-shuffing of motors as per loading
- ♥ Possibility of operating motors in star mode wherever motors are under-loaded
- ♥ Reactive power compensation for motors

Steam System

An in-depth study of steam system covering steam generation, distribution and utilization would cover the following:

- ♥ Efficiency evaluation of boiler by indirect heat loss method
- ♥ Optimum steam generating pressure
- ♥ Quantification of steam leakages
- ♥ Steam trap survey
- ♥ Insulation aspects including insulation surveys
- ♥ Optimization of steam utilization
- ♥ End use equipment (generally, heat transfer equipment, viz. driers, etc.)
- ♥ Alternate (cheaper) fuels for combustion.

ENERGY AUDIT OF PROCESS INDUSTRY:-

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

i) Preparation and planning

ii) Data collection and review

iii) Plant surveys and system measurements

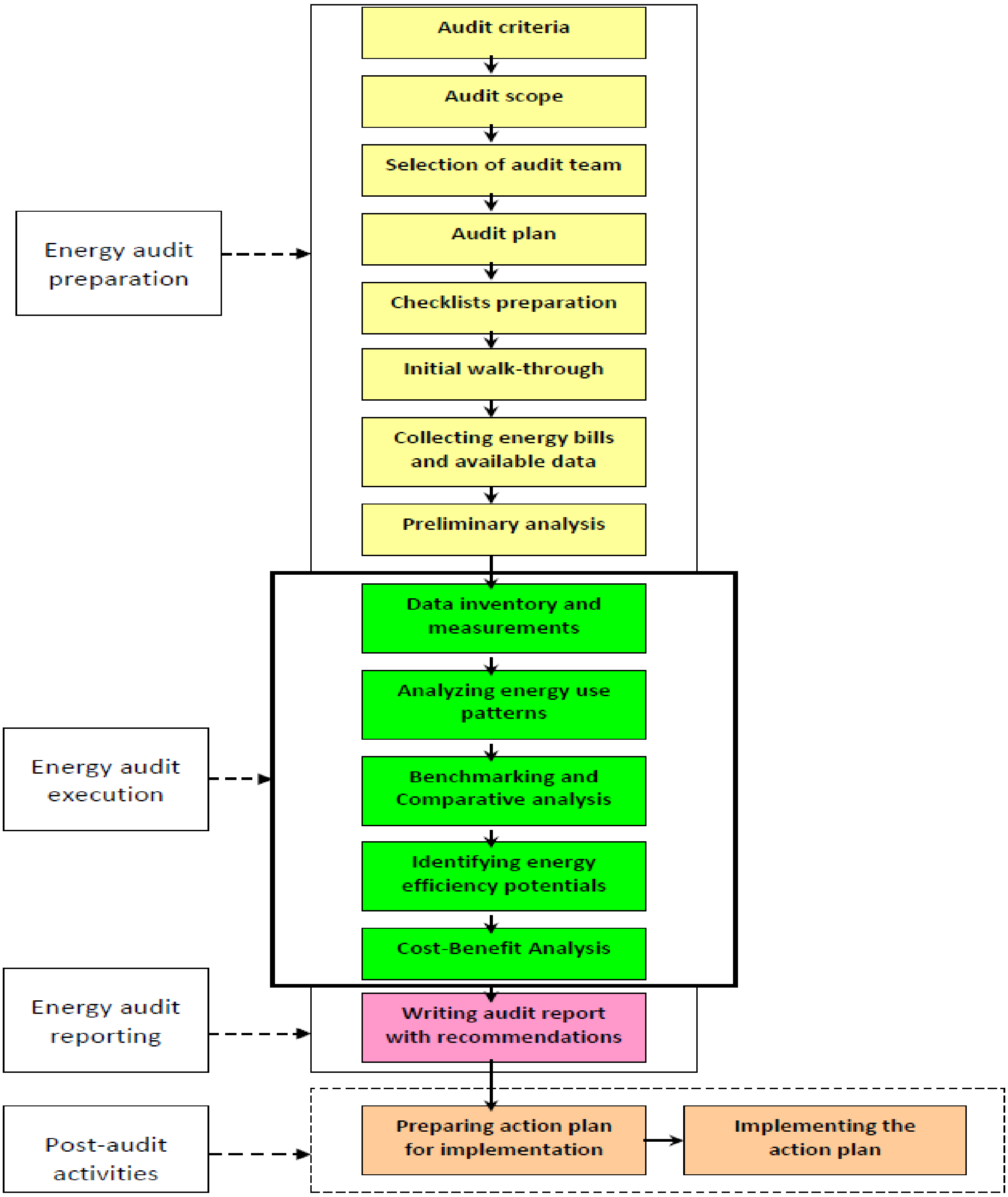
iv) Observation and review of operating practices

v) Data documentation and analysis

vi) Reporting of the results and recommendations.

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

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



ENERGY SAVING POTENTIAL:-

We estimate the energy savings potential for each of the selected industries. Methodologically such an exercise involves use of (energy) efficiency benchmark of some of the best performing units within the concerned industry.

Energy efficiency benchmarking for an industry is a process by which energy performance of an individual firm/unit within the industry or a sector comprising of similar units are compared against a common metric which represents a standard.

As benchmarking is used as a tool for comparison it should have an important characteristic that the metric used should be independent of unit size. In the present study the metric used for benchmark analysis is energy intensity.

There are a large number of units/firms of varying sizes within an industry. Comparing energy intensity of a small unit with that of a large one may not be meaningful because of the scale of operation. In order to overcome the problem of comparing dissimilar units, units within an industry are grouped/classified into different groups on the basis of

a) Share in final energy consumption (measured in kgoe),

b) Share in electricity consumption (measured in Kwh), and

c) Total output (measured in rupees), so that units within a group are all similar.

Energy savings potential is then calculated for each group within the industry. Having classified the units within an industry into different groups, units within a group are ranked in order of their energy intensities.

Energy intensity of a unit is defined as total final energy consumed for generating one unit of output. Since the output is measured in monetary units, energy intensity is defined as energy consumed for generating Re. 1 worth of output. Two measures of energy intensity has been used depending on the way in which the units are grouped. These are

	Unit of energy intensity	Definition of Energy Intensity
1	**Classification based on Share of total energy consumption**	
	a) Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
2	**Classification based on Share of total electricity consumption**	
	b) Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$
3	**Classification based on Value of Output**	
	a) Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
	b) Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$

BUILDING ENERGY AUDIT:-

The energy audit in a building is a feasibility study. For it not only serves to identify energy use among the various services and to identify opportunities for energy conservation, but it is also a crucial first step in establishing an energy management programmed. The audit will produce the data on which such a programmer is based. The study should reveal to the owner, manager, or management team of the building the options available for reducing energy waste, the costs involved, and the benefits achievable from implementing those energy-conserving opportunities (ECOs). The complexity of the audit is therefore directly related to the stages or degree of sophistication of the energy management programmed and the cost of the audit exercise.

The first stage is to reduce energy use in areas where energy is wasted and reductions will not cause disruptions to the various functions. The level of service must not be compromised by the reduction in energy consumed. It begins with a detailed, step-by-step analysis of the building's energy use factors and costs, such as insulation values, occupancy schedules, chiller efficiencies, lighting levels, and records of utility and fuel expenditures.

The second stage is to improve efficiency of energy conversion equipment and to reduce energy use by proper operations and maintenance. For this reason, it is necessary to reduce the number of operating machines and operating hours according to the demands of the load, and fully optimize equipment operations.

The first two stages can be can be implemented without remodeling buildings and existing facilities.

The third stage would require changes to the underlying functions of buildings by remodeling, rebuilding, or introducing further control upgrades to the building. This requires some investment.

The last stage is to carry out large-scale energy reducing measures when existing facilities have past their useful life, or require extensive repairs or replacement because of obsolescence. In this case higher energy savings may be achieved. For these last two stages, the audit may be more extensive in order to identify more ECOs for evaluation, but at an increased need for heavier capital expenditure to realize these opportunities.

MODULE-II

Energy Management

Meaning of Energy Management:

- The phrase 'energy management' can be different to different people.
- Energy management is the art and science of optimum use of energy to maximise profits (minimise costs) and thereby improve the economic competiveness. The energy should be used efficiently, economically and optimally.
- *"The judicious and effective use of energy to maximise profits (minimise costs) and enhance competitive positions." "The strategy of adjusting and optimising 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 "*

Energy management is the art and science of optimum use of energy to maximise profits (minimise costs) and thereby improve the economic competiveness. The energy should be used efficiently, economically and optimally.

Energy management can also be defined as the science involving planning, directing, con-trolling the supply and consumption of energy to maximise productivity and comforts and minimise the energy costs and pollution with conscious, judicious and effective use of energy.

The energy management involves strategy, policy, organisational changes, energy audit, energy conservation measures, administrative actions, training and awareness programmes, monitoring of energy conservation efforts etc.

Energy management is an important management function of every organisation (like production, finance, marketing, planning, and design). Energy organisation must have a written energy management policy document and the top management must be committed to implement the energy policy. The energy objectives must be known to energy executive and supervisor.

Necessity of Energy Management

Energy Management is necessarily required because it influences a number of aspects of company operation and activities including the following:

- energy costs which affect the company profitability
- energy costs which affect the competitiveness in the world market
- national energy supply/demand balance
- national trade and financial balance
- local and global environments
- occupational safety and health
- loss prevention and waste disposal reduction
- productivity
- quality

Objectives of Energy Management

The primary objective of energy management is to produce goods and provide services with the least cost and energy and the least effecting the environment.

The objective of energy management is also to achieve and maintain optimum energy procurement and utilisation throughout the organisation and the following:

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

Principles of Energy Management

The principles of energy management are as follows:

- Procure all the energy needed at the lowest possible price: Example: Buy from original sources, review the purchase terms.

- Manage energy use at the highest energy efficiency: Example: Improving energy use efficiency at every stage of energy transport, distribution and use.
- Reusing and recycling energy by cascading: Example: Waste heat recovery.
- Use the most appropriate technology: select low investment technology to meet the present requirement and environment condition
- Reduce the avoidable losses: Make use of wastes generated within the plant as sources of energy and reduce the component of purchased fuels and bills.

Energy Management Skills

Energy management involve a combination of both managerial and technical knowledge/skills.

- **Managerial skills**: These include, bringing about awareness, motivating people at all levels, changing structure and procedure, monitoring energy consumption, norms, target setting, etc. Both organisational and people changes are required.
- **Technical skills**: These include, pre-requisite in improving the energy efficiency of a process or equipment such as boilers, furnaces etc.

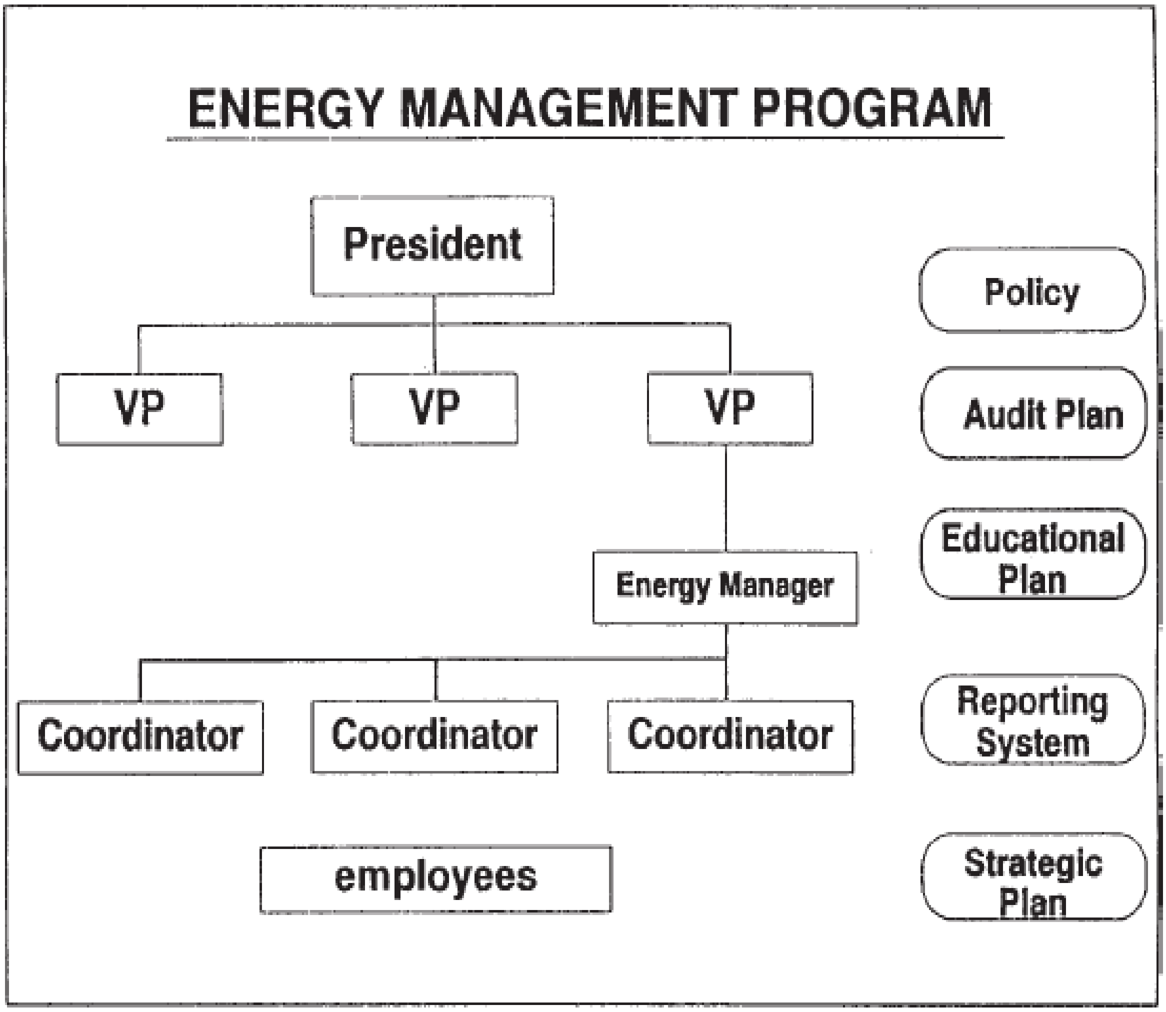
The energy manager should be technically well versed with the manufacturing process, energy utilisation technologies, in addition to awareness of statistical techniques of data processing, applied economics and cost accountancy.

ENERGY MANAGEMENT PROGRAM

All the components of a comprehensive energy management program are depicted in Figure. These components are the organizational structure, a policy, and plans for audits, education, reporting, and strategy. It is hoped that by understanding the fundamentals of managing energy, the energy manager can then adapt a good working program to the existing organizational structure.

ORGANIZATIONAL STRUCTURE

The organizational chart for energy management shown in Figure is generic. It must be adapted to fit into an existing structure for each organization. For example, the presidential block may be the general manager, and VP blocks may be division managers, but the fundamental principles are the same. The main feature of the chart is the location of the energy manager. This position should be high enough in the organizational structure to have access to key players in management, and to have knowledge of current events within the Company. For example, the timing for presenting energy projects can be critical. Funding availability and other management priorities should be known and understood.



SUCCESSFULL ENERGY MANAGEMENT

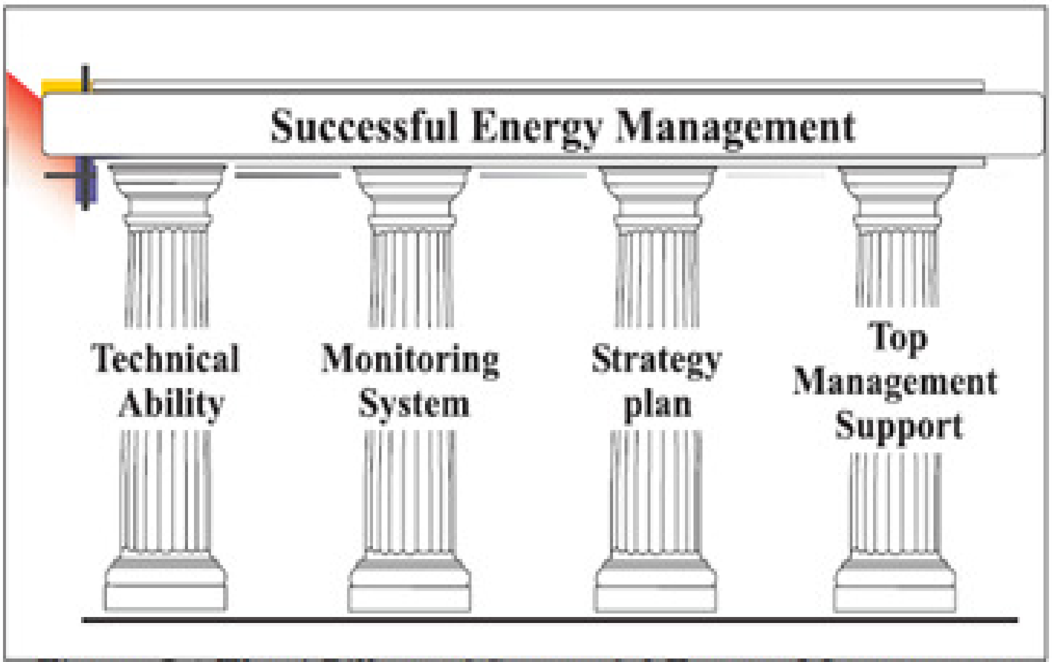


Figure The 4 Pillars of Successful Energy Management

- Energy efficiency is extremely important to all organisations, especially those that are energy intensive.

- The four vital requirements for a successful energy management is shown in Figure.

- Any successful energy management programme within an organisation needs the total support of top management. Hence, top management support is the key requirement for success.

- Top management should give energy efficiency equal importance in their corporate objectives as manpower, raw materials, production and sales.

- The other important requirements are a well charted strategy plan, an effective monitoring system and adequate technical ability for analysing and implementing energy saving options.

Energy Management Strategy

Energy management should be seen as a continuous process. Strategies should be reviewed annually and revised as necessary. The key activities (see Fig) are outlined below

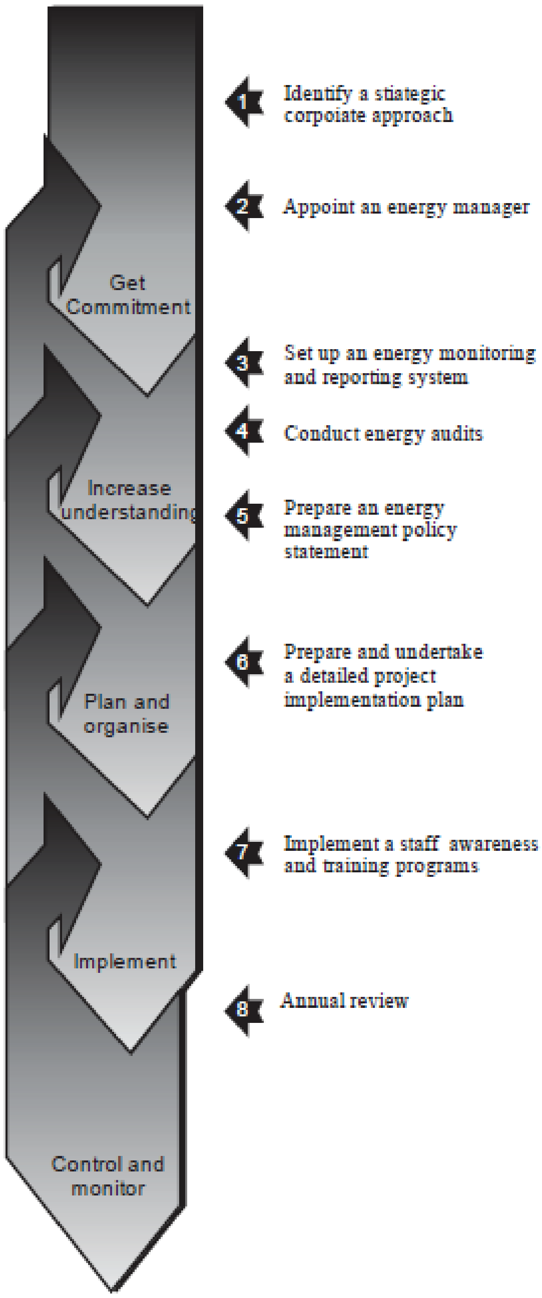


Fig. Energy management steps

Identify a Strategic Corporate Approach

- The starting point in energy management is to identify a strategic corporate approach to energy management.
- Clear accountability for energy management needs to be established, appropriate financial and staffing resources must be allocated, and reporting procedures initiated.
- An energy management programme requires commitment from the whole organisation in order to be successful.

Top Management Commitment is the most important for the success of Energy Conservation activities within companies or factories to have clear and official commitment of top management – either the corporate top (senior) management or factory managers. The top (senior) management shall announce explicit commitment to the Energy Management (or Energy Conservation) and behave along this line – for example, participate in EC (Energy Conservation) events and encourage the people there for EC promotion.

Appoint energy manager

- The energy manager, who should be a senior staff member, will be responsible for the overall co-ordination of the programme and will report directly to the top management.
- Energy managers need to have a technical background, need to be familiar with the organisation's activities and have appropriate technical support.
- In some cases, Energy Committee, with members from the major departments, may be formed to assure the company-wide or factory-wide cooperation.

Set up an energy monitoring and reporting system

- Successful energy management requires the establishment of a system to collect analyse and report on the organisation's energy costs and consumption.

- This will enable an overview of energy use and its related costs, as well as facilitate the identification of savings that might otherwise not be detected.

- The system needs to record both historical and ongoing energy use, as well as cost information from billing data, and be capable of producing summary reports on a regular basis.

- This information will provide the means by which trends can be analysed and tariffs reviewed.

Conduct energy audit

- An energy audit establishes both where and how energy is being used and the potential for energy savings.

- It includes a walk-through survey, a review of energy using systems, analysis of energy use and the preparation of an energy budget, and provides a baseline from which energy consumption can be compared over time.

- An audit can be conducted by an employee of the organisation who has appropriate expertise, or by a specialist energy-auditing firm.

- An energy audit report also includes recommendations for actions, which will result in energy and cost savings.

- It should also indicate the costs and savings for each recommended action, and apriority order for implementation.

Formalise an energy management policy statement

A written energy management policy will guide efforts to improve energy efficiency, and represent a commitment to saving energy. It will also help to ensure that the success of the programme is not dependent on particular individuals in the organisation. An energy management policy statement includes a declaration of commitment from senior management, as well as general aims and specific targets relating to:

- energy consumption reduction (electricity, fuel oil, gas, petrol etc.)

- energy cost reduction (by lowering consumption and negotiating lower unit rates)
- time tables
- budgetary limits
- organisation of management resources

Prepare and undertake a detailed project implementation plan

A project implementation plan should be developed as part of the energy audit and be endorsed by the management. The plan should include an implementation time-table and state any funding and budgetary requirements.

Projects may range from establishing or changing operational procedures to ensure that plant and equipment use minimum energy, renegotiating electricity supply arrangements etc. to adopt asset acquisition programmes that will reduce energy consumption.

An overall strategy could introduce energy management projects, which will achieve maximum financial benefits at the least cost to the organisation.

A key ingredient to the success of an energy management programme is maintaining a high level of awareness among staff. This can be achieved in a number of ways, including formal training, newsletters, posters and publications, and by incorporating energy management into existing training programmes.

It is important to communicate programme plans and case studies that demonstrate savings, and to report results at least at 12-month intervals. Staff may need training from specialists on energy saving practices and equipment.

Annual review

An energy management programme will be more effective if its results are reviewed annually. Review of energy management policy and strategies will form the basis for developing an implementation plan for the next 12months. The annual review has normally to be under the chairmanship of either a senior level top manager or CEO if possible. As the policies are signed by the CEO, it is expected that the review is carried out under his guidance so that the implementation becomes more effective.

Energy Manager: Responsibilities and Duties to be assigned under the Energy Conservation Act, 2001.

Responsibilities of Energy Managers

1. Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs.

2. Establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell.

3. Initiate activities to improve monitoring and process control to reduce energy costs.

4. Analyze equipment performance with respect to energy efficiency.

5. Ensure proper functioning and calibration of instrumentation required to assess level of energy consumption directly or indirectly.

6. Prepare information material and conduct internal workshops about the topic for other staff.

7. Improve disaggregating of energy consumption data down to shop level or profit center of a firm.

8. Establish a methodology how to accurately calculate the specific energy consumption of various products/services or activity of the firm.

9. Develop and manage training programme for energy efficiency at operating levels.

10. Co-ordinate nomination of management personnel to external programs.

11. Create knowledge bank on sectoral, national and international development on energy efficiency echnology and management system and information denomination.

12. Develop integrated system of energy efficiency and environmental up gradation, Wide internal & external networking.
13. Co-ordinate implementation of energy audit/efficiency improvement projects through external agencies.
14. Establish and/or participate in information exchange with other energy managers of the same sector through association.

Duties

- Report to BEE and State level Designated Agency once a year the information with regard to the energy consumed and action taken on the recommendation of the accredited energy auditor, as per BEE Format.
- Establish an improved data recording, collection and analysis system to keep track of energy consumption.
- Provide support to Accredited Energy Audit Firm retained by the company for the conduct of energy audit.
- Provide information to BEE as demanded in the Act, and with respect to the tasks given by a mandate, and the job description.
- Prepare a scheme for efficient use of energy and its conservation and implement such scheme keeping in view of the economic stability of the investment in such form and manner as may be provided in the regulations of the Energy Conservation Act.

MODULE - III

ENERGY EFFICIENT MOTORS

ENERGY EFFICIENT MOTORS:-

In a commercial building, lighting is predominant user of as it is on for a major portion of a day. However, electric motor driving pumps and air-handling fans may also operate for a larger part of the time or even continuously. Therefore in industry, power used by electric motors and other processes generally will be the larger user of electric power, although lighting is still a major consumer.

–*Energy-Efficient motors* cost more than motor first cost (Standard Motor)‖. On a life cycle basis, electric motor efficiency can be far more important than motor first cost.

During the period from 1960 to 1975, electric motors, particularly those in the 1 to 250-hp range, were designed for minimum first cost. The amount of active material, i.e., lamination steel, copper or aluminum or magnet wire, and rotor aluminum, was selected as the minimum levels required meeting the performance requirements of the motor. Efficiency was maintained at levels high enough to meet the temperature rise requirements of the particular motor. As a consequence, depending on the type of enclosure and ventilation system, a wide range in efficiencies exists for standard **NEMA** (National Electrical Manufacturers Association) design B poly-phase motors.

The minimum efficiency is the lowest level of efficiency to be expected when a motor is marked with the nominal efficiency in accordance with the NEMA standard. This method of identifying the motor efficiency takes into account variations in materials, manufacturing processes, and test results in motor-to-motor efficiency variations for a given motor design.

The nominal efficiency represents a value that should be used to compute the energy consumption of a motor or group of motors. For example, a standard 10-hp electric motor may have an efficiency range of 81–88%.

At 81% efficiency,

$$\text{Input to electric motor} = \frac{10*746}{0.81} = 9210 \text{ W}$$

$$\text{Motor losses} = 9210 - 7460 = 1750 \text{ W}$$

At 88% efficiency,

$$\text{Input to electric motor} - \frac{10*746}{0.88} - 8477 \text{ W}$$

$$\text{Motor losses} = 8477 - 7460 = 1077 \text{ W}$$

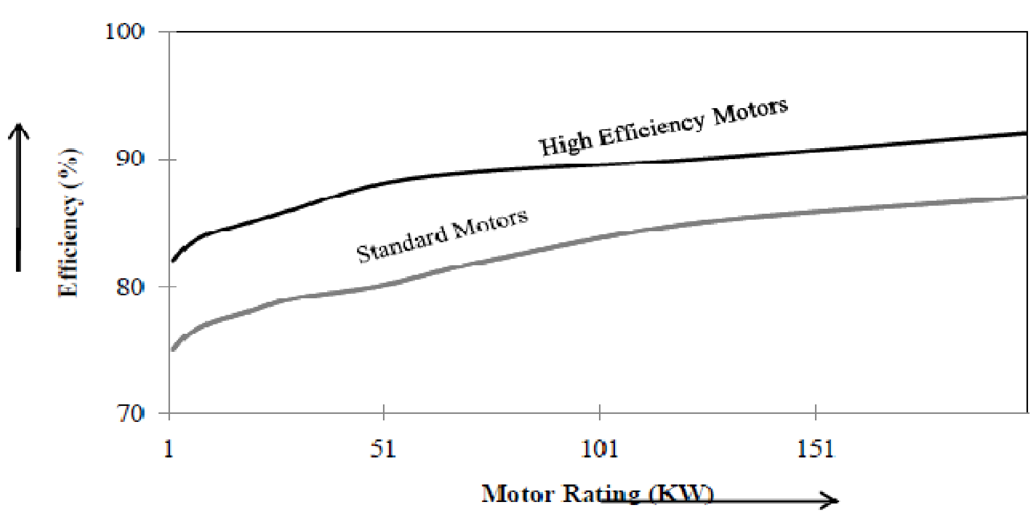
Therefore, for the same output the input can range from 8477 W to 9210 W, or an increase in energy consumption and power costs of 8%, to operate the less efficient motor.

WHY MORE EFFICIENT MOTORS?

The escalation in the cost of electric power that began in 1972 made it increasingly expensive to use inefficient electric motors. From 1972 through 1979, electric power rates increased at an average annual rate of 11.5% per year. From 1979 to the present, the electric power rates have continued to increase at an average annual rate of 6% per year. The annual electric power cost to operate a 10-hp motor 4000 hr/yr increased from $850 in 1972 to $1950 in 1980 and to over $2500 by 1989. By 1974, electric motor manufacturers were looking for methods to improve three-phase induction motor efficiencies to values above those for standard NEMA design B motors.

Unfortunately, there is no single definition of an energy effective motor. Similarly, there are no efficiency standards for stand NEMA design B poly-phase induction motors. Energy-efficient motors (EEM) are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of standard design (see Figure). Design improvements focus on reducing intrinsic motor improvements focus on reducing intrinsic motor losses. Improvements include the use of lower loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller cooling fan, etc.,

Fig. STANDARD (vs) HIGH EFFICIENCY MOTORS
(Typical 3-ϕ Induction Motor)



Energy-efficient motors operate with efficiencies that are typically 4 to 6% higher than the standard motors. In keeping with the stipulations of the BIS, energy-efficient motors are designed to operate without loss in efficiency at loads between 75% and 100% of rated capacity.

This may result in major benefits in varying load applications. The power factor is about the same or may be higher than for standard motors. Furthermore, energy-efficient motors have lower operating temperatures and noise levels, greater ability to accelerated higher-inertia loads, and are less affected by supply voltage fluctuations.

Energy-efficient motors, also called premium or high- efficiency motors, are 2 to 8% more efficient than standard motors. Motors qualify as "energy-efficient" if they meet or exceed the efficiency levels listed in the National Electric Manufacturers Association's (NEMA's).

Energy-efficient motors owe their higher performance to key design improvements and more accurate manufacturing tolerances. Lengthening the core and using lower-electrical-loss steel, thinner stator laminations, and more copper in the windings reduce electrical losses. Improved bearings and a smaller, more aerodynamic cooling fan further increase efficiency. Energy-efficient motors generally have longer insulation and bearing lives, lower heat output, and less vibration. In addition, these motors are often more tolerant of overload conditions and phase imbalance. This results in low failure rates, which has prompted most manufacturers to offer longer warranties for their energy-efficient lines. Purchasing an energy-efficient motor can dramatically cut energy costs.

The advantages are,

- Saves energy and money
- Near uniform efficiency from 50% to 100% of full load ensuring energy savings even at part load conditions also
- Short payback period
- Substantial savings after payback period

The applications of an energy efficient motor are specially suited for industries which are power intensive and equipments which run on constant load for long duration.

FACTORS AFFECTING EFFICIENCY AND LOSS DISTRIBUTION:-

Motor efficiency is simply of the watts output divided by the watts input. This is better expressed as the watts output minus the losses, divided by the watts input.

$$\text{Efficiecy} = \frac{746 \ x \ HP \ output}{watts \ \ input}$$

$$= \frac{input - losses}{input}$$

The only way to improve efficiency is to reduce motor losses. The components of motor losses can be broadly defined as no-load and load losses. The typical loss distribution for an AC motor is shown in below as,

Percentage Motor Component's Loss:

Sr. No.	Motor component Loss	Total Loss %
1.	Stator I^2R loss(copper loss)	37%
2.	Rotor I^2R loss(copper loss)	18%
3.	Iron Loss	20%
4.	Friction and Windage loss	9%
5.	Stray Loss	16%

Description of Motor component's Losses:

Copper Loss:

Depends on the effective resistance of motor winding:

- Caused by the current flowing through it.
- Is equal to I^2R
- Proportional to Load.
- Is equal to I^2R + Rotor I^2R Loss.

Iron Loss:

Depending on the magnetic structure of the core and results from a combination of hysterisis and eddy current effect due to changing magnetic fields in the motor's core

- Voltage Related.
- Constant for any particular motor irrespective of load.

Friction and Windage loss:

- Occurs due to the friction in the bearing of the motor.
- The windage loss of the ventilation fan, other rotating element of the motor.

- Depend on the bearing size, speed type of bearing, lubrication used and fan blade profile.
- Constant for given speed irrespective of load.

Stray Loss:

It is very complex and Load related.

- Arises from harmonics and circulating current.
- Manufacturing process variations can also add to stray losses arises from harmonics and circulating current.
- Manufacturing process variations can also add to stray losses.

SUMMARY OF LOSS DISTRIBUTION

Energy Efficient Motors

Energy efficient motors cover a wide range of ratings and the full load efficiencies are higher by 3-7%. The mounting dimensions are also maintained as per IS1231 to enable easy replacement. As a result of the modifications to improve performance, the costs of energy-efficient motors are higher than those of standard motors by about 30%.

The higher cost will often be paid back rapidly in saved operating costs, particularly in new applications or end-of-life motor replacements. In cases where existing motors have not reached the end of their useful life, the economics will be less positive.

Because the favorable economics of energy-efficient motors are based on savings in operating costs, there may be certain cases which are economically ill-suited to energy-efficient motors.

These include highly intermittent duty or special torque applications such as hoists and cranes, traction drives, punch presses, machine tools, and centrifuges.

In addition, energy efficient designs of multi-speed motors are generally not available. Further, energy-efficient motors are not yet available for many special applications, e.g. for flame-proof operation in oil-field or fire pumps or for very low speed applications (below 750 rpm). Also, most energy-efficient motors produced today are designed only for continuous duty cycle operation.

Given the tendency of over-sizing on the one hand and ground realities like: Voltage, Frequency variations, efficacy of rewinding in case of a burnout, on the other hand, benefits of EEMs can be achieved only by careful selection, implementation, operation and maintenance efforts of energy managers.

Summary of energy efficiency improvements in EEMs is given in the following Table. Within a limited range, the various motor losses discussed are independent of each other. However, in trying to make major improvements in efficiency, one finds that the various losses are very dependent.

The final motor design is a balance among several losses to obtain a high efficiency and still meet other performance criteria, including locked-rotor torque, locked-rotor amperes, breakdown torque, and the power factor.

Table: Energy Efficient Motors

Sr. No.	**Power Loss Area**	**Efficiency Improvement**
1.	Stator I^2R	Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers resistance (R) of the windings and reduces losses due to current flow (I)
2.	Rotor I^2R	Use of larger rotor conductor bars increases size of cross section, lowering conductor resistance (R) and losses due to current flow (I)
3.	Iron	Use of thinner gauge, lower loss core steel reduces eddy current losses. Longer core adds more steel to the design, which reduces losses due to lower operating flux densities.
4.	Friction & Windage	Use of low loss fan design reduces losses due to air movement.
5.	Stray Load Loss	Use of optimized design and strict quality control procedures minimizes stray load losses.

CONSTRUCTIONAL DETAILS:-

The efficiency of energy efficient motors is higher due to the following constructional features are,

1) By increasing the amount of copper in the motor (>60%) which reduces the resistance loss in the winding & temperature rise. Performance improves because of increased thermal mass.

2) Use of more & thinner laminations of high quality motor steel reduces core losses in the stator and rotor.

3) Narrowing of air gap between stator and rotor increases the intensity of magnetic flux, thereby improving the motor ability to deliver the same torque at reduced power. Increasing the length of the stator and rotor increases the net flux linkages in the air gap to the same effect.

4) More complex rotor bar designs enable good starting torque with efficient full speed operation.

5) Improved overall design reduces windage losses and stray load losses.

Applications

Energy efficient motors hold their efficiency better at part loads enhancing their advantage over standard motors. Economic benefits of installing energy efficient motors can be recognized in three situations:

- In a new application (plant expansion)
- In lieu of rewinding of failed motors
- Proactive replacement for in-service standard motors

Energy efficient motors are more cost effective than standard motors in the above cases. Efficiency of EEMs is *4-6%* higher compared to the efficiency of standard motors.

Energy efficient motors run cooler, and therefore have potentially longer life than their standard efficiency counterparts.

Three Phase (3- ϕ) Induction Motors

In the integral horsepower sizes, i.e., above 1 hp, three-phase induction motors of various types drive more industrial equipment than any other means. NEMA means *National Electrical Manufacturers Association.*

The most common three-phase (polyphase) induction motors fall within the following major types:

NEMA design B: Normal torques, normal slip, normal locked amperes

NEMA design A: High torques, low slip, high locked amperes

NEMA design C: High torques, normal slip, normal locked amperes

NEMA design D: High locked-rotor torque, high slip

Wound-rotor: Characteristics depend on external resistance

Multispeed: Characteristics depend on design-variable torque, constant torque, and constant Horsepower

There are many specially designed electric motors with unique characteristics to meet specific needs. However, the majority of needs can be met with the preceding motors.

NEMA Design B Motors

The NEMA design B motor is the basic integral horsepower motor. It is a three-phase motor designed with normal torque and normal starting current and generally has a slip at the rated load of less than 4%. Thus, the motor speed in revolutions per minute is 96% or more of the synchronous speed for the motor.

For example, a four-pole motor operating on a 60-Hz line frequency has a synchronous speed of 1800 rpm or a full-load speed of

$$
\begin{aligned}
1800 - (1800 \times \text{Slip}) &= 1800 - (1800 \times 0.04) \\
&= 1800 - 72 \\
&= 1728 \text{ rpm}
\end{aligned}
$$

(or)

$$1800 \times 0.96 = 1728 \text{ rpm}$$

In general, most three-phase motors in the 1- to 200-hp range have a slip at the rated load of approximately 3% or, in the case of four-pole motors, a full-load speed of 1745 rpm. Figure 2.2 shows the typical construction for a totally enclosed, fan-cooled NEMA design B motor with a die-cast aluminum single-cage rotor.

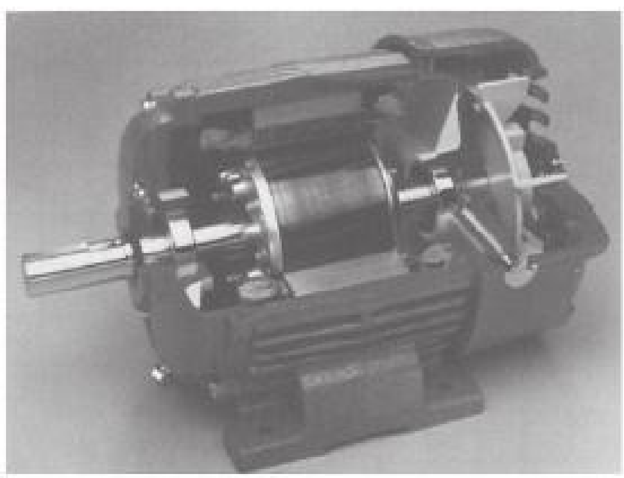
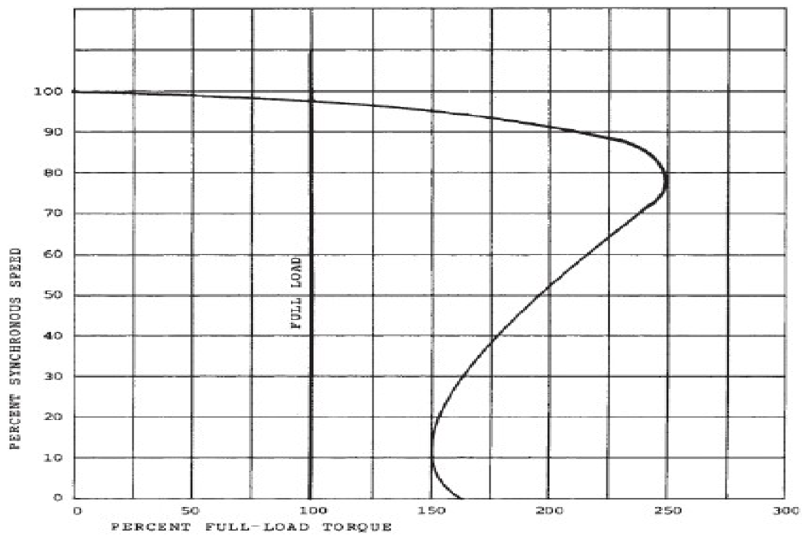


FIGURE: NEMA design B totally enclosed, fan-cooled poly-phase induction motor.

Figure(a) below shows the typical speed-torque curve for the NEMA design B motor. This type of motor has moderate starting torque, a pull-up torque exceeding the full-load torque, and a breakdown torque (or maximum torque) several times the full-load torque.

Thus, it can provide starting and smooth acceleration for most loads and, in addition, can sustain temporary peak loads without stalling.



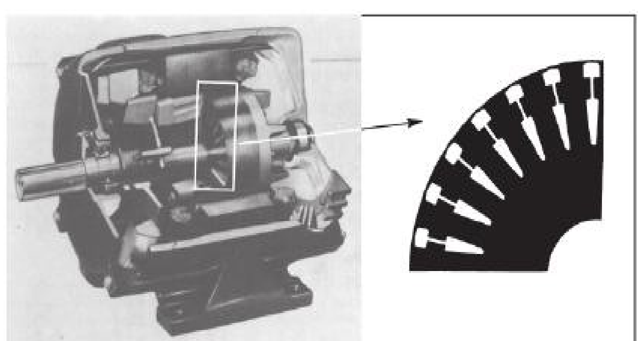
Fig(a): NEMA design B motor speed-torque curve

NEMA Design A Motors

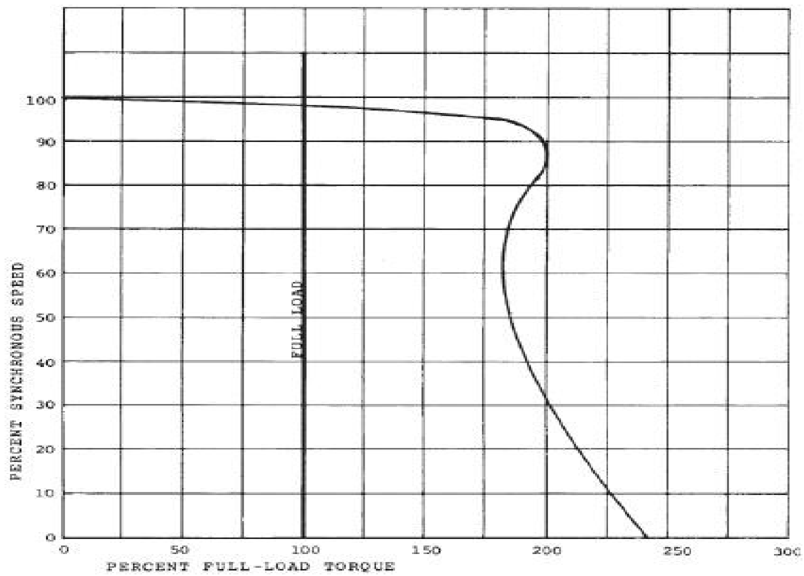
The NEMA design A motor is a poly-phase, squirrel-cage induction motor designed with torques and locked-rotor current that exceed the corresponding values for NEMA design B motors. The criterion for classification as a design A motor is that the value of the locked-rotor current be in excess of the value for NEMA design B motors. The NEMA design A motor is usually applied to special applications that cannot be served by NEMA design B motors, and most often these applications require motors with higher than normal breakdown torques to meet the requirements of high transient or short-duration loads. The NEMA design A motor is also applied to loads requiring extremely low slip, on the order of 1% or less.

NEMA Design C Motors

The NEMA design C motors are a squirrel-cage induction motor that develops high locked-rotor torques for hard-to-start applications. Figure(b) shows the construction of a drip-proof NEMA design C motor with a double-cage, die-cast aluminum rotor. Figure (c) shows the typical speed torque curve for the NEMA design C motor. These motors have a slip at the rated load of less than 5%.



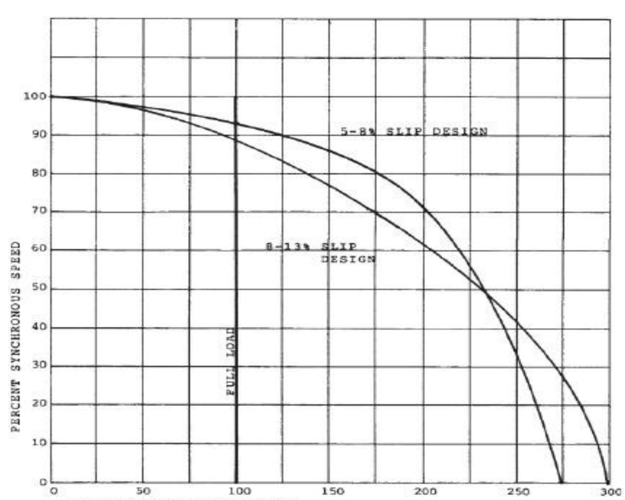
FIGURE(b): NEMA design C drip-proof poly phase induction motor.



FIGURE(c): NEMA design C motor speed-torque curve.

NEMA Design D Motors

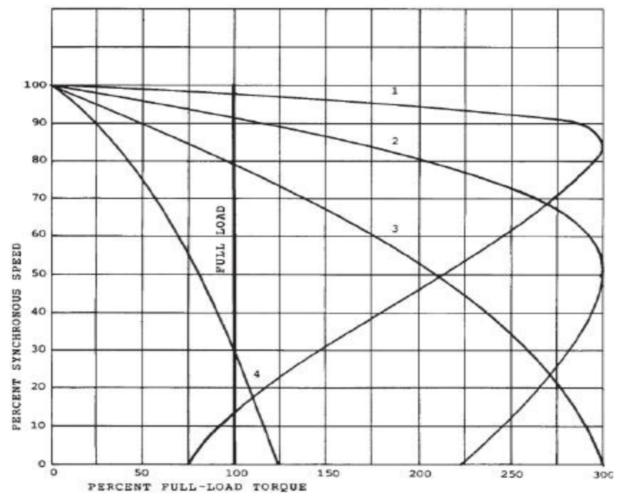
The NEMA design D motor combines high locked-rotor torque with high full-load slip. Two standard designs are generally offered, one with full-load slip of 5–8 % and the other with full-load slip of 8–13%. The locked-rotor torque for both types is generally 275–300% of full-load torque; however, for special applications, the locked-rotor torque can be higher. Figure (d) shows the typical speed-torque curves for NEMA design D motors. These motors are recommended for cyclical loads such as those found in punch presses, which have stored energy systems in the form of flywheels to average the motor load and are excellent for loads of short duration with frequent starts and stops.



FIGURE(d): NEMA design D motor speed-torque curves: 5–8% and 8–13% slip.

The proper application of this type of motor requires detailed information about the system inertia, duty cycle, and operating load as well as the motor characteristics. With this information, the motors are selected and applied on the basis of their thermal capacity.

Wound-Rotor Induction Motors



FIGURE(e): Wound-rotor motor speed-torque curves: 1, rotor short-circuited; 2–4, increasing values of external resistance.

The wound-rotor induction motor is an induction motor in which the secondary (or rotating) winding is an insulated polyphase winding similar to the stator winding. The rotor winding generally terminates at collector rings on the rotor, and stationary brushes are in contact with each collector ring to provide access to the rotor circuit. A number of systems are available to control the secondary resistance of the motor and hence the motor's characteristics. The use and application of wound-rotor induction motors have been limited mostly to hoist and crane applications and special speed-control applications. Typical wound-rotor motor speed-torque curves for various values of resistance inserted in the rotor circuit are shown in Fig.(e).

As the value of resistance is increased, the characteristic of the speed-torque curve progresses from curve 1 with no external resistance to curve 4 with high external resistance. With appropriate control equipment, the characteristics of the motor can be changed by changing this value of external rotor resistance. Solid-state inverter systems have been developed that, when connected in the rotor circuit instead of resistors, return the slip loss of the motor to the power line. This system substantially improves the efficiency of the wound-rotor motor used in variable-speed applications.

Multispeed Motors

Motors that operate at more than one speed, with characteristics similar to those of the NEMA-type single-speed motors, are also available. The multispeed induction motors usually have one or two primary windings. In one-winding motors, the ratio of the two speeds must be 2 to 1; for example, possible speed combinations are 3600/1800, 1800/900, and 1200/600 rpm.

In two-winding motors, the ratio of the speeds can be any combination within certain design limits, depending on the number of winding slots in the stator. The most popular combinations are 1800/1200, 1800/900, and 1800/600 rpm. In addition, two-winding motors can be wound to provide two speeds on each winding; this makes it possible for the motor to operate at four speeds, for example, 3600/1800 rpm on one winding and 1200/600 rpm on the other winding. Multispeed motors are available with the following torque characteristics.

Variable Torque:

The variable-torque multispeed motor has a torque output that varies directly with the speed, and hence the horsepower output varies with the square of the speed. This motor is commonly used with fans, blowers, and centrifugal pumps to control the output of the driven device.

Constant Torque:

The constant-torque multispeed motor has a torque output that is the same at all speeds, and hence the horsepower output varies directly with the speed. This motor can be used with friction-type loads such as those found on conveyors to control the conveyor speed.

Constant Horsepower:

The constant-horsepower multispeed motor has the same horsepower output at all speeds. This type of motor is used for machine tool applications that require higher torques at lower speeds.

Note:

The construction details of Energy Efficient Motors (EEM) i.e., efficient or high efficiency 3-ϕ Induction motors are shown above. Similar for other type of machines also but the design changes have been made to the normal standard motors.

CHARACTERISTICS - VARIABLE SPEED, VARIABLE DUTY CYCLE SYSTEMS:-

The single most potent source of energy savings in induction motor system lies not in the motor, but rather in the controls that govern its operation. Adjustable speed, intelligent controls and other ways of modifying or controlling motor behavior hold great promise for improving performance and efficiency in drive systems. Controlling motor speed to correspond to load requirements provides many benefits, including increased energy efficiency and improved power factor. Adjustable speed capability can significantly improve productivity of many manufacturing processes by reducing scrap, enabling quality manufacturing during transition times and allowing more control over start up and shut down. Following are the benefits of variable speed drives (VSD):

1) Matching motor and load to the output
2) Improved power factor
3) Improved process precision
4) Faster response
5) Extend operating range
6) increased production & flexibility
7) Improved tool life.
8) Electrical isolation
9) Cube-law load savings ($P \alpha N^3$)
10) Throttled load saving (throttling is the most energy inefficient operation)
11) Driving multiple motors

In addition, the basis of rating specifies the type of duty:

- ♥ Continuous duty
- ♥ Intermittent duty
- ♥ Varying duty

It is desirable to use standard motors for as many different applications as possible. Consequently, general-purpose continuous rated motors should be used when

1. The peak momentary overloads do not exceed 75% of the breakdown torque
2. The root-mean-square (rms) value of the motor losses over an extended period of time does not exceed the losses at the service factor rating
3. The duration of any overload does not raise the momentary peak temperature above a value safe for the motor‘s insulation system

In many applications, the load imposed on the driving motor varies from no load to a peak load. When the motor load fluctuates, the temperature rise of the motor fluctuates. When there is a definite repeated load cycle, the motor size selection can be based on the rms value of motor losses for the load cycle.

However, normally, the losses at each increment of the load cycle are not available to the user. Therefore, a good approximation for the motor size selection can be based on the rms horsepower for the load cycle. The rms horsepower is then defined as that equivalent steady-state horsepower that would result in the same temperature rise as that of the defined load cycle. When making the rms calculation, it is assumed that, when the motor is running, the heat dissipation is 100% effective.

However, when the motor is at standstill, the heat dissipation is severely reduced and is limited to dissipation by radiation and natural convection. This can be compensated for by using an effective cooling time at standstill of one-fourth of the total standstill time.

An important word of caution:

This method of selecting electric motors is not satisfactory for applications requiring frequent starting or plug reversing or systems with a high load inertia.

RMS HORSEPOWER (RMS HP):-

The root-mean-square (RMS) value of the horsepower over one cycle can be calculated to estimate the possible heating effect on the motor. The RMS horsepower is the square root of the sums of the horsepower squared, multiplied by the time per horsepower; divided by the sums of all the time intervals.

To determine the RMS load on the motor, use the following equation:

$$\text{RMS HP} = \sqrt{\frac{HP_1^2 * t_1 + HP_2^2 * t_2 + HP_3^2 * t_3 + HP_4^2 * t_4 + \ldots\ldots\ldots + HP_n^2 * t_n}{t_1 + t_2 + t_3 + t_4 + \ldots\ldots\ldots + t_n}}$$

$$HP_{RMS} = \sqrt{\frac{(t_1 \times hp_1^2) + (t_2 \times hp_2^2) + \ldots\ldots + (t_i \times hp_i^2)}{t_1 + t_2 + \ldots\ldots + t_i}}$$

Where:

hp_i = load, in horsepower, for each part of the cycle

t_i = time, in seconds, that the motor is subject to load hp_i

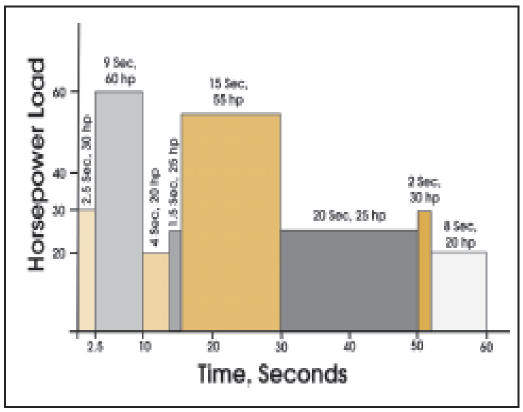
As long as the RMS horsepower does not exceed the full load horsepower of the motor used in the application, the motor should not overheat.

This, of course, is only true as long as there is adequate ventilation during the entire cycle. To keep it simple, we have disregarded the effect of acceleration time on a self-ventilated motor.

Example…

To properly size a motor for varying, repetitive duty, you will need to know the duration and horsepower load for each. It is helpful to develop a graph showing the required horsepower vs. time, as shown in Fig. 1, as well as a visual that lists each time and horsepower, using the RMS horsepower for this example gives the following result:

Fig. 1. Required horsepower vs. time



$$HP_{RMS} = \sqrt{\frac{(t_1 \times hp_1^2) + (t_2 \times hp_2^2) + \dots + (t_i \times hp_i^2)}{t_1 + t_2 + \dots + t_i}}$$

$$HP_{RMS} = \sqrt{\frac{(2.5 \times 900)+(7 \times 3600)+(4 \times 400)+(1.5 \times 625)+(15 \times 3025)+(20 \times 625)+(2 \times 900)+(8 \times 400)}{2.5+7+4+1.5+15+20+2+8}}$$

$$HP_{RMS} = \sqrt{\frac{(2250)+(25200)+(1600)+(937.5)+(45375)+(12500)+(1800)+(3200)}{60}}$$

$$HP_{RMS} = \sqrt{\frac{92862.5}{60}} = 39.3\ hp$$

VOLTAGE VARIATION-VOLTAGE UNBALANCE:-

Voltage variation:-

National Electrical Manufacturers Association (NEMA) standard recognizes the effect of voltage and frequency variation on electric motor performance.

The standard recommends that the voltage deviation from the motor rated voltage not exceed 10% at the rated frequency. The rated motor voltage has been selected to match the utilization voltage available at the motor terminals.

This voltage allows for the voltage drop in the power distribution system and for voltage variation as the system load changes.

The basis of the NEMA standard rated motor voltages for three phase 60 Hz induction motors is as follows:

System voltage	rated motor voltage
208	200
240	230
480	460
600	575

Voltage unbalance:-

Voltage unbalance can be more detrimental than voltage variation to motor performance and motor life. When the line voltages applied to a polyphase induction motor are not equal in magnitude and phase angle, unbalanced currents in the stator windings will result. A small percentage voltage unbalance will produce a much larger percentage current unbalance.

Some of the causes of voltage unbalance are the following:

1) An open circuit in the primary distribution system.

2) A combination of single phase and three phase loads on the same distribution system, with the single phase loads unequally distributed.

Percentage Voltage Unbalance is defined by NEMA as 100 times the deviation of the line Voltage from the average voltage divided by the average voltage. If the measured voltages are 420, 430 and 440V, the average is 430V and the deviation is 10V. The Percentage Unbalance is given by,

$$= \frac{10\text{ V x }100}{430\text{ V}} = 2.3\%$$

(or)

Voltage unbalance is defined as the NEMA as 100 times the absolute value of the maximum deviation of the line voltage from the average voltage on a three phase system divided by the average voltage.

$$\%\ voltage\ unbalance = \frac{\text{max.voltage deviation from average voltage}}{\text{average voltage}} \text{x } 100$$

1% voltage unbalance will increase the motor losses by 5%. Fig shows the increase in motor losses due to voltage unbalance.

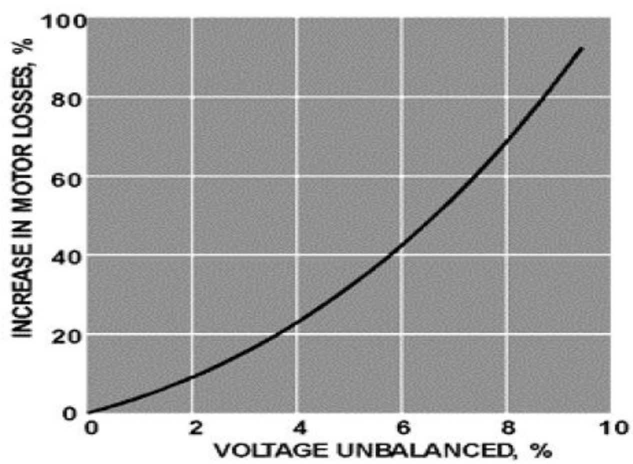


Figure: Effect of voltage unbalance on motor losses

OVER MOTORING:-

–Rating of motor is higher than the required rating of the motor is called over motoring‖.

In many instances, the practice has been to over motor an application, i.e., to select a higher horsepower motor than necessary. The disadvantages of this practice are,

- Lower efficiency
- Lower power factor
- Higher motor cost
- Higher controller cost

MOTOR ENERGY AUDIT:-

The **Electrical Motor Energy Audit** is the collection of actual electrical motor load data including: voltage, current, active power, total power, reactive power, and power factor under normal operating conditions.

Average **Energy Conservation** ranges from 3 -35% depending on motor load conditions and will **always** be dependent upon the load. Motor applications that are under loaded or oversized have more electrical losses and therefore more potential for **Energy Conservation** and dollar savings. If necessary an additional **Electrical Motor Energy Audit** can be conducted following Implementation to verify the actual **Energy Conservation** and dollar savings. The verification process simply entails the collection of an average baseline motor load sample (before process) followed by another comparable average motor load sample with the **ECI** method (after process), and the evaluation of the difference. **Energy Conservation** is realized immediately upon Implementation.

The process of electric motor management as,

- Save energy
- Reduce operating costs
- Minimize downtime
- Increase productivity.

Five Basic Concepts of Energy conservation in Drive Power are as follows:

- Drive power is huge – **Think big** ,
- Motors are part of a system – **Think systems,**
- Optimize the application & process – **Deliver service,**
- The further the downstream savings, the higher is the upstream benefits – **Start down stream,**
- Pursue integrated packages of savings opportunities rather than isolated measures because many savings are Inter – Dependent – **Integrate measures.**

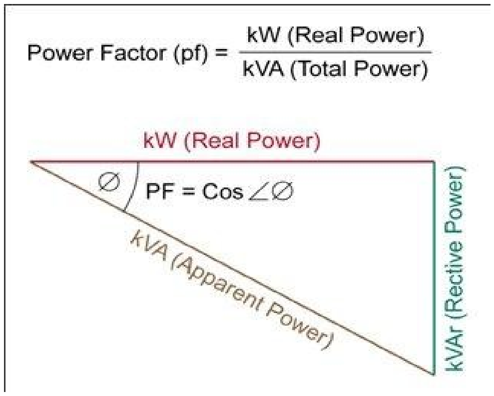
MODULE-IV

POWER FACTOR

The **power factor** of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit.

(or)

Power factor is defined as the ratio of real power (kw) to the apparent power (kvA) and cosine of the angle by which the current lags (or leads) the voltage.



It is a dimensionless number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred.

The higher currents increase the energy lost in the distribution system, and require larger wires and other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor. Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor.

The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

AC power flow has the three components: real power (also known as active power) (P), measured in watts (W); apparent power (S), measured in volt-amperes (VA); and reactive power (Q), measured in reactive volt-amperes (var).

The power factor is defined as: active power/apparent power

In the case of a perfectly sinusoidal waveform, P, Q and S can be expressed as vectors that form a vector triangle such that:

$$S^2 = P^2 + Q^2.$$

If φ is the phase angle between the current and voltage, then the power factor is equal to the cosine of the angle, |cosφ|, and:

$$|P| = |S|\,|\cos\varphi|.$$

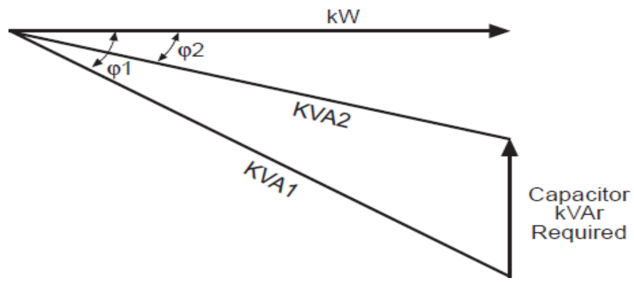
Since the units are consistent, the power factor is by definition a dimensionless number between 0 and 1. When power factor is equal to 0, the energy flow is entirely reactive, and stored energy in the load returns to the source on each cycle. When the power factor is 1, all the energy supplied by the source is consumed by the load. Power factors are usually stated as "leading" or "lagging" to show the sign of the phase angle.

METHODS OF IMPROVEMENT:-

The most practical and economical power factor improvement device is the capacitor. As stated previously, all inductive loads produce inductive reactive power (lagging by a phase angle of 90°). Capacitors on the other hand produce capacitive reactive power, which is the exact opposite of inductive reactive power. In this instance, the current peak occurs before the voltage peak, leading by a phase angle of 90°. By careful selection of capacitance required, it is possible totally cancel out the inductive reactive power when placed in circuit together.

To prevent the continual flow of reactive current back and forth between the load and power station, a capacitor, which is in effect a reactive current storage device, is connected in parallel with the load. The reactive current supplied by the power station and used for the magnetic force when the load is switched on does not now return to the power station but instead flows into the capacitor and merely circulates between the latter and the load. Consequently the distribution lines from the power station are relieved of the reactive current. Capacitors can therefore be utilized to reduce kVA and electrical costs. Improved power factor results in:

1. Reduced kVA charges
2. Improved plant efficiency
3. Additional loads can be added to the system
4. Reduced overloading of cables, transformers, switchgear, etc.
5. Improved starting torque of motors
6. Reduce fuel requirements to generate power due to lower losses.



Cosϕ1 is the kVA used before Power Factor Improvement equipment was added to the network.

Cosϕ2 is the kVA used after Power Factor improvement equipment was added to the network.

LOCATION OF CAPACITORS:-

In general, capacitor banks are installed in power systems for voltage support, power factor correction, reactive power control, loss reduction, system capacity increase, and billing charge reduction. This process involves determining capacitor size, location, control method, and connection type (star or Delta).

The main effort usually is to determine capacitor size and location for voltage support and power factor correction. Secondary considerations are harmonics and switching transients.

Any installation including the following types of machinery or equipment is likely to have low power factor which can be corrected, with a consequent saving in charges, by way of reduced demand charges, lesser low power factor penalties:

1. Induction motors of all types (which from by far the greatest industrial load on a. c. mains).
2. Power thyristor installation (for d.c. motor control and electro-chemical processes).
3. Power transformers and voltage regulators.
4. Welding machines
5. Electric-arc and induction furnaces.
6. Choke coils and magnetic system.
7. Neon sins and fluorescent lighting.

There are different methods for determining capacitor size and location.

1. The most common method (intuitive) is based on rules of thumb followed by running multiple load flow studies for fine-tuning the size and location. This method may not yield the optimal solution and can be very time consuming and impractical for large systems.

2. The second method is to use the ETAP Optimal Power Flow (OPF) program to optimize the capacitor sizes based on the candidate locations selected by the engineer. This method requires per-selected locations, since OPF can optimize the capacitor sizes but not the locations.

3. The most effective method is to use the Optimal Capacitor Placement (OCP) program to optimize capacitor sizes and locations with cost considerations. OCP employs a genetic algorithm, which is an optimization technique based on the theory of nature selection. OCP uses the ―Present worth Method‖ to do alternative comparisons. It considers initial installation and operating costs, which includes maintenance, depreciation, and interest rate.

Two methods of improving power factor using capacitors are:

a) Individual motor compensation (static capacitors)

b) Centralized compensation (automatic capacitor banks)

a) Individual Motor Compensation:-

Most effective correction is obtained by connecting individual capacitors directly to the terminals of each motor. The motor and capacitor can be controlled jointly by the motor switchgear. The capacitor rating should be matched as closely as possible so that the power factor of the entire plant can be corrected to the optimum value, irrespective of the number of motors switched on.

If the magnetizing current is not known, 95% of the motor no-load current can be used as an approximate value. Care should be taken not to exceed the value calculated to avoid dangerous overvoltages and possible self excitation of motors at switch-off. Over compensation can cause higher supply voltages which can cause consequent break down of motor insulation and flashover at motor terminals. To be safe, rather use standard capacitor sizes (as indicated below). For this reason, individual motor compensation is not recommended for motors which are rapidly reversed e.g. cranes, hoists, etc.

b) Centralized Compensation (Automatic Power Factor Correction):-

In large industrial plants where many motors are generally in use or, when the main reason for power factor is to obtain lower electricity bills, then centralized compensation is far more practical and economical than individual motor compensation. In this instance, large banks or racks of capacitors are installed at the main incoming distribution boards of the plant and are sub-divided into steps which are automatically switched in or out depending on specific load requirements by means of an automatic control system, improving the overall power factor of the network. Generally an automatic power factor system consists of:

a) A main load-break isolator (or circuit breaker)

b) An automatic reactive control relay

c) Power factor capacitors backed by suitable fuse protection

d) Suitably rated contactors for capacitor switching

The automatic reactive control relay monitors the total network and will switch-in the required capacitor banks at pre-determined intervals compensating for capacitor discharge times and load dependant requirements. As capacitor switching subject‘s components to exceptionally high stresses it is imperative to correctly size and rate all components utilized in a system.

PF WITH NON LINEAR LOADS:-

Applies to those ac loads where the current is not proportional to the voltage. Foremost among loads meeting their definition is gas discharge lighting having saturated ballast coils and thyristor (SCR) controlled loads. The nature of non-linear loads is to generate harmonics in the current waveform. This distortion of the current waveform leads to distortion of the voltage waveform. Under these conditions, the voltage waveform is no longer proportional to the current. Non Linear Loads are: COMPUTER, LASER PRINTERS, SMPS, REACTIFIER, PLC, ELECTRONIC BALLAST, REFRIGERATOR, TV ETC.

EFFECT OF HARMONICS ON P.F:-

But for many applications, the classic triangle is oversimplified. That‘s because it does not take into account the effects of harmonic voltages and currents found in today‘s power-distribution systems. Harmonics add a third dimension to the classic power-factor triangle, thereby increasing the apparent power required to do a particular amount of work. The presence of harmonics requires that you change the way you think about–and the way you measure–power factor.

When active power is divided by apparent power in the presence of harmonics, the result is known as total power factor (PF). The component of power factor not contributed by harmonics is known as displacement power factor (DPF). Note that PF and DPF are equal in completely linear circuits–such as a 208-V, 3-phase induction motor operating a blower–but are different in non- linear circuits, for example a variable-frequency drive controlling cooling-tower fans.

O&M personnel should understand three practical effects of the PF/DPF definitions: (1) The difference between PF and DPF readings is proportional to the degree of harmonics in the power distribution system; (2) a power meter must provide both PF and DPF readings in order to effectively troubleshoot systems with harmonics; and (3) manufacturers of nonlinear equipment often provide only a single power-factor specification for their equipment, and it may be unclear whether the specification refers to PF or DPF.

If PF and DPF differ by a factor of 10% or more, the difference is probably caused by harmonics. The degree of difference may also suggest a course of action, depending on the types of loads in the system.

Case 1: Predominantly linear systems. When PF and DPF are essentially the same value, motors or other linear loads dominate the circuit. In this case, low power factor can be compensated for with kVAr correction capacitance. Use caution in diagnosing problems involving both low power factor and harmonics, because kVAr capacitors may be only part of the solution. Even in systems with low levels of harmonics, kVAr capacitors applied improperly can cause resonant conditions that can lead to overvoltages.

Case 2: Predominantly nonlinear systems. When PF is significantly lower than DPF correct low power factor by applying line reactors directly to the sources of harmonic current or by using kVAr capacitor networks with series inductors to limit harmonic current in the capacitors. Always exercise caution in the use of kVAr correction capacitors and compensating filters to avoid resonance problems at harmonic frequencies and consult the capacitor manufacturer or an expert in filter design.

Case 3: Systems with kVAr capacitors already installed. When variable-frequency drives are added to existing motors, and kVAr correction capacitors are already installed, DPF can actually be overcorrected, causing current to lead voltage. Without system modifications, these new components might cause instability and overvoltage problems. Under these conditions take readings in the circuit to determine whether it is necessary to remove the kVAr correction capacitors.

Users can measure both PF and DPF with a single meter. The best ones show three views of the measured signal: a numeric reading of signal parameters, a visual display of the waveform, and a view of the entire harmonic spectrum.

P.F MOTOR CONTROLLERS:-

Electric motor savings are achieved in several ways. The first is in the motor design itself, through the use of better materials, design, and construction. Another is by optimizing the mechanical angle between the various rotating magnetic fields inside the motor. This is done using the newer family of motor control algorithms, generally referred to together as space vector control, flux vector control, or field-oriented control. By keeping the magnetic fields of the rotor and stator oriented with the optimal angles between them under various speed and torque conditions (typically near 90 degrees), the motor can always be operated at peak efficiency. As a side benefit, other characteristics can also be optimized, such as fast and stable dynamic response to load changes, precise control of speed or torque, soft starting and braking, prevention of stalling at low speeds, high starting torques, and fault detection; often without sacrificing much in the way of overall energy efficiency. Some of these features were once obtainable only from a more expensive motor type, but can be achieved with the now ubiquitous, low-cost, and reliable AC induction motor, which comprises 90 percent of U.S. motor sales. One of the most significant advantages of the newer control algorithms is efficient variable speed operation.

A very large opportunity for system-level energy savings comes from using variable speed motor drives. A well-designed pump or fan motor running at half the speed consumes only one-eighth the energy compared to running at full speed. Many older pump and fan installations used fixed-speed motors connected directly to the power mains, and controlled the liquid or air flow using throttling valves or air dampers. The valves or dampers create a back pressure, reducing the flow, but at the expense of efficiency. This is probably how the HVAC forced-air system works in your office building; dampers control the airflow into each workspace while the central fan, which is sized for peak requirements, runs at full speed all the time—even if the combined airflow requirements of the building are currently very low. Replacing these motors with variable speed drives and eliminating or controlling the dampers more intelligently can save up to two-thirds their overall energy consumption.

LIGHTING AND ENERGY INSTRUMENTS FOR AUDIT

LIGHTING INTRODUCTION:-

In today‘s cost-competitive, market-driven economy, everyone is seeking technologies or methods to reduce energy expenses and environmental impact. Because nearly all buildings have lights, lighting retrofits are very common and generally offer an attractive return on investment.

–Lighting‖ is good lighting when it provides adequate illuminance to enable the task to be performed efficiently, is perceived as comfortable, and people have a high level of satisfaction. Good lighting design is not simply about achieving a required illuminance on the working plane; it is about creating and controlling the lit environment.

Standards often specify lighting in terms of the illumination on the horizontal plane, which is the amount of light falling onto a horizontal surface. (Figure 1) This is because it is easy to measure and easy to calculate. It is not a good indicator of the visual environment however, as people generally judge the adequacy of the lighting by the luminance or relative brightness of the vertical surfaces.

The luminance is the amount of light that leaves a surface, either by transmission through the material or, more commonly, reflection from the surface. (Figure 2) In simple terms, the luminance is the product of the illuminance and the reflectance of the surface divided by π. The eye sees luminance rather than illuminance. Therefore with the same illumination, by changing the surface reflectance, the luminance of the surface changes proportionally.

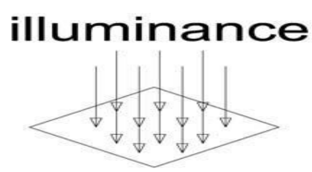


Figure 1. Illuminance: a measure of the light falling on a surface

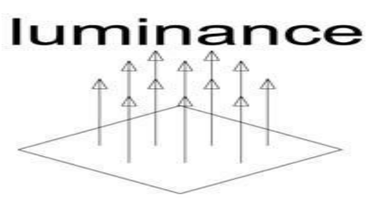


Figure 2. Luminance is a measure of the light leaving a surface.

GOOD LIGHTING SYSTEM DESIGN:-

‑Design‖ is the science and art of making things useful to human kind and lighting design is the application of lighting including daylight when it is specifically used as source of lighting to human spaces.

Like architecture, engineering and other design professions, lighting design relies on a combination of specific scientific principles, established standards and conventions, and a number of aesthetic, cultural and human factors applied in an artful manner.

The two objectives of the lighting designer are,

(1) To provide the right quantity of light,

(2) Provide the right quality of light.

Lighting Quantity:-

Lighting quantity is the amount of light provided to a room. Unlike light quality, light quantity is easy to measure and describe.

Units:-

Lighting quantity is primarily expressed in three types of units: watts, lumens and foot-candles (fc). Figure 3.1 shows the relationship between each unit.

The watt is the unit for measuring electrical power. It defines the rate of energy consumption by an electrical device when it is in operation. The amount of watts consumed represents the electrical input to the lighting system.

The output of a lamp is measured in lumens. For example, one standard four-foot fluorescent lamp would provide 2,900 lumens in a standard office system. The amount of lumens can also be used to describe the output of an entire fixture (comprising several lamps). Thus, the number of lumens describes how much light is being produced by the lighting system.

The number of foot-candles shows how much light is actually reaching the workplane (or task). Foot-candles are the end result of watts being converted to lumens, the lumens escaping the fixture and traveling through the air to reach the workplane. In an office, the workplane is the desk level.

You can measure the amount of foot-candles with a light meter when it is placed on the work surface where tasks are performed. Foot-candle measurements are important because they express the ‑result‖ and not the ‑effort‖ of a lighting system. The Illuminating Engineering Society (IES) recommends light levels for specific tasks using foot-candles, not lumens or watts.

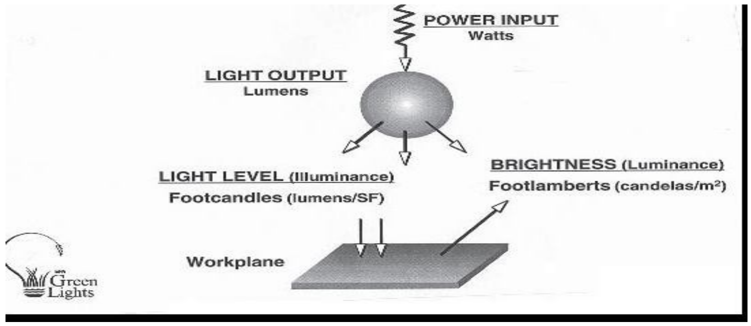


Figure 3.1 Units of measurement.

Efficacy:-

Similar to efficiency, efficacy describes an output/ input ratio, the higher the output (while input is kept constant), the greater the efficacy. Efficacy is the amount of lumens per watt from a particular energy source. A common misconception in lighting terminology is that lamps with greater wattage provide more light. However, light sources with high efficacy can provide more light with the same amount of power (watts), when compared to light sources with low efficacy.

IES Recommended Light Levels:-

The Illuminating Engineering Society (IES) is the largest organized group of lighting professionals in the United States. Since 1915, IES has prescribed the appropriate light levels for many kinds of visual tasks.

Lamp Family	Lamp Type	Watts (nominal)	Efficacy (LPW)
Incandescent	Incandescent	3 – 1,500	4 – 23
	Halogen	42 – 1,500	14 – 22
CFL	Screw-base	9 – 85	40 – 65
	Twin-tube Pre-heat (2-pin)	5 – 13	50 – 69
	Quad Pre-heat (2-pin)	9 – 26	64 – 69
	Rapid-start (4-pin)	5 – 57	46 – 87
Linear Fluorescent	T2	6 – 13	52 – 66
	T5	14 – 35	96 – 104
	T5HO	24 – 80	83 – 94
	T8 4′ Standard	32	53 – 88
	T8 4′ Reduced-Wattage	30	94 - 95
	T8 4′ High-Performance	32	94 – 98
	T10 4′	40	83
	T12 Reduced-Wattage	34	49 – 85
	T12 4′ Standard	40	53 – 83
	T12 8′ Slimline Reduced-Wattage	60	64 – 97
	T12 8′ Slimline	75	58 – 87
	T12 8′ HO Reduced-Wattage	95	81 – 92
	T12 8′ HO (110-w)	110	55 – 85
	T12 8′ VHO Reduced-Wattage	195	67
	T12 8′ VHO Fluorescent	215	65 – 70
Mercury Vapor	Standard	50 – 1,000	32 – 58
	Self-ballasted	160 – 750	14 - 19
Metal Halide	Standard Probe-start	50 – 1,500	69 – 115
	Pulse-start	50 – 1,000	69 – 110
	Ceramic Arc-tube	20 – 400	83 – 95
High-Pressure Sodium	Standard	35 – 1,000	64 – 150
	Improved CRI	70 – 400	63 – 94
Low-Pressure Sodium		18 – 180	100 – 175
Induction	QL	55 – 165	64 – 73
	ICETRON™	70 – 150	70 – 79

Figure 3.2 Lamp Efficacies for Various Lamp Types. (Source: Effective Lighting Solutions, Inc.)

Lighting Quality:-

Lighting quality can have a dramatic influence on the attitude and performance of occupants. In fact, different –moods‖ can be created by a lighting system. Consider the behavior of people when they eat in different restaurants. If the restaurant is a fast-food restaurant, the space is usually illuminated by bright white lights, with a significant amount of glare from shiny tables. Occupants rarely spend much time there partly because the space creates an uncomfortable mood and the atmosphere is –fast‖ (eat and leave). In contrast, consider an elegant restaurant with a candle-lit tables and a –warm‖ atmosphere. Occupants tend to relax and take more time to eat. Although occupant behavior is also linked to interior design and other factors, lighting quality represents a significant influence. Occupants perceive and react to a space‘s light color. It is important that the lighting designer be able to recognize and create the subtle aspects of an environment that define the theme of the space. For example, drug and grocery stores use white lights to create a –cool‖ and –clean‖ environment. Imagine if these spaces were illuminated by the same color lights as in an elegant restaurant. How would the perception of the store change? Occupants can be influenced to work more effectively if they are in an environment that promotes a –work-like‖ atmosphere.

The goal of the lighting designer is to provide the appropriate quality of light for a particular task to create the right –mood‖ for the space. Employee comfort and performance are worth more than energy savings. Although the cost of energy for lighting ($.50-$1.00/year/ft2) is substantial, it is relatively small compared to the cost of labor ($100-$300/year/ft2). Improvements in lighting quality can yield high dividends for businesses because gains in worker productivity are common when lighting quality is improved. Conversely, if a lighting retrofit reduces lighting quality, occupant performance may decrease, quickly off-setting any savings in energy costs. Good energy managers should remember that buildings were not designed to save energy; they exist to create an environment where people can work efficiently. Occupants should be able to see clearly without being distracted by glare, excessive shadows or other uncomfortable features.

Lighting quality can be divided into four main considerations are Uniformity, Glare, Color Rendering Index and Coordinated Color Temperature.

Uniformity:-

The uniformity of illuminance describes how evenly light spreads over an area. Creating uniform illumination requires proper fixture spacing. Non-uniform illuminance creates bright and dark spots, which can cause discomfort for some occupants. Lighting designers have traditionally specified uniform illumination. This option is least risky because it minimizes the problems associated with non-uniform illumination and provides excellent flexibility for changes in the work environment. Unfortunately, uniform lighting applied over large areas can waste large amounts of energy. For example, in a manufacturing building, 20% of the floor space may require high levels of illumination (100 fc) for a specific visual task. The remaining 80% of the building may only require 40 foot candles. Uniform illumination over the entire space would require 100 fc at any point in the building. Clearly, this is a tremendous waste of energy and money. Although uniform illumination is not needed throughout the entire facility, uniform illumination should be applied on specific tasks. For example, a person assembling small parts on a table should have uniform illumination across the table top.

Glare:-

Glare is a sensation caused by relatively bright objects in an occupant‘s field of view. The key word is relative, because glare is most probable when bright objects are located in front of dark environments. For example, a car‘s high beam headlights cause glare to oncoming drivers at night, yet create little discomfort during the day. Contrast is the relationship between the brightness of an object and its background.

Although most visual tasks generally become easier with increased contrast, too much brightness causes glare and makes the visual task more difficult. Glare in certain work environments is a serious concern because it usually will cause discomfort and reduce worker productivity.

Visual Comfort Probability (VCP):-

The Visual Comfort Probability is a rating given to a fixture which indicates the percent of people who are comfortable with the glare. Thus, a fixture with a VCP = 80 means that 80% of occupants are comfortable with the amount of glare from that fixture. A minimum VCP of 70 is recommended for general interior spaces. Fixtures with VCPs exceeding 80 are recommended in computer areas and high-profile executive office environments.

To improve a lighting system that has excessive glare, a lighting designer should be consulted. However there are some basic ―rules of thumb‖ which can assist the energy manager. A high-glare environment is characterized by either excessive illumination and reflection, or the existence of very bright areas typically around fixtures. To minimize glare, the energy manager can try to obscure the bare lamp from the occupant‘s field of view, relocate fixtures or replace the fixtures with ones that have a high VCP.

Reducing glare is commonly achieved by using indirect lighting, using deep cell parabolic troffers, or special lenses. Although these measures will reduce glare, fixture efficiency will be decreased because more light will be –trapped‖ in the fixture. Alternatively, glare can be minimized by reducing ambient light levels and using task lighting techniques.

Visual Display Terminals (VDTs):-

Today‘s office environment contains a variety of special visual tasks, including the use of computer monitors or visual display terminals (VDTs). Occupants using VDTs are extremely vulnerable to glare and discomfort. When reflections of ceiling lights are visible on the VDT screen, the occupant has difficulty reading the screen. This phenomenon is also called –discomfort glare,‖ and is very common in rooms that are uniformly illuminated by fixtures with low a VCP. Therefore, lighting for VDT environments must be carefully designed, so that occupants remain comfortable. Because the location VDTs can be frequently changed, lighting upgrades should also be designed to be adjustable. Moveable task lights and fixtures with high VCP are very popular for these types of applications. Because each VDT environment is unique, each upgrade must be evaluated on a case-by-case basis.

Color:-

Color considerations have an incredible influence on lighting quality. Light sources are specified based on two color-related parameters: the Color Rendering Index (CRI) and the Coordinated Color Temperature (CCT).

Color Rendering Index (CRI):-

In simple terms, the CRI provides an evaluation of how colors appear under a given light source. The index range is from 0 to 100. The higher the number, the easier to distinguish colors. Generally, sources with a CRI > 75 provide excellent color rendition. Sources with a CRI < 55 provide poor color rendition. To provide a –base-case,‖ offices illuminated by most T12 Cool White lamps have a CRI = 62. It is extremely important that a light source with a high CRI be used with visual tasks that require the occupant to distinguish colors. For example, a room with a color printing press requires illumination with excellent color rendition. In comparison, outdoor security lighting for a building may not need to have a high CRI, but a large quantity of light is desired.

Coordinated Color Temperature (CCT):-

The Coordinated Color Temperature (CCT) describes the color of the light source. For example, on a clear day, the sun appears yellow. On an over-cast day, the partially obscured sun appears to be gray. These color differences are indicated by a temperature scale. The CCT (measured in degrees Kelvin) is a close representation of the color that an object (black-body) would radiate at a certain temperature. For example, imagine a wire being heated. First it turns red (CCT = 2000K). As it gets hotter, it turns white (CCT = 5000K) and then blue (CCT = 8000K). Although a wire is different from a light source, the principle is similar. CCT is not related to CRI, but it can influence the atmosphere of a room. Laboratories, hospitals and grocery stores generally use ―cool‖ (blue-white) sources, while expensive restaurants may seek a ―warm‖ (yellow-red) source to produce a candle-lit appearance. Traditionally, office environments have been illuminated by Cool White lamps, which have a CCT = 4100K. However, a more recent trend has been to specify 3500K tri-phosphor lamps, which are considered neutral. Table illustrates some common specifications for different visual environments.

Lamp characteristics

	Incandescent Including Tungsten Halogen	Fluorescent	Compact Fluorescent	Mercury Vapor (Self-ballasted)	Metal Halide	High-Pressure Sodium (Improved Color)	Low-Pressure Sodium
Wattages (lamp only)	15-1500	15-219	4-40	40-1000	175-1000	70-1000	35-180
Life (hr)	750-12,000	7,500-24,000	10,000-20,000	16,000-15,000	1,500-15,000	24,000 (10,000)	18,000
Efficacy (lumens/W) lamp only	15-25	55-100	50-80	50-60 (20-25)	80-100	75-140 (67-112)	Up to 180
Lumen maintenance	Fair to excellent	Fair to excellent	Fair	Very good (good)	Good	Excellent	Excellent
Color rendition	Excellent	Good to excellent	Good to excellent	Poor to excellent	Very good	Fair	Poor
Light direction control	Very good to excellent	Fair	Fair	Very good	Very good	Very good	Fair
Relight time	Immediate	Immediate	Imm- 3 seconds	3-10 min.	10-20 min.	Less than 1 min.	Immediate
Comparative fixture cost	Low: simple	Moderate	Moderate	Higher than fluorescent	Generally higher than mercury	High	High
Comparative operating cost	High	Lower than incandescent	Lower than incandescent	Lower than incandescent	Lower than mercury	Lowest of HID types	Low

LIGHTING CONTROLS:-

A lighting control system is an intelligent network based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems serve to provide the right amount of light where and when it is needed.

Lighting control systems are employed to maximize the energy savings from the lighting system, satisfy building codes, or comply with green building and energy conservation programs. Lighting control systems are often referred to under the term Smart Lighting.

Lighting controls offer the ability for systems to be turned ON and OFF either manually or automatically. There are several control technology upgrades for lighting systems, ranging from simple (installing manual switches in proper locations) to sophisticated (installing occupancy sensors).

The term **lighting controls** is typically used to indicate stand-alone control of the lighting within a space. This may include occupancy sensors, time clocks, and photocells that are hard-wired to control fixed groups of lights independently. Adjustment occurs manually at each devices location.

The term **lighting control system** refers to an intelligent networked system of devices related to lighting control. These devices may include relays, occupancy sensors, photocells, light control switches or touch screens, and signals from other building systems (such as fire alarm of HVAC). Adjustment of the system occurs both at device locations and through and at central computer locations via software programs or other interface devices.

Switches:-

The standard manual, single-pole switch was the first energy conservation device. It is also the simplest device and provides the least options. One negative aspect about manual switches is that people often forget to turn them OFF. If switches are far from room exits or are difficult to find, occupants are more likely to leave lights ON when exiting a room. Occupants do not want to walk through darkness to find exits. However, if switches are located in the right locations, with multiple points of control for a single circuit, occupants find it easier to turn systems OFF. Once occupants get in the habit of turning lights OFF upon exit, more complex systems may not be necessary. The point is: switches can be great energy conservation devices as long as they are convenient to use them.

Time Clocks:-

Time clocks can be used to control lights when their operation is based on a fixed operating schedule. Time clocks are available in electronic or mechanical styles. However, regular check-ups are needed to ensure that the time clock is controlling the system properly. After a power loss, electronic timers without battery backups can get off schedule—cycling ON and OFF at the wrong times. It requires a great deal of maintenance time to reset isolated time clocks if many are installed.

LIGHTING ENERGY AUDIT:-

Assess opportunities for increasing lighting energy:-

a) Turn off lights in unoccupied areas.

1) Post reminder stickers to turn off lights when leaving the area.
2) Install time switches or occupancy sensors in areas of brief occupancy and remote areas (warehouses, storage areas, etc.).
3) Rewire switches so that one switch does not control all fixtures for multiple work areas.
4) Ensure wall-switch timers function properly.

b) Determine if existing lighting levels are higher than recommended levels.

Use a light meter to measure light levels and consult the Illuminating Engineering Society of North America (IESNA) illumination standards.

1) Reduce lighting levels where appropriate.
2) Reduce lighting hours.
3) Employ uniform or task delamping to reduce power and lighting.

c) Review outside lighting needs.

1) Eliminate outdoor lighting where possible and where safety and security are not compromised.
2) Replace exterior incandescent lights with more efficiency lights such as high pressure sodium (HPS) or metal halide (MH).
3) Replace burned out lamps with lower wattage lamps.

d) Remove unneeded lamps (delamp).

e) Install more efficient lighting.

f) Employ more effective lighting settings.

g) Follow a regular a maintenance schedule.

h) Upgrade exit signs with the help of an expert.

i) Use day lighting effectively.

j) Remove unnecessary lighting in beverage machines.

k) Train staff, especially housekeeping staff, on lighting policies/efficiency.

Top reasons to audit your lighting system:-

1) To save energy and money with existing equipment by using new light control strategies.
2) To improve your facility's image — go green.
3) To enhance your facility's atmosphere for occupants with added comfort, safety, and productivity.
4) Because lighting uses 39% of electricity in office buildings (EIA Commercial Buildings Energy Consumption Survey, 2003 data, released in 2008).
5) Because you know that older equipment needs to be replaced with more energy efficient Products.
6) Because, sometimes, simple operational changes can impact energy savings dramatically.
7) To re-optimize system operation after facility changes.

ENERGY AUDIT INSTRUMENTS:-

The requirement for an energy audit such as identification and quantification of energy necessitates various measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive.

The parameters generally monitored during the energy audit may include the following :

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

Parameters of importance other than electrical such as temperature and heat flow, radiation, air and gas flow, liquid flow, revolutions per minute, air velocity, noise and vibration, dust concentration, total dissolved solids, pH, moisture content, relative humidity, flue gas analysis – CO_2, O_2, CO, SO_X, NO_X, combustion efficiency etc.

Typical instruments used in energy audits:

The below are some of the typical instruments utilized depending on the process or system being audited. The operating instructions for all instruments must be understood and staff should familiarize themselves with the instruments and their operation prior to actual audit use.

Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument type are:

1. *Flow/Velocity*: Orifice plate, picot tube, Ventura tube, turbine meter, vortex shedding flow meter, ultrasonic flow meter.
2. *Temperature*: Thermometers – Bimetallic, Resistance etc., Thermocouple, Radiation pyrometer.
3. *Pressure*: Bourdon gauge, Diaphragm gauge, manometers
4. *Stack Gas Analysis*: Orsat apparatus, Oxygen analyzers, carbon dioxide analyzers, Carbon monoxide analyzers.
5. *Heat Flow*: Thermograph equipment
6. *Electrical*: Multi-meter, Ammeter, Wattmeter, Power Factor meter, Light meter
7. *Stream Trap Testing*: Stethoscope, Ultrasonic Detector

Analyses, evaluation and interpretation of data lead to identification of various measures that would save energy. These measures are then evaluated with regard to their technical and economic feasibility resulting in recommendations for further action.

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 stopping the motor.

Instantaneous measurements can be taken with hand-held meters, while more advanced models facilitate cumulative readings with printouts at desired intervals.

Ammeter: it measures the current absorbed by appliances and motors.

Voltmeter: it measures the voltage or voltage drop in the grid or electrical circuits.

Watt-meter: it measures instant power demand of appliances/motors or the power performance of generators.

Cosϕ-meter: it measures the power factor or monitors the rectification devices.

Multi-meter: it measures all the above quantities.

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.

All the above instruments are usually portable. They are connected to the wiring with the use of nippers and they could feature a data-logger. Measurements of electrical power and energy consumption should be made on all energy intensive areas and installations.

Since these instruments are generally not expensive, it is advised to examine their permanent installation in some of the above cases.

During the measurement of all the above quantities, a strict distinction must be made between the total power (metered in kVA) and the active power (usually metered in kW), as well as of Cosϕ.

Care is also needed with electrical loads that are not expected to present a sinusoidal waveform, as is the case with variable speed motors and UPS. Usual measuring instrumentation is based on a sinusoidal waveform, which gives wrong readings. In such cases, the use of meters measuring real RMS (Root Mean Square) values is necessary.

The function of such meters is based on digital sampling, so they could be substituted with PC-based meters.

Thermometers:-

Contact thermometer: These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.

Infrared Thermometer: This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.

Lux Meter:-

Illumination levels are measured with a lux meter. It consists of a photo cell that senses the light output, converting it to electrical impulses that are calibrated as lux and indicated by a digital meter.

Data logger:-

A **data logger** (also **data logger** or **data recorder**) is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor (or computer). They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors. Some data loggers interface with a personal computer and utilize software to activate the data logger and view and analyze the collected data, while others have a local interface device (keypad, LCD) and can be used as a stand-alone device.

Pyrometer:-

A **pyrometer** is a non-contacting device that intercepts and measures thermal radiation, a process known as pyrometer. This device can be used to determine the temperature of an object's surface.

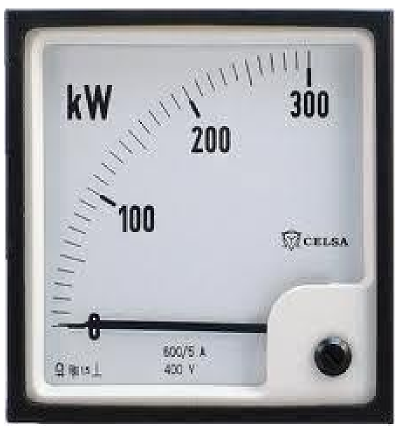
A pyrometer has an optical system and a detector. The optical system focuses the thermal radiation onto the detector. The output signal of the detector (temperature *T*) is related to the thermal radiation or irradiance j^* of the target object through the Stefan–Boltzmann law, the constant of proportionality σ, called the Stefan-Boltzmann constant and the emissivity ε of the object.

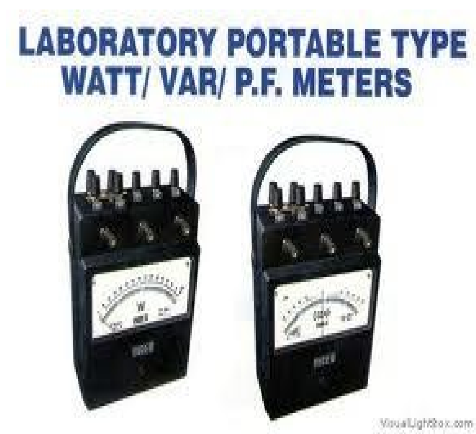
$$j^{\star} = \varepsilon \sigma T^4$$

This output is used to infer the object's temperature. Thus, there is no need for direct contact between the pyrometer and the object, as there is with thermocouples and resistance temperature detectors (RTDs).

Wattmeter:-

The **wattmeter** is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeter are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements.





Thermocouples:-

They are widely used and are not expensive. They cover a wide range of temperatures, from a few degrees up to 1000^0C and are usually portable. They need frequent calibration with specialized instruments. Their main disadvantage is that they have a weak signal, easily affected by industrial noise.

APPLICATIONS OF PLC'S:-

Power line communication (PLC):-

Power line communication (PLC) carries data on a conductor that is also used simultaneously for AC electric power transmission or electric power distribution to consumers. It is also known as power line carrier, power line digital subscriber line (PDSL), mains communication, power line telecom (PLT), power line networking (PLN), and broadband over power lines(BPL).

A wide range of power line communication technologies are needed for different applications, ranging from home automation to Internet access. Most PLC technologies limit themselves to one type of wires (such as premises wiring within a single building), but some can cross between two levels (for example, both the distribution network and premises wiring). Typically transformers prevent propagating the signal, which requires multiple technologies to form very large networks. Various data rates and frequencies are used in different situations.

A number of difficult technical problems are common between wireless and power line communication, notably those of spread spectrum radio signals operating in a crowded environment. Radio interference, for example, has long been a concern of amateur radio groups.

Power line communications systems operate by adding a modulated carrier signal to the wiring system. Different types of power line communications use different frequency bands. Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power line communications.

The main issue determining the frequencies of power line communication is laws to limit interference with radio services. Many nations regulate unshielded wired emissions as if they were radio transmitters. These jurisdictions usually require unlicensed uses to be below 500 KHz or in unlicensed radio bands. Some jurisdictions (such as the EU), regulate wire-line transmissions further. The U.S. is a notable exception, permitting limited-power wide-band signals to be injected into unshielded wiring, as long as the wiring is not designed to propagate radio waves in free space.

Data rates and distance limits vary widely over many power line communication standards. Low-frequency (about 100–200 kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second; however, these circuits may be many miles long. Higher data rates generally imply shorter ranges; a local area network operating at millions of bits per second may only cover one floor of an office building, but eliminates the need for installation of dedicated network cabling.

Programmable logic controller:-

A programmable logic controller, commonly known as PLC, is a solid state, digital, industrial computer using integrated circuits instead of electromechanical devices to implement control functions. It was invented in order to replace the sequential circuits which were mainly used for machine control. They are capable of storing instructions, such as sequencing, timing, counting, arithmetic, data manipulation and communication, to control machines and processes.

According to NEMA (National Electrical Manufacture‘s Association, USA), the definition of PLC has been given as,

–Digital electronic devices that uses a programmable memory to store instructions and to Implement specific functions such as logic , sequencing, timing, counting, and arithmetic to control machines and processes.‖

PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

Some of PLC applications are,

- Equipment Status
- Process Control
- Chemical Processing
- Equipment Interlocks
- Machine Protection
- Smoke Detection
- Gas Monitoring
- Envelope Monitoring
- Personnel Safety
- High-precision Synchronized Control in Crimping Equipment using PLC
- Bottle Filling Control using PLC
- High-speed Sorting on Conveyors using PLC
- Image-processing Inspection of Electronic Components using PLC
- Shopping Mall Fountain Control using PLC
- Air Cleaner Control using PLC

- Sheet Feeding Control in Packing Machine using PLC
- Testing Equipment
- Warming Moulding Machines
- Annunciator
- Lighting Pattern Control
- Escalator with Automatic Operation Function
- Drilling PCBs with High-speed, High-precision Positioning
- Hydraulic Pressure Control in Forming Machine
- Temperature Cascade Control in Industrial Furnace
- Production Control System

	Narrowband PLC	**Broadband PLC**
Data rate	Up to 200kbps	Over 1Mbps
Frequency	Up to 500kHz	Over 2MHz
Modulation	FSK, S-FSK, BPSK, SS, OFDM	OFDM
Applications	Building Automation Renewable Energy Advanced Metering Street Lighting Electric Vehicle Smart Grid	Internet HDTV Audio Gaming
Providers	Ariane Controls Cypress Echelon Maxim ST Microelectronics Texas Instruments Yitran	Atheros Broadcom Lantiq Marvell Maxim Sigma

MODULE – V

ECONOMIC ASPECTS AND ANALYSIS

ECONOMICS ANALYSIS:-

Energy economics is a broad scientific subject area which includes topics related to supply and use of energy in societies. Due to diversity of issues and methods applied and shared with a number of academic disciplines, energy economics does not present itself as a self-contained academic discipline, but it is an applied sub discipline of economics.

From the list of main topics of economics, some relate strongly to energy economics:

- Econometrics
- Environmental economics
- Finance
- Industrial organization
- Microeconomics
- Macroeconomics
- Resource economics

Energy economics also draws heavily on results of energy engineering, geology, political sciences, ecology etc. Recent focus of energy economics includes the following issues:

- Climate change and climate policy
- Risk analysis and security of supply
- Sustainability
- Energy markets and electricity markets - liberalization, (de- or re-) regulation
- Demand response
- Energy and economic growth
- Economics of energy infrastructure
- Environmental policy
- Energy policy
- Energy derivatives
- Forecasting energy demand
- Elasticity of supply and demand in energy market
- Energy elasticity

DEPRECIATION:-

Depreciation refers to two aspects of the same concept:

- The decrease in value of assets (fair value depreciation), and
- The allocation of the cost of assets to periods in which the assets are used (depreciation with the matching principle).

Depreciation is a fixed cost; it represents the loss of value of an asset. This loss may be the result of physical wear and tear, chemical degradation or economic or technological obsolescence. Since depreciation is the time dependent, it is normally expressed as a rate.

The energy equipment will normally depreciate even if the plant is shut down. The four main methods used to calculate or express depreciation are,

Straight-line Depreciation

Sum-of-Years Digits

Declining-Balance Depreciation

7.2.4) Sinking Fund Depreciation

Straight-line Depreciation:-

The straight line method assumes that the annual depreciation is constant throughout the service; the simplest method is referred to as a straight-line depreciation and is defined as

$$D = \frac{P - L}{n}$$

Where, **D** is the annual depreciation rate.

L is the value of equipment at the end of its useful life, commonly referred to as salvage value.

P is the initial expenditure.

n is the life of the equipment which is determined by Internal Revenue Service guidelines.

(or)

Straight-line depreciation is the simplest and most often used method. In this method, the company estimates the salvage value of the asset at the end of the period during which it will be used to generate revenues (useful life).

The salvage value is an estimate of the value of the asset at the time it will be sold or disposed of; it may be zero or even negative. Salvage value is also known as scrap value or residual value. The company will then charge the same amount to depreciation each year over that period, until the value shown for the a set has reduced from the original cost to the salvage value.

$$\text{Annual Depreciation Expense} = \frac{\text{Cost of Fixed Asset} - \text{Residual Value}}{\text{Useful Life of Asset}(years)}$$

Sum-of-Years Digits:-

The sum of the year‘s digits, like the declining balance method, results in a faster _write off‘ during the earlier years of service and has the advantage of being applicable even when the salvage or junk value is zero.

Another method is referred to as the sum-of-years digits. In this method the depreciation rate is determined by finding the sum of digits using the following formula:

$$N = n \quad \frac{n+1}{2}$$

Where n is the life of equipment.

Each year‘s depreciation rate is determined as follows:

First year	$D = \frac{n}{N} \quad (P - L)$
Second year	$D = \frac{n-1}{N} \quad (P - L)$
n year	$D = \frac{1}{N} \quad (P - L)$

Declining-Balance Depreciation:-

The declining balance method, results in a more rapid _write off‘ during the earlier years of service. This assumes depreciation to be a fixed fraction of the residual asset value.

The declining-balance method allows for larger depreciation charges in the early year, which is sometimes referred to as fast write-off. The rate is calculated by taking a constant percentage of the declining undepreciated balance. The most common method used to calculate the declining balance is to predetermine the depreciation rate. Under certain circumstances a rate equal to 200% of the straight-line depreciation rate may be used. Under other circumstances the rate is limited to 1-1/2 or 1-1 /4 times as great as straight-line depreciation. In this method the salvage value or undepreciated book value is established once the depreciation rate is pre-established.

To calculate the undepreciated book value, Formula is used:

$$D = 1 - \left(\frac{L}{P}\right)^{1/N}$$

Where

D is the annual depreciation rate.

L is the salvage value.

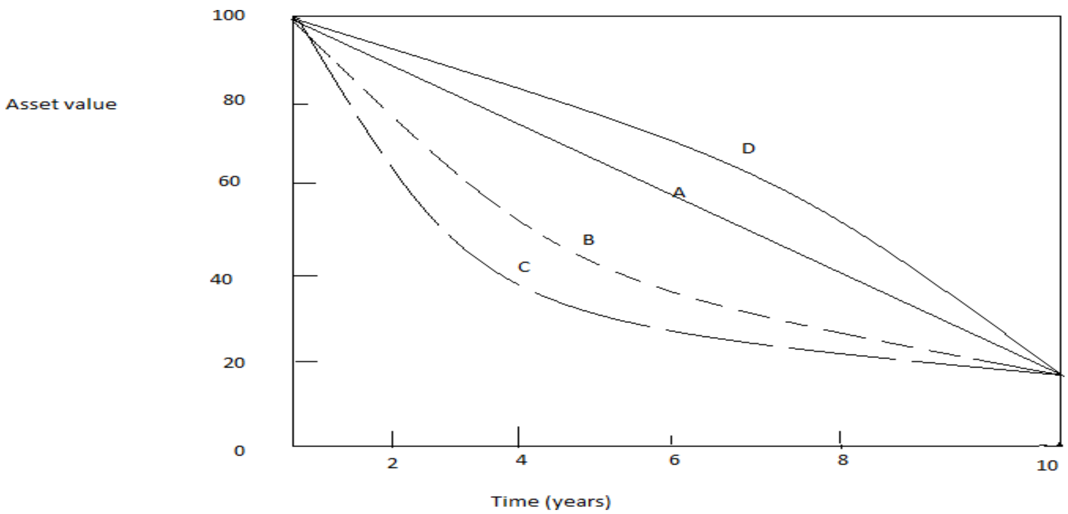
P is the first cost.

Sinking Fund Depreciation:-

In the sinking fund method, it is assumed that the annual depreciation is invested each year at a given rate of interest. At the end of the service life, the accrued interest must equal the total depreciation.

$$d = (P - L)\frac{i}{(1+i)^n - 1}$$

The figure compares the four methods of calculating depreciation for an asset having a service life of 10 years.



A) Straight-line Depreciation, B) Sum-of-Years Digits, C) Declining-Balance Depreciation D) Sinking Fund Depreciation

Tax depreciation:-

Most income tax systems allow a tax deduction for recovery of the cost of assets used in a business or for the production of income. Such deductions are allowed for individuals and companies. Where the assets are consumed currently, the cost may be deducted currently as an expense or treated as part of cost of goods sold. The cost of assets not currently consumed generally must be deferred and recovered over time, such as through depreciation. Some systems permit full deduction of the cost, at least in part, in the year the assets are acquired. Other systems allow depreciation expense over some life using some depreciation method or percentage. Rules vary highly by country, and may vary within a country based on type of asset or type of taxpayer. Many systems that specify depreciation lives and methods for financial reporting require the same lives and methods be used for tax purposes. Most tax systems provide different rules for real property (buildings, etc.) and personal property (equipment, etc.).

THE TIME VALUE OF MONEY CONCEPT:-

To compare energy utilization alternatives, it is necessary to convert all cash flow for each measure to an equivalent base. The life-cycle cost analysis takes into account the ‖time value‖ of money; thus a dollar in hand today is more valuable than one received at some time in the future. This is why a time value must be placed on all cash flows into and out of the company.

Money has time value. A rupee today is more valuable than a year hence. It is on this concept –the time value of money‖ is based. The recognition of the time value of money and risk is extremely vital in financial decision making.

TECHNIQUES OF TIME VALUE OF MONEY (or) DEVELOPING CASH FLOW MODELS:-

There are two techniques for adjusting time value of money. They are:

1. Compounding Techniques/Future Value Techniques
2. Discounting/Present Value Techniques

The value of money at a future date with a given interest rate is called future value. Similarly, the worth of money today that is receivable or payable at a future date is called Present Value.

Compounding Techniques/Future Value Technique:-

In this concept, the interest earned on the initial principal amount becomes a part of the principal at the end of the compounding period.

FOR EXAMPLE: Suppose you invest 1000 Rs for three years in a saving account that pays 10 per cent interest per year. If you let your interest income be reinvested, your investment will grow as follows:

First year : Principal at the beginning Rs 1,000

Interest for the year (Rs 1,000 × 0.10) 100

Principal at the end Rs 1,100

Second year : Principal at the beginning Rs 1,100

Interest for the year (Rs 1,100 × 0.10) 110

Principal at the end Rs 1210

Third year : Principal at the beginning Rs 1210

Interest for the year (Rs 1210 × 0.10) 121

Principal at the end Rs 1331

This process of compounding will continue for an indefinite time period. The process of investing money as well as reinvesting interest earned there on is called *Compounding*. But the way it has gone about calculating the future value will prove to be cumbersome if the future value over long maturity periods of 20 years to 30 years is to be calculated. A generalized procedure for calculating the future value of a single amount compounded annually is as follows:

Formula: $FVn = PV(1 + r)n$

In this equation $(1 + r)n$ is called the future value interest factor (FVIF).

where, FVn = Future value of the initial flow n year hence

PV = Initial cash flow

r = Annual rate of Interest

n = number of years

By taking into consideration, the above example, we get the same result.

$FVn = PV\ (1 + r)n$

= 1,000 *(1.10)*3

$FVn = 1331$

FUTURE VALUE OF MULTIPLE CASH FLOWS is,

The transactions in real life are not limited to one. An investor investing money in installments may wish to know the value of his savings after _n‘ years. The formulae is\

$$FV_n = PV\left(1+\frac{r}{m}\right)$$

Where FVn = Future value after _n‘ years

PV = Present value of money today

r = Interest rate, m = Number of times compounding is done in a year.

The formulae to calculate the Effective Interest Rate is

$$EIR = \left(1+\frac{r}{m}\right)^m - 1$$

Where EIR = Effective Rate of Interest

r = Nominal Rate of Interest (Yearly Interest Rate)

m = Frequency of compounding per year

DISCOUNTING OR PRESENT VALUE CONCEPT:-

Present value is the exact opposite of future value. The present value of a future cash inflow or outflow is the amount of current cash that is of equivalent value to the decision maker. The process of determining present value of a future payment or receipts or a series of future payments or receipts is called discounting.

The compound interest rate used for discounting cash flows is also called the discount rate. In the next chapter, we will discuss the net present value calculations. To calculate the present value as,

$$P = Fn (1+i)-n$$

The factor (1+i)-n is known as the single sum, present worth factor or the single payment, present worth factor. This factor is denoted (P|F,i,n) and is read ―to find P given F at i% for n years.‖

SIMPLE AND COMPOUND INTEREST

In compound interest, each interest payment is reinvested to earn further interest in future periods. However, if no interest is earned on interest, the investment earns only simple interest. In such a case, the investment grows as follows:

Future value = Present value [1 + Number of years × Interest rate]

For example, if Rs 1,000 is invested @ 12% simple interest, in 5 years it will become

➔ 1,000 [1 + 5 × 0.12] = Rs 1,600

INVESTMENT APPRAISAL TECHNIQUES:-

Investment appraisal methods divide into two groups:

1. Simple, easy to calculate methods. They are not very accurate or sensitive, but are good for screening out poor projects from a long list. All projects should be subjected to these tests. These screening tests are
   - ♥ **Payback period or Payback method**
   - ♥ **Average rate of return (ARR) or Rate of Return(RR) method**
2. Detailed and more accurate tests. If a project passes through the initial screening, then in larger businesses, which can afford the cost, the project may be it is subjected to more complex tests are based on discounted cash flow methods. They are:
   - ♥ **Discounted cash flow (DCF) or Internal Rate of Return(IRR) method**
   - ♥ **Net present value (NPV) method**

Rate of return method (RR):-

The Rate of return method is the ratio of the average annual savings to a projects capital investment, and is frequently called _return on capital invested‘.

(or)

The **average rate of return (ARR)**, or accounting rate of return, method of investment appraisal ***measures the annual income of a project as a percentage of the total investment cost***, which is something that simple payback does not do. This is a measure of average profit, and is expressed in a familiar percentage form. It is also a relatively straightforward method and the result can be compared with returns from alternative uses of funds and with the base bank interest rate.

Pay back method (PB):-

The payback method measures the time a project takes to generate a cash income equal to its capital value. The payback period or pay out time is the reciprocal of the rate of return.

(or)

Payback period is a method of investment appraisal that estimates the time period taken to recover the initial cash outlay on an investment. Although simplistic it is the most popular method of investment decision making.

Net present value (NPV):-

This method is based on discounted cash flow and the net present value of a future amount is the present capital which must be invested at a given interest rate to yield the desired amount at some future date. It means of comparing energy projects.

(or)

The Net Present Value (NPV) of a project is the return on the investment (the sum of the discounted cash flows) less the cost of the investment.

Internal rate of return or yield method (IRR):-

This is also a discounted cash flow (DCF) method and is the true compound interest on the capital tied up in the energy project.

(or)

Discounted cash flow (DCF) analysis is a method of valuing a project, company, or asset using the concepts of the *time value of money*. DCF is used to calculate the value of future cash flows in terms of an equivalent value today. All future cash flows are estimated and discounted to give their present values (PVs).

LIFE CYCLE COSTING ANALYSIS:-

Life-cycle cost analysis (LCCA) is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings.

For example, LCCA will help determine whether the incorporation of a high-performance HVAC or glazing system, which may increase initial cost but result in dramatically reduced operating and maintenance costs, is cost-effective or not. LCCA is not useful for budget allocation.

Lowest life-cycle cost (LCC) is the most straightforward and easy-to-interpret measure of economic evaluation. Some other commonly used measures are Net Savings (or Net Benefits), Savings-to-Investment Ratio (or Savings Benefit-to-Cost Ratio), Internal Rate of Return, and Payback Period.

They are consistent with the Lowest LCC measure of evaluation if they use the same parameters and length of study period. Building economists, certified value specialists, cost engineers, architects, quantity surveyors, operations researchers, and others might use any or several of these techniques to evaluate a project.

The approach to making cost-effective choices for building-related projects can be quite similar whether it is called **cost estimating, value engineering, or economic analysis.**

Life-cycle cost analysis (LCCA) is a method for evaluating all relevant costs over time of a project, product, or measure.

The LCC method takes into account first costs, including capital investment costs, purchase, and installation costs; future costs, including energy costs, operating costs, maintenance costs, capital replacement costs, financing costs; and any resale, salvage, or disposal cost, over the life-time of the project, product, or measure.

Life-Cycle Cost formula:-

To find the total LCC of a project, sum the present values of each kind of cost and subtract the present values of any positive cash flows such as a resale value. Thus, the following formula applies:

Life-cycle cost = first cost + maintenance and repair + energy + water+ Replacement - salvage value,

Where all dollar amounts are converted to present values by discounting.

(or)

After identifying all costs by year and amount and discounting them to present value, they are added to arrive at total life-cycle costs for each alternative:

$$LCC = I + Repl - Res + E + W + OM\&R + O$$

where,

LCC = Total LCC in present-value (PV) dollars of a given alternative

I = PV investment costs (if incurred at base date, they need not be discounted)

Repl = PV capital replacement costs

Res = PV residual value (resale value, salvage value) less disposal costs

E = PV of energy costs

W = PV of water costs

OM&R = PV of non-fuel operating, maintenance and repair costs

O = PV of other costs (e.g., contract costs for ESPCs or UESCs)

LCCA process:-

LCCA should be conducted as early in the project development cycle as possible. The level of detail in the analysis should be consistent with the level of investment.

Basically, the process involves the following steps:

1) Develop rehabilitation and maintenance strategies for the analysis period
2) Establish the timing (or expected life) of various rehabilitation and maintenance strategies
3) Estimate the agency costs for construction, rehabilitation, and maintenance
4) Estimate user and non-user costs
5) Develop expenditure streams
6) Compute the present value
7) Analyze the results using either a deterministic or probabilistic approach
8) Reevaluate strategies and develop new ones as needed

<u>CALCULATION OF SIMPLE PAYBACK METHOD:-</u>

The payback period can also be calculated without using the cumulative method by the following formula:

$$\frac{\textit{Initial investment}}{\textit{Contribution per month (revenue less variable cost)}}$$

Example:-

Initial investment = 3000

monthly contribution = 300

Payback is 9000/300 = 30 months or 2 years 6 months

Benefits of payback method

- Easy to calculate and understand
- Includes the cost of the investment
- Focuses on short-term cash flow and is appropriate for equipment with a relatively short life

Limitations of payback period

- Not a measure of profit.
- Ignores all cash flows after the payback point.
- Ignores the pattern of cash flow.
- Ignores the 'time value' of money.
- Encourages a short-term view of investment

CALCULATION OF AVERAGE RATE OF RETURN (ARR):-

The ARR measures the net return each year as a percentage of the initial cost of the investment.

$$average\ rate\ of\ return = \frac{net\ return\ (profit\ )\ per\ annum}{capital\ \ outlay} * 100$$

EXAMPLE: Three projects have the following costs and expected income:

		Project A ($)	Project B ($)	Project C ($)
Cost		50,000	40,000	90,000
Return				
	Yr 1	10,000	10,000	20,000
	Yr 2	10,000	10,000	20,000
	Yr 3	15,000	10,000	30,000
	Yr 4	15,000	15,000	30,000
	Yr 5	20,000	15,000	30,000
Total		70,000	60,000	130,000

STEP 1. Calculate the total net profit from each project by subtracting the total return of the project from its cost.

$i.e. \$70,000 - \$50,000 = \$20,000 \; for \, project \, A$

STEP 2. Calculate the net profit per annum by dividing the total net profit by the number of years the project runs for.

$i.e. \frac{\$20,000}{\$5,000} = \$4,000 \; for \; project \; A$

STEP 3. Calculate the ARR using the following formula:

$$ARR\ (project\ A) = \frac{\$4,000}{\$50,000} \times 100 = 8\%$$

Benefits of ARR

- ♥ Measures profitability
- ♥ Uses all the cash flows
- ♥ Easy to understand
- ♥ Easy to compare percentage returns with other investment opportunities

Limitations of ARR

- ♥ Ignores the pattern of cash flow - when they occur
- ♥ Later cash flows are unlikely to be accurate as they are longer term forecasts
- ♥ The length of the project or the life span of a machine maybe an estimate
- ♥ Ignores the timing of cash flows
- ♥ Ignores the 'time value' of money
- ♥ Ignores the risk factors associated with a long payback period on liquidity

CALCULATION OF NET PRESENT VALUE METHOD:-

An investment project costing $100,000 yields an expected stream of income over a three year period of:

Year 1 - $30,000

Year 2 - $40,000

Year 3 - $50,000

If the interest rate is 10%, the discount values (present values) can be calculated using the technique below:

$$\text{Present value} = \frac{\$30{,}000}{(1+0.1)^1} + \frac{\$40{,}000}{(1+0.1)^2} + \frac{\$50{,}000}{(1+0.1)^3}$$

$$\text{Present value} = \frac{\$30{,}000}{(1.1)^1} + \frac{\$40{,}000}{(1.1)^2} + \frac{\$50{,}000}{(1.1)^3}$$

$$\text{Present value} = \frac{\$30{,}000}{1.1} + \frac{\$40{,}000}{1.21} + \frac{\$50{,}000}{1.331}$$ (you may recognize these numbers!)

Present value = $27,272 + $33,057 + $37,565 = **<u>$97,894</u>**

The above project is not viable since the present value of the return of $97,894 is less than the cost of the project of $100,000.

Present value of return	-	Cost of the investment	=	NPV
$97,894	-	$100,000	=	- $2,106

Benefits of Discounting/NPV

- ♥ Considers all cash flows
- ♥ Accounts for the time value of money and therefore considers the opportunity cost
- ♥ It is more scientific than the other methods

Limitations of NPV

- ♥ Complex to calculate
- ♥ Only as good as the original data. If the estimates of cost or net cash inflows are wrong, so will be the NPV
- ♥ The selection of the discount factor is crucial, but it is mostly guesswork as this rate is constantly changing
- ♥ NPV's look deceptively accurate
- ♥ Ignores all and any non-financial factors.

APPLICATIONS OF LIFE CYCLE COSTING ANALYSIS:-

LCCA can be applied to any capital investment decision in which relatively higher initial costs are traded for reduced future cost obligations. It is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance but may have different initial investment costs, different operating and maintenance and repair costs, and possibly different lives.

LCCA provides a significantly better assessment of the long-term cost-effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run.

LCCA can be performed at various levels of complexity. Its scope might vary from a "back-of-the-envelope" study to a detailed analysis with thoroughly researched input data, supplementary measures of economic evaluation, complex uncertainty assessment, and extensive documentation. The extensiveness of the effort should be tailored to the needs of the project.

COST EFFECTIVENESS TEST FOR DEMAND SIDE MANAGEMENT PROGRAMS

Cost-effectiveness in its simplest form is a measure of whether an investment‘s benefits exceed its costs. Key differences among the cost-effectiveness tests that are currently used include the following:

• **The stakeholder perspective of the test.** Is it from the perspective of an energy efficiency program participant, the organization offering the energy efficiency program, a non-participating ratepayer, or society in general? Each of these perspectives represents a valid viewpoint and has a role in assessing energy efficiency programs.

• **The key elements included in the costs and the benefits.** Do they reflect avoided energy use, incentives for energy efficiency, avoided need for new generation and new transmission and distribution, and avoided environmental impacts?

• **The baseline against which the cost and benefits are measured.** What costs and benefits would have been realized absent investment in energy efficiency?

The five cost-effectiveness tests commonly used across the country are listed below:

• Participant cost test (PCT).
• Program administrator cost test (PACT).
• Ratepayer impact measure test (RIM).
• Total resource cost test (TRC).

PARTICIPANT COST TEST

The PCT examines the costs and benefits from the perspective of the customer installing the energy efficiency measure (homeowner, business, etc.). Costs include the incremental costs of purchasing and installing the efficient equipment, above the cost of standard equipment, that are borne by the customer. The benefits include bill savings realized to the customer through reduced energy consumption and the incentives received by the customer, including any applicable tax credits. Table outlines the benefits and costs included in the PCT. In some cases the NPV of incremental operations and maintenance costs (or savings) may also be included. The primary use of the PCT is to assess the appeal of an energy efficiency measure to potential participants. The higher the PCT, the stronger the economic incentive to participate. The PCT functions similarly to a simple payback calculation, which determines how many years it takes to recover the costs of purchasing and installing a device through bill savings.

Benefits and Costs from the Perspective of the Customer Installing the Measure	
Benefits	**Costs**
▪ Incentive payments ▪ Bill savings realized ▪ Applicable tax credits or incentives	▪ Incremental equipment costs ▪ Incremental installation costs

The PCT also provides useful information for designing appropriate customer incentive levels. A high incentive level will produce a high PCT benefit-cost ratio, but reduce the PACT and RIM results. This is because incentives given to customers are seen as ―costs‖ to the utility. The PCT, PACT, and RIM register incentive payments in different ways based on their perspective. Utilities must balance the participant payback with the goal of also minimizing costs to the utility and ratepayers.

PROGRAM ADMINISTRATOR COST TEST

The PACT examines the costs and benefits of the energy efficiency program from the perspective of the entity implementing the program (utility, government agency, nonprofit, or other third party). The costs included in the PACT include overhead and incentive costs. Overhead costs are administration, marketing, research and development, evaluation, and measurement and verification. Incentive costs are payments made to the customers to offset purchase or installations costs (mentioned earlier in the PCT as benefits). The benefits from the utility perspective are the savings derived from not delivering the energy to customers. Depending on the jurisdiction and type of utility, the ―avoided costs‖ can include reduced wholesale electricity or natural gas purchases, generation costs, power plant construction, transmission and distribution facilities, ancillary service and system operating costs, and other components.

Benefits and Costs to the Utility, Government Agency, or Third Party Implementing the Program	
Benefits	**Costs**
▪ Energy-related costs avoided by the utility ▪ Capacity-related costs avoided by the utility, including generation, transmission, and distribution	▪ Program overhead costs ▪ Utility/program administrator incentive costs ▪ Utility/program administrator installation costs

The PACT allows utilities to evaluate costs and benefits of energy efficiency programs (and/or demand response and distributed generation) on a comparable basis with supply-side investments. A positive PACT indicates that energy efficiency programs are lower-cost approaches to meeting load growth than wholesale energy purchases and new generation resources (including delivery and system costs). States with large needs for new supply resources may emphasize the PACT to build efficiency alternatives into procurement planning.

RATEPAYER IMPACT MEASURE

The RIM examines the impact of energy efficiency programs on utility rates. Unlike typical supply-side investments, energy efficiency programs reduce energy sales. Reduced energy sales can lower revenues and put upward pressure on retail rates as the remaining fixed costs are spread over fewer kWh. The costs included in the RIM are program overhead and incentive payments and the cost of lost revenues due to reduced sales. The benefits included in the RIM are the avoided costs of energy saved through the efficiency measure (same as the PACT). Table outlines the benefits and costs included in the RIM.

Benefits and Costs to Ratepayers Overall; Would Rates Need to Increase?	
Benefits	**Costs**
▪ Energy-related costs avoided by the utility ▪ Capacity-related costs avoided by the utility, including generation, transmission, and distribution	▪ Program overhead costs ▪ Utility/program administrator incentive costs ▪ Utility/program administrator installation costs ▪ Lost revenue due to reduced energy bills

The RIM also gives an indication of the distributional impacts of efficiency programs on non-participants. Participants may see net benefits (by lowering their bills through reduced energy consumption) while non-participating customers may experience rate increases due to the same programs. As the impacts on non-participating customers depend on many factors including the timing of adjustments to rates, the RIM is only an approximation of these impacts.

TOTAL RESOURCE COST TEST

The TRC measures the net benefits of the energy efficiency program for the region as a whole. Costs included in the TRC are costs to purchase and install the energy efficiency measure and overhead costs of running the energy efficiency program. The benefits included are the avoided costs of energy (as with the PACT and the RIM).

Benefits and Costs from the Perspective of All Utility Customers (Participants and Non-Participants) in the Utility Service Territory	
Benefits	**Costs**
▪ Energy-related costs avoided by the utility ▪ Capacity-related costs avoided by the utility, including generation, transmission, and distribution ▪ Additional resource savings (e.g., gas and water if utility is electric) ▪ Monetized environmental and non-energy benefits (see Section 4.9) ▪ Applicable tax credits (see text)	▪ Program overhead costs ▪ Program installation costs ▪ Incremental measure costs (whether paid by the customer or the utility)

The primary purpose of the TRC is to evaluate the net benefits of energy efficiency measures to the region as a whole. Unlike the tests describe above, the TRC does not take the view of individual stakeholders. It does not include bill savings and incentive payments, as they yield an intra-regional transfer of zero (–benefits‖ to customers and –costs‖ to the utility that cancel each other on a regional level). For some utilities, the region considered may be limited strictly to its own service territory, ignoring benefits (and costs) to neighboring areas (a distribution-only utility may, for example, consider only the impacts to its distribution system). In other cases, the region is defined as the state as a whole, allowing the TRC to include benefits to other stakeholders (e.g., other utilities, water utilities, local communities). The TRC is useful for jurisdictions wishing to value energy efficiency as a resource not just for the utility, but for the entire region. Thus the TRC is often the primary test considered by those states seeking to include the benefits not just to the utility and its ratepayers, but to other constituents as well. The TRC may be considered the sum of the PCT and RIM, that is, the participant and non-participant cost-effectiveness tests. The TRC is also useful when energy efficiency might fall through the cracks taken from the perspective of individual stakeholders, but would yield benefits on a wider regional level.

IMPORTANCE OF EVALUATION

The content of a program evaluation can cover many aspects, for instance, market needs assessments, process evaluations, retrospective outcome/impact assessments, and cost-benefit evaluations. These types of evaluation studies help managers determine if timely adjustments are needed in program design or implementation to improve the rate, or quality of achievements relative to the committed resources. Program evaluations are in-depth studies of program performance and customer needs. They can be used to produce information about the linkage between program performance and resources and about how to improve performance.

The benefits of conducting an evaluation are numerous. For example,

1) They can help to estimate how well the program is achieving its intended objectives

2) They help to improve the program development and implementation

3) They quantify results and cost-effectiveness, as necessary, to help better communicate the value of the program.

Some key definitions are described below:

PROGRAM: A project or group of projects with similar characteristics and installed in similar applications, where multi-faceted effects are observed and evaluated.

EVALUATION: The performance of studies and activities aimed at determining the effects of a program; any of a wide range of assessment activities associated with understanding or documenting program performance, assessing program or program-related markets and market operations; any of a wide range of evaluative efforts including assessing program-induced changes in energy efficiency markets, levels of demand or energy savings, environmental impacts, social and economic impacts and program cost-effectiveness.

PROGRAM EVALUATIONS: Program evaluations are systematic and objective studies, conducted periodically or on an ad hoc basis, to assess how well a program is achieving its intended goals. These evaluations have a retrospective focus, with a view to assessing past performance and developing recommendations for improvements, with an exception of the evaluations of market needs that can have a current or prospective focus. Some evaluations usually require certain level of details in data collection and analytical methodology that goes beyond routine performance-monitoring reporting. This helps the decision makers determine what kinds of timely adjustments may be needed in program design or implementation to improve the rate or quality of achievement relative to the committed resources. It is not necessary to have in-depth familiarity with these methods to benefit from a general program evaluation, but program managers need to have enough familiarity to select and monitor an evaluation contractor who will make decisions about evaluation methodologies.

MEASUREMENT AND VERIFICATION OF DEMAND SIDE MANAGEMENT PROGRAMS

Energy efficient demand side management (EEDSM) programs are developed by contracted energy analysts, or the so-called Energy Service Companies (ESCos). As the customer contracted program developer, an ESCo needs to make thorough investigation and comes up with a feasible EEDSM program. The ESCo often claims certain impact from the implementation of this EEDSM program. According to the evaluation criteria in the previous section, the ESCo can develop the program and thus claim the relevant engineering, environmental, social, and economic impacts of the program. Both the customer and ESCo want to know if these claimed impacts have been achieved after implementation, therefore, as an independent third party, the M&V team will help further to measure and verify these claimed impacts.

The M&V process for the EEDSM program is similar to usual energy saving M&V process in as explained below.

1) This program evaluation guideline document is distributed to ESCos or any other program developer. The M&V team will award a final mark to each EEDSM program at the end of the evaluation.

2) The ESCo will develop an EEDSM program from all the engineering, environmental, social, and economic aspects; then the ESCo claims the corresponding impact of the program on each evaluating factor, where the impact of each evaluating factor is claimed in either a quantitative way or a qualitative way. Examples for quantitative achievements include the exact amount of energy saving to be achieved, the number of jobs created each year, the reduced amount greenhouse gas emission, etc. Examples for qualitative achievements can be statements on how the program is aligned with national economic strategic positioning, why the program is compatible with local participation, etc.

3) The ESCo submits the M&V request to the M&V governing body (e.g. ESKOM Energy Audit), then the governing body will allocate this request to an M&V team.

4) The M&V team prepares the scoping report to describe the overall program after the necessary communication with the ESCo and customer.

5) The M&V team prepares the M&V plan report which needs the sign off from both the ESCo and the client. This M&V plan includes not only key parameters to be monitored, metering plan, but also the evaluating and marking criteria. The agreement among the ESCo, the customer, and the M&V team must be reached on the evaluating and marking criteria. For example, the three parties need to determine which factors need to be evaluated and the

corresponding weight that each factor occupies in the total mark; the percentages of crediting/debiting marks awarded for over/under performing; etc.

6) The M&V team issues the baseline report according to the M&V plan, this baseline report needs also the agreement from both the ESCo and the client. The baseline report is based on the data and information collected from the project sites before the implementation of the EEDSM program. Meters need to be installed to quantify baseline information in engineering indicators, and surveys and site visit will be performed to confirm other quantitative and qualitative baselines (or baseline marks) for other evaluation indicators. A baseline information or baseline mark will be given for the existing situation within the project boundary.

7) The EEDSM is implemented, and the M&V team issues the post implementation certificate to confirm the implementation.

8) The M&V team issues the performance assessment report to evaluate if the claimed impact has been achieved. Usually this performance assessment will be issued at least once and usually three times. A mark will be awarded to the assessed project in each assessment report. The success of a program will depend on if the post-implementation mark is higher than the baseline mark. Baseline mark adjustment might be needed if necessary. The principle for baseline mark adjustment is the same as the energy saving baseline adjustment principle.

9) The M&V team will issue a series of performance tracking reports to continuously monitor the impact from the implementation of the program after the performance assessment reporting period. Details on the frequency and the number of performance tracking reports can be determined by the needs of the customer and ESCo.