SYLLABUS

Energy and Environment			
[AS PER CHOICE BASED CREDIT SYSTEM (CBCS) SCHEME) (EFFECTIVE FROM THE ACADEMIC YEAR 2016 - 2017)			
Subject Code	15ME562	IA Marks	20
Number of Lecture Hours/Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

MODULE 1

Basic Introduction to Energy : Energy and power, forms of energy, primary energy sources, energy flows, world energy production and consumption, Key energy trends in India: Demand, Electricity, Access to modern energy, Energy production and trade, Factors affecting India's energy development: Economy and demographics Policy and institutional framework, Energy prices and affordability, Social and environmental aspects, Investment. **08 Hours**

MODULE 2

Energy storage systems: Thermal energy storage methods, Energy saving, Thermal energy storage systems

Energy Management: Principles of Energy Management, Energy demand estimation, Energy pricing

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries

Economic Analysis: Scope, Characterization of an Investment Project **10 Hours**

MODULE 3

Environment: Introduction, Multidisciplinary nature of environmental studies- Definition, scope and importance, Need for public awareness.

Ecosystem: Concept, Energy flow, Structure and function of an ecosystem. Food chains, food webs and ecological pyramids, Forest ecosystem, Grassland ecosystem, Desert ecosystem and Aquatic ecosystems, Ecological succession. **08 Hours**

MODULE 4

Environmental Pollution: Definition, Cause, effects and control measures of - Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution and Nuclear hazards , Solid waste Management, Disaster management Role of an individual in prevention of pollution, Pollution case studies. **08 Hours**

MODULE 5

Social Issues and the Environment: Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case Studies. Wasteland reclamation, Consumerism and waste products, Environment Protection Act, Air (Prevention and Control of Pollution) Act, Water (Prevention and control of Pollution) Act, Wildlife Protection Act, Forest Conservation Act, Issues involved in enforcement of environmental legislation. **08 Hours**

TEXT BOOKS:

1. Textbook for Environmental Studies For Undergraduate Courses of all Branches of Higher Education by University grant commission and Bharathi Vidyapeeth Institute of environment education and Research ,Pune
2. De, B. K., Energy Management audit & Conservation, 2nd Edition, Vrinda Publication, 2010.

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1. Turner, W. C., Doty, S. and Truner, W. C., Energy Management Hand book, 7th edition, Fairmont Press, 2009.
2. Murphy, W. R., Energy Management, Elsevier, 2007.
3. Smith, C. B., Energy Management Principles, Pergamum, 2007
4. Environment pollution control Engineering by C S rao, New Age International, 2006, reprint 2015, 2nd edition
5. Environmental studies, by Benny Joseph, Tata McGraw Hill, 2008, 2nd edition.

CONTENTS

MODULE - 1

BASIC INTRODUCTION TO ENERGY

***Basic Introduction to Energy:** Energy and power, forms of energy, primary energy sources, energy flows, world energy production and consumption, Key energy trends in India: Demand, Electricity, Access to modern energy, Energy production and trade, Factors affecting India's energy development: Economy and demographics Policy and institutional framework, Energy prices and affordability, Social and environmental aspects, Investment.*

1.1 ENERGY

Expressed essentially, energy is the capacity to do work in various forms. Energy is what makes it attainable to push things around. The "thing" can be a automobile moving, A cup of hot coffee, child swinging on a swing. In the event that we know the quality of the power we require so as to move an object, and the extent we will move it, we can compute the measure of energy we require.

1.2 POWER

Energy measures the total quantity of work done, it doesn't say how fast you can get the work done. Power is defined as the rate of producing or consuming energy.

1.3 ENERGY V/S POWER

Table 1.1 Energy V/s Power

	Energy	Power
Definition	Energy is the capacity to do work. Energy is power integrated over time.	Power is the rate at which work is done, or energy is transmitted.
Unit	joule = Newton-metre	watt = joule/second
Common symbol(s)	W	P
	Energy can be transformed from one form to another	Power is generated/ transmitted

1.4 FORMS OF ENERGY

The numerous existing energy sources can be classified in different ways:

1. Primary sources
2. Secondary sources

1. Primary Sources: Can be used directly, as they appear in the natural environment:

Ex: Coal, Oil, Natural Gas And Wood, Nuclear Fuels The Sun and The Earth Heat That Supplies Geothermal Energy.

2. Secondary Sources: Derived from the transformation of primary energy sources

Ex: petrol, that derives from the treatment of crude oil, Electric energy, obtained from the conversion of mechanical energy (power plants)

1.5 WORLD ENERGY SCENARIO

Interest in energy everywhere throughout the world is expanding

progressively. Significant development in energy is anticipated in developing nations. Coal, Oil and gas are the three noteworthy essential primary sources of energy. World coal reserves are probably to last over 200 years and each oil & gas reserves probably to last 45-65 years.

1.5.1 PRODUCTION

The global energy production at the end of 2014 was equivalent to 14000 Million Tonnes of Oil Equivalent (MToE). Coal Accounted for 29%, Oil 31 %, Natural gas for 21% and other at 18% (including nuclear, hydro, biofuels etc).

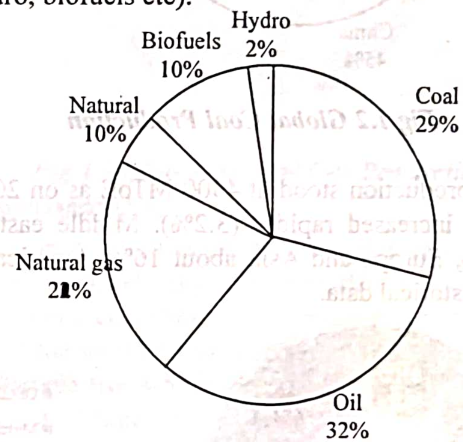

Fig 1.1 Global energy production (as on 2014)

Coal

Global coal production stood at 7700 MToE as on 2015. Global coal production fell by 4% when compared to historical data. China accounted for a larger share with about 46%, other Asian countries about 17%, OECD (Organisation for Economic Co-operation and Development) countries about 25%.

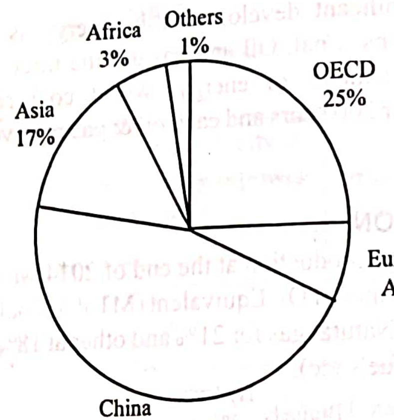

Fig 1.2 Global Coal Production

Oil

Global oil production stood at 4300 MToE as on 2015. Global oil production increased rapidly (3.2%). Middle east accounted for about 32%, Europe and Asia about 16%, America about 9% compared to historical data.

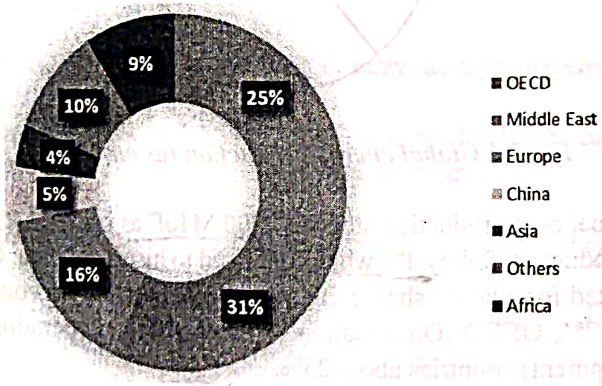

Fig 1.3 Global Oil Production

Natural Gas

Global natural gas production stood at 4000 billion cubic meter (bcm) as on 2015. Global production grew by 2.2% compared to historical data. OECD countries accounted for 37 % share while Europe and Eurasia 24 %, Asia about 9%.

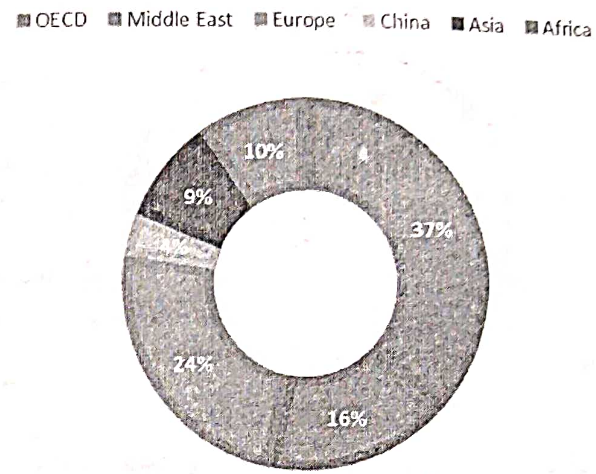

Fig 1.4 Global Natural Gas Production

1.5.2 CONSUMPTION

The developed countries attributed to high energy consumption as compared to developing countries.80% of world population lies in developing countries. Their energy consumption amount is only 40% of the world's total energy consumption. Industrialized countries /people use 4-5 times more than world average energy consumption & 9 times more than the average of the developing countries. ***Primary energy consumption*** is projected to grow at an average ***annual rate of 2.7%*** between 2011-2020.

Global energy consumption was 9425 MToE as on 2014.Oil accounted for 40%, Electricity about 18%, natural gas about 15%, Coal about 11%.

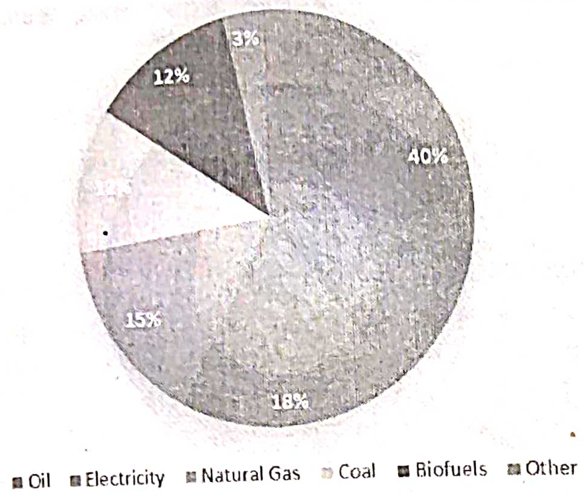

Fig 1.5 Global Energy Consumption (as on 2014)

Coal: Global coal consumption fell by 1.8% compared historically. This was accounted by US by a decline of 12.7%, China of 1.5%. India recorded an increase in coal dependence by about 5%.

Oil: Global Oil consumption grew by 1.9 million barrels/day (nearly 1.9%) as compared to historical data. US accounted for increase in 1.6%, China about 6.5%, India about 8.1% with an exception of Japan which recorded a decline of about 4%.

Natural Gas: Global natural gas consumption grew by nearly 1.7%. Iran accounted for 6.2%, China about 4.7%, US about 3%. Meanwhile, few countries recorded largest volumetric decline including Russia (5%) and Ukraine (21%).

Conclusion

Developed countries are consuming more energy with energy demand continues to grow strongly. Renewable sources will gain importance and energy system will become more complex rapidly. Energy efficiency is crucial in dealing with demand outstripping supply. Investments should be huge with focus on requirement of solid ecological arrangements.

1.6 KEY ENERGY TRENDS IN INDIA

The various key energy trends in India include

- Demand
- Electricity
- Access to Modern Energy
- Energy Production and Trade

1.6.1 DEMAND

India has been accountable for virtually 100% of the rise in international energy demand since 2000. Its energy demand during this amount has virtually doubled, pushing the country's share in International demand up to 5.7% in 2013 from 4.4% at the start of the century. Expressed on a per-capita basis, energy demand in our country has fully grown by 46% since 2000 and remains only around one-third of the world average.

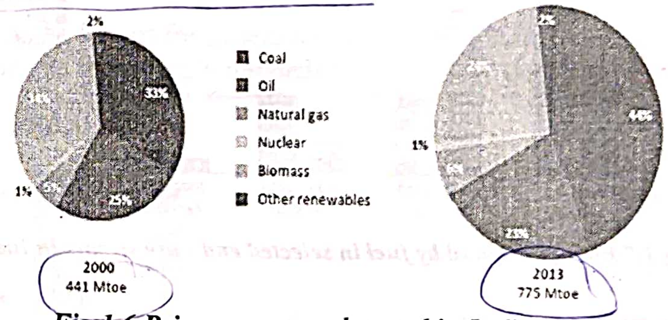

Fig 1.6 Primary energy demand in India by fuel

Almost three-quarters of Indian energy demand is met by fossil fuels, a share that has increased since 2000 because of a rapid rise in coal consumption. Coal now accounts for 44% of the primary energy mix. The availability and affordability of coal relative to other fossil fuels has contributed to its rise, especially in the power sector.

Oil consumption in 2014 stood at 3.8 million barrels per day (mb/d), 40% of which is used in the transportation sector. Natural gas makes up a relatively small share of the energy mix (6% in 2013 compared with 21% globally). Hydropower, nuclear and modern renewables (solar, wind and geothermal) are used predominantly in the power sector but play a relatively small role in the total energy mix.

Sector Wise comparison

Energy demand had traditionally been dominated by the buildings sector (which includes residential and services). In the buildings sector, a key driver of consumption in both rural and urban areas has been rising levels of use of appliances. As a result, electricity demand in the buildings sector grew at an average rate of 8% per year over 2000-2013 as shown.

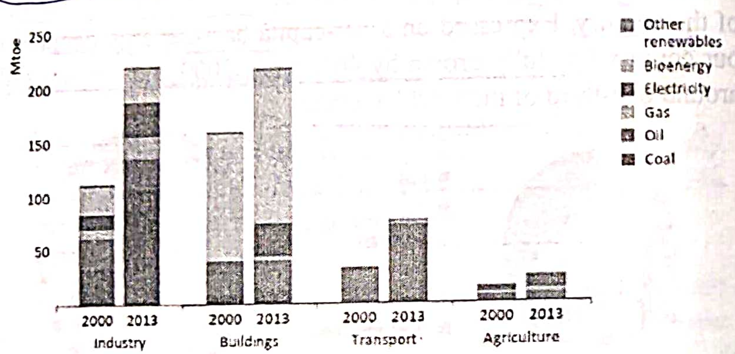

Fig 1.7 Energy demand by fuel in selected end - use sectors in India

1.6.2 ELECTRICITY

The country's electricity demand in 2013 was 897 terawatt-hours (TWh), up from 376 TWh in 2000, having risen over this period at an average annual rate of 6.9%. Electricity now constitutes some 15% of final energy consumption since 2000. The situation varies from state to state, but higher tariffs paid by commercial and industrial consumers are typically not enough to offset the losses arising from subsidies to residential and agricultural consumers, despite efforts to raise retail rates in recent years.

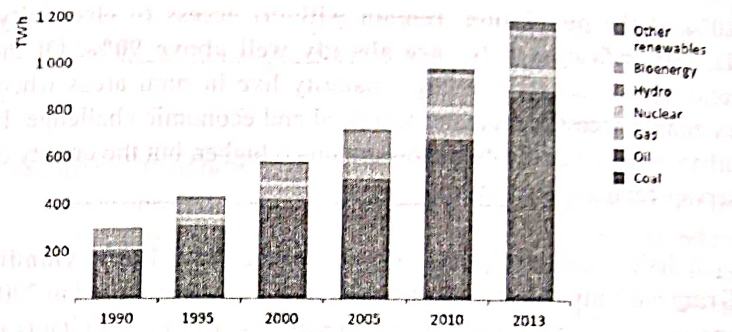

Fig 1.8 Total electricity generation in India by fuel

On the supply side, India has some 290 gigawatt (GW) of power generation capacity, of which coal (60%) makes up by far the largest share, followed by hydropower (15%) and natural gas (8%). The mix has become gradually more diverse: since 2000, almost 40% of the change in installed capacity was non-coal. This is reflected also in the figures for generation, which show how renewables are playing an increasingly important role.

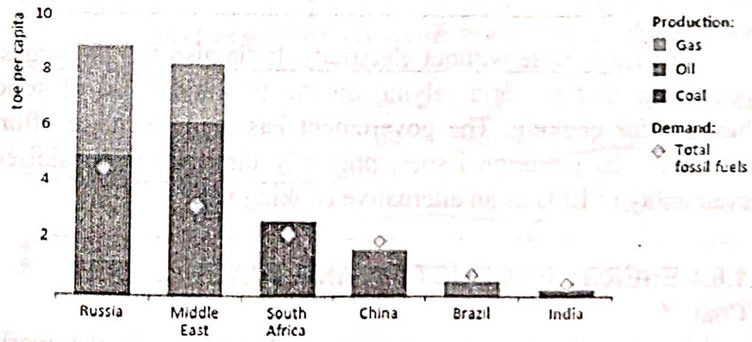

Fig 1.9 Fossil fuel production and demand per capita by selected countries, 2013

1.6.3 ACCESS TO MODERN ENERGY

India has made great strides in improving access to modern energy in recent years. Since 2000, India has more than halved the number of people without access to electricity and doubled rural electrification rates. Nonetheless, around 240 million people, or

20% of the population, remain without access to electricity. The **electrification rates are already well above 90%.** Of the total without access, the large majority live in rural areas where extending access is a greater technical and economic challenge. In urban areas, electrification rates are much higher, but the quality of service remains very uneven.

India's rural electrification programme, **the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY),** was launched in 2005 and aimed to provide electricity to villages of 100 inhabitants or more and free electricity to people below the poverty line. The effective implementation of RGGVY has faced several challenges and there are strong variations in outcomes between states.

In July 2015, RGGVY was subsumed within a new scheme, the **Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY).** The main components of this scheme are the separation of distribution networks between agricultural and non-agricultural consumers to reduce load shedding, strengthening local transmission and distribution infrastructure, and metering.

Aside from those without electricity, India also has the largest population in the world relying on the traditional use of solid biomass for cooking. The government has made a major effort to address its pollution issues, primarily through the subsidised availability of LPG as an alternative cooking fuel.

1.6.4 ENERGY PRODUCTION AND TRADE

Coal

India has the third-largest hard coal reserves in the world (roughly 12% of the world total), as well as significant deposits of lignite. Yet the deposits are generally of low quality and India faces major obstacles to the development of its coal resources. In 2013, India produced almost 340 million tonnes of coal equivalent (Mtce), but it also imported some 140 Mtce.

Around 7% of national production comes from captive mining, i.e. large coal-consuming companies that mine for their own use. At present, more than 90% of coal in India is produced by open cast mining.

Oil and Oil Products

India is one of the few countries in the world that rely on imports of crude oil while also being significant net exporters of refined products. India has relatively modest oil resources and **most of the proven reserves (around 5.7 billion barrels) are located** in the western part of the country, notably **in Rajasthan and in offshore areas near Gujarat and Maharashtra.** Most of the remaining production comes from joint ventures with the national oil and gas companies and from blocks awarded under successive licensing. India has almost doubled its refining capacity in the last ten years and has added more than 2 mb/d of new capacity since 2005, with strong private sector participation. With refinery output exceeding total demand by roughly 1 mb/d, India is a net exporter of all refined products except LPG.

Natural Gas

Natural gas has a relatively small share (6%) of the domestic energy mix. Production of conventional gas reached 34 bcm in 2013 and was supplemented by LNG imports. The majority state-owned gas company, GAIL, is the largest player in the midstream and downstream gas market.

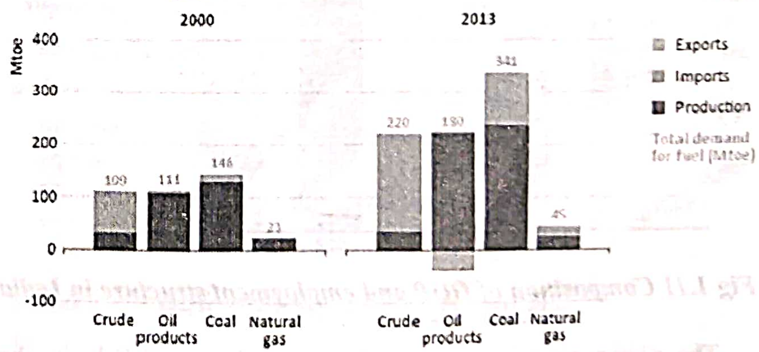

Fig 1.10 Fossil fuel balance in India

1.7 FACTORS AFFECTING INDIA'S ENERGY DEVELOPMENT

The various factors that affect our country's energy development are

- Energy and Demographics
- Policy and Institutional Framework
- Energy Process and affordability
- Social and environmental aspects
- Investment

1.7.1 ENERGY AND DEMOGRAPHICS

India's economy has grown at an **average rate of 6.5%** a year, second only to China among the large emerging economies, and **two-and-a-half-times the global average.** India alone has accounted for over **9% of the increase in global economic output since 1990.** Despite this progress, income per capita is still low and a gap has emerged between India and its counterparts. Services sector has been the major driver of growth in India's economy, accounting **for around 60% of the increase in GDP** between 1990 and 2013. The services sector employs only around one-quarter of the labour force. The agricultural sector, with less than 20% of GDP (compared with just over 35% in 1990), continues to account for around half of total employment as shown below.

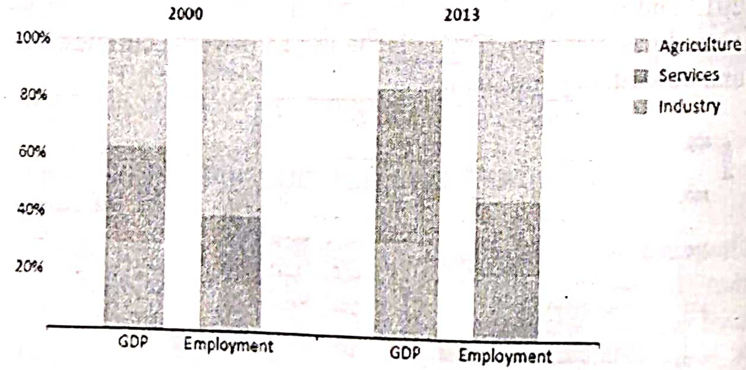

Fig 1.11 Composition of GDP and employment structure in India

The government has expressed its intention to re-balance the economy and announced the **"Make in India" initiative**, with an intention of increasing the **share of manufacturing in GDP to 25% by 2022 and creating 100 million jobs in the process.**

1.7.2 POLICY AND INSTITUTIONAL FRAMEWORK

The direction that national and state policies take, and the rigour and effectiveness with which they are implemented, will naturally play a critical role in India's energy outlook and has few policies listed such as **Integrated Energy Policy 2008, National Action Plan on Climate Change**, Planning Commission (now the National Institution for Transforming India, **[NITI Aayog]**)

Some key aspects of the emerging energy vision are

- A commitment to the efficient use of all types of energy in order to meet rapidly growing demand
- **Increase the target for renewables to 175 GW by 2022**
- A sharpened focus on achieving universal access to modern energy, including the objective of supplying round-the-clock electricity to all of India's population
- Reorientation of energy subsidy programmes
- A drive for market-oriented solutions and **increased private investment (including foreign investment) in energy**, both through some energy-specific reforms
- Drive to simplify and deregulate the business environment.
- A pledge to pursue a more climate-friendly and cleaner path than the one followed thus far by others at corresponding levels of economic development.
- Twin energy-related commitments **to increase the share of non-fossil fuel power generation capacity to 40% by 2030** and **to reduce the emissions intensity of the economy by 33-35% by the same date, measured against a baseline of 2005.**

1.7.3 ENERGY PRICES AND AFFORDABILITY

The relationship between income levels, energy prices and energy expenditure is fundamental to the evolution of India's energy system. Energy consumption increases with income. Level of consumption and the fuel choice are also affected by location. Household expenditure on energy is, on average, almost **two-and-a-half-times higher in urban centres than in rural areas.** India has made significant moves towards market-based pricing for energy in recent years. Gasoline (in 2010) and diesel (2014) prices have both been deregulated.

Subsidies to oil product consumption remain.

Ex: LPG : the government is committed to make them more efficient through the use of **"AADHAAR"**

1.7.4 SOCIAL AND ENVIRONMENTAL ASPECTS

Pollution

India is burning more fossil fuels and biomass than it has at any other time in the past, releasing more pollutants, including fine particulate matter and sulphur and nitrogen oxides, into the air. Deteriorating air quality in growing urban centres is becoming an alarming issue for India. Estimated that life **expectancy, as a result, is reduced by 3.2 years** for each person living in these areas

Land

Welfare of India's rural population is closely linked to the amount of land they have available for productive use. Land acquisition for public or private enterprises wishing to build infrastructure, from roads and railways to power plants and steel mills, is therefore an issue. Legislative changes introduced in 2013 introduced stringent procedural requirements for land acquisition. Some of the measures include

- Defining compensation payments and
- Rehabilitation and resettlement benefits
- Need to secure the consent of 80% of affected families in the case of land acquisition (70% for acquisitions by public-private partnerships)

Water

High rates of population and economic growth, along with highly inefficient patterns of water use in the agricultural sector, are putting severe strain on India's water resources. **Around 90% of India's water withdrawal is for use in agriculture and livestock,** often extracted by tube wells powered from the grid and drawing from groundwater reserves. Subsidised electricity tariffs for agricultural users and a lack of metering have led to hugely inefficient consumption of both electricity and water.

1.7.5 INVESTMENT

Since 2000, investment in energy supply in India has increased substantially, reaching **almost $77 billion on average since 2010** with power sector absorbing the largest share. India's government aims to **increase investment in infrastructure to 8.2% of GDP from roughly 7.2% in 2007-2011.** 2014 saw a significant **increase in FDI inflows,** which rose by **22% compared to the previous year.**

LIST OF QUESTIONS

1. Define Energy and Power. Differentiate the same.
2. Interpret World Energy Scenario with respect to production and consumption using relevant statistics.
3. Explain the various key energy trends in India.
4. With relevant statistics, enumerate the primary energy production trend for our country India.
5. Outline the factors that affect India's energy development.

REFERENCE

1. BP Statistical Review of World Energy, June 2016
2. Key world energy statistics, International Energy Agency, 2016
3. World Energy Outlook Special Report, International Energy Agency, 2015

MODULE - 2

ENERGY SYSTEMS AND ITS ANALYSIS

Energy storage systems: *Thermal energy storage methods, Energy saving, Thermal energy storage systems*
Energy Management: *Principles of Energy Management, Energy demand estimation, Energy pricing*
Energy Audit: *Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries*
Economic Analysis: *Scope, Characterization of an Investment Project*

2.1 INTRODUCTION

Energy storage (ES) has only recently been developed to a point where it can have a significant impact on modern technology. In particular, ES is critically important to the success of any intermittent energy source in meeting demand. For example, the need for storage for solar energy applications is severe, especially when solar energy is least available, namely, in winter.

ES systems can contribute significantly to meeting society's needs for more efficient, environmentally benign energy use in building heating and cooling, aerospace power, and utility applications. The use of ES systems often results in such significant benefits as

- reduced energy costs;
- reduced energy consumption;
- improved indoor air quality;
- increased flexibility of operation; and
- reduced initial and maintenance costs.

In addition, Dincer (1997) point out some further advantages of ES:

- reduced equipment size;
- more efficient and effective utilization of equipment;
- conservation of fossil fuels (by facilitating more efficient energy use and/or fuel substitution); and
- reduced pollutant emissions (e.g., CO_2 and chlorofluoro carbons (CFCs)).

2.2 ENERGY DEMAND

Energy demand in the commercial, industrial, public, residential, and utility sectors varies on a daily, weekly, and seasonal basis. Ideally, these demands are matched by various energy-conversion systems that operate synergistically. Peak hours are the most difficult and expensive to supply. Peak electrical demands are generally met by conventional gas turbines or diesel generators, which are reliant on costly and relatively scarce oil or gas. ES provides an alternative method of supplying peak energy demands. Likewise, ES systems can improve the operation of cogeneration, solar, wind, and run-of-river hydro facilities. Some details on these ES applications follow:

Utility. Relatively inexpensive base-load electricity can be used to charge ES systems during evening or off-peak weekly or seasonal periods. The electricity is then used during peak periods, reducing the reliance on conventional gas and oil peaking generators.

Industry. High-temperature waste heat from various industrial processes can be stored for use in preheating and other heating operations.

Cogeneration. Since the closely coupled production of heat and electricity by a cogeneration system rarely matches demand exactly, excess electricity or heat can be stored for subsequent use.

Wind and run-of-river hydro. Conceivably, these systems can operate around the clock, charging an electrical storage system during low-demand hours and later using that electricity for peaking purposes. ES increases the capacity factor for these devices, usually enhancing their economic value.

Solar energy systems. By storing excess solar energy received on sunny days for use on cloudy days or at night, ES systems can increase the capacity factor of solar energy systems.

2.3 ENERGY STORAGE

Mechanical and hydraulic ES systems usually store energy by converting electricity into energy of compression, elevation, or rotation. Pumped storage is proven, but quite limited in its applicability by site considerations. Compressed-air ES has been tried successfully in Europe, although limited applications appear in the United States. This concept can be applied on a large scale using depleted natural gas fields for the storage reservoir. Alternatively, energy can be stored chemically as hydrogen in exhausted gas fields. Energy of rotation can be stored in flywheels, but advanced designs with high-tensile materials appear to be needed to reduce the price and volume of storage. A substantial energy penalty of up to 50% is generally incurred by mechanical and hydraulic systems in a complete storage cycle because of inefficiencies.

Reversible chemical reactions can also be used to store energy. There is a growing interest in storing low-temperature heat in chemical form, but practical systems have not yet emerged. Another idea in the same category is the storage of hydrogen in metal hydrides (lanthanum, for instance). Tests of this idea are ongoing.

Electrochemical ES systems have better turnaround efficiencies but very high prices. Intensive research is now directed toward improving batteries, particularly by lowering their weight-to-storage capacity ratios, as needed in many vehicle applications. As a successor to the lead–acid battery, sodium–sulfur and lithium–sulfide alternatives, among others, are being tested. A different type of electrochemical system is the redox flow cell, so named because charging and discharging is achieved through reduction and

oxidation reactions occurring in fluids stored in two separate tanks. To make the leading candidate (an iron redox system) competitive with today's batteries, its price would have to be at least halved.

Thermal energy storage (TES) systems are varied, and include designed containers, underground aquifers and soils and lakes, bricks and ingots. Some systems using bricks are operating in Europe. In these systems, energy is stored as sensible heat. Alternatively, thermal energy can be stored in the latent heat of melting in such materials as salts or paraffin. Latent storages can reduce the volume of the storage device by as much as 100 times, but after several decades of research many of their practical problems have still not been solved. Finally, electric energy can be stored in superconducting magnetic systems, although the costs of such systems are high.

Some current research and development areas in the field of ES are as follows:

- advanced ES and conversion systems with phase transformation, chemical and electro chemical reactions;
- fundamental phenomena inside a single cell as well as engineering integration of whole battery packs into vehicles;
- high-dielectric-constant polymers;
- high K composites for capacitors;
- polymer electrode interfaces (low- and high-frequency effects);
- integrated polymer capacitors.

2.4 ENERGY STORAGE METHODS

For many energy technologies, storage is a crucial aspect. If we consider the storage of fuels as the storage of the energy embedded in them, then oil is an excellent example. The massive amounts of petroleum stored worldwide are necessary for the reliable, economic availability of gasoline, fuel oil, and petrochemicals.

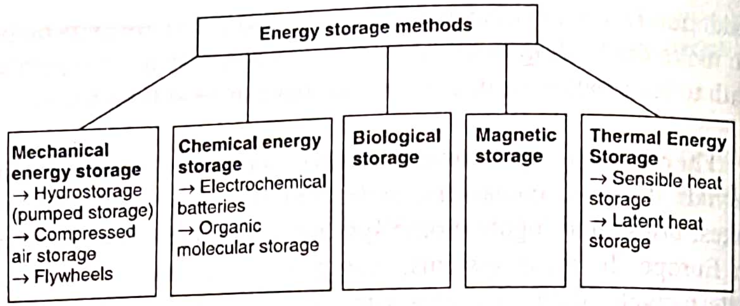

Fig 2.1 A classification of energy storage methods

2.4.1 MECHANICAL ENERGY STORAGE

Mechanical energy may be stored as the kinetic energy of linear or rotational motion, as the potential energy in an elevated object, as the compression or strain energy of an elastic material, or as the compression energy in a gas. It is difficult to store large quantities of energy in linear motion because one would have to chase after the storage medium continually. However, it is quite simple to store rotational kinetic energy. In fact, the potter's wheel, perhaps the first form of ES used by man, was developed several thousand years ago and is still being used. As seen in Figure 2.1, there are three main mechanical storage types that we discuss in this section: hydrostorage, compressed-air storage, and flywheels.

2.4.2 HYDROSTORAGE (PUMPED STORAGE)

Upper reservoir: Like a conventional hydropower plant, a dam creates a reservoir. The water in this reservoir flows through the hydropower plant to create electricity. Using a reversible turbine, the plant can pump water back to the upper reservoir. This is done in off-peak hours. Essentially, the second reservoir refills the upper reservoir.

Lower reservoir: Water exiting the hydropower plant flows into a lower reservoir rather than re-entering the river and flowing downstream.

Reversible turbine pump: Water back to the upper reservoir,this is done in off-peak hours. By pumping water back to upper reservoir, plant has more water to generate electricity during periods of peak consumption.

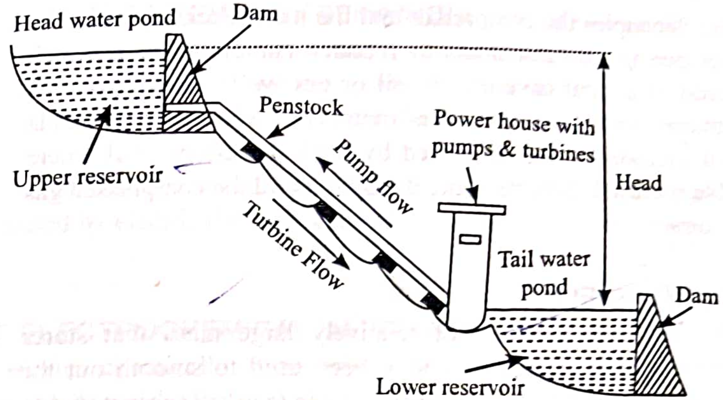

Fig 2.2 Pump Storage

2.4.3 COMPRESSED-AIR STORAGE

In a compressed-air ES system, air is compressed during off-peak hours and stored in large underground reservoirs, which may be naturally occurring caverns, salt domes, abandoned mine shafts, depleted gas and oil fields, or man-made caverns. During peak hours, the air is released to drive a gas turbine generator.

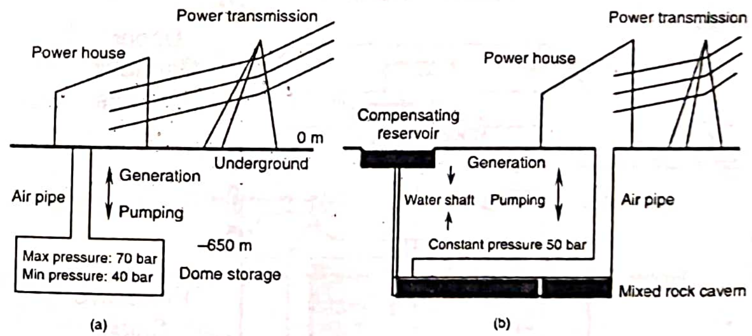

Fig 2.3 Compresses air ES systems
(a) Sliding Pressure System
(b) Compensated Pressure System

The technique used by such a system to compress air to store energy is relatively straightforward. In a conventional gas turbine, high-pressure hot gas is supplied, and about two-thirds of the gross power output is used to drive the compressor. A compressed-air ES system decouples the compressor and the turbine and operates the former during off-peak hours to produce compressed air, which is stored in natural caverns, old oil or gas wells, or porous rock formations. Such ES storage is advantageous when an appreciable part of the power load is carried by nuclear stations, and where suitable spent salt caverns make it easy to build the compressed gas reservoirs.

2.4.4 FLYWHEELS

The flywheel, a wheel of relatively large mass that stores rotational kinetic energy, has long been used to smooth out the shaft power output from one- or two-cycle (stroke) engines and to adjust for uneven loads. New uses of this device, and of the other two mechanical storage techniques discussed in this section, take advantage of the ability of the electric motor/generator operation to reverse. Such a device can be designed to work both as a motor when driven by electric power and as a generator when driven by mechanical power.

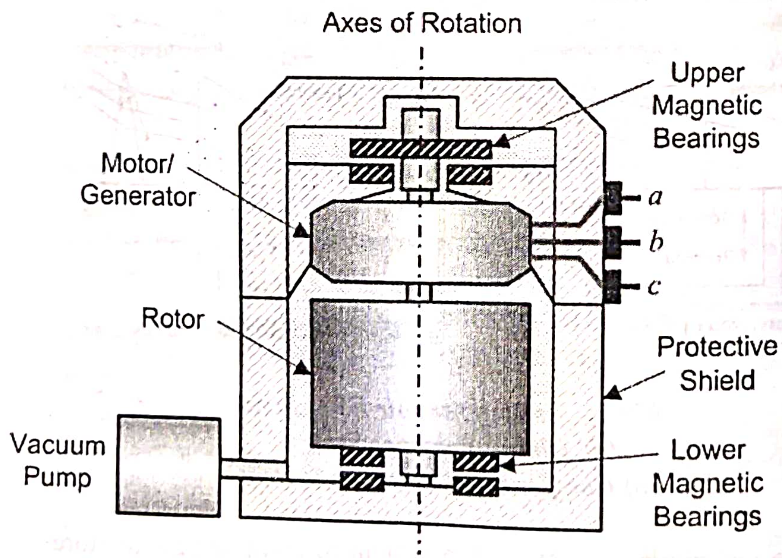

Fig 2.4 Flywheels Storage Energy

2.4.5 CHEMICAL ENERGY STORAGE

Energy may be stored in systems composed of one or more chemical compounds that release or absorb energy when they react to form other compounds. The most familiar chemical ES device is the battery. Energy stored in batteries is frequently referred to as *electrochemical energy* because chemical reactions in the battery are caused by electrical energy and subsequently produce electrical energy.

2.4.6 ELECTROCHEMICAL BATTERIES

Batteries chemically store energy and release it as electric energy on demand. Batteries are a stable form of storage and can provide high energy and power densities, such as those needed for transportation. The lead–sulfuric acid battery has long been considered to be advantageous and has been widely applied. Recently, fuel cells have demonstrated the ability to act as large-scale chemical storages like batteries.

2.4.7 ORGANIC MOLECULAR STORAGE

The intermittent availability of solar radiation, its seasonal and geographical variations, and its relatively low intensity, will limit the exploitation of that resource until it can be converted to forms of energy that can be efficiently stored and transported. However, most technologies that are presently available for the utilization of solar energy depend on the direct conversion of solar radiation to low-grade heat or electricity, both of which are difficult to store.

2.4.8 BIOLOGICAL STORAGE

Biological storage is the storage of energy in chemical form by means of biological processes and is considered an important method of storage for long periods of time.

2.4.9 MAGNETIC STORAGE

Energy can be stored in a magnetic field (e.g., in a large electromagnet). An advanced scheme that employs superconducting materials is under development. At temperatures near absolute zero, certain metals have almost no electrical resistance and thus large currents can circulate in them with almost no losses. Because this scheme stores DC electricity, some losses are incurred in converting standard AC power to and from DC, and some energy is used to drive the refrigeration device to maintain the requisite low temperatures. Overall storage efficiencies of 80–90% are anticipated for these superconducting magnetic ES systems.

Magnetic storage is considered for two main purposes. First, large superconducting magnets capable of storing 1000–10,000 MWh of electricity could be attractive as load-leveling devices for central power stations, and may be cost-effective at such capacities. Second, smaller magnets with storage capacities in the 10-kWh range may be cost-effective in smoothing out transmission line loads, to better match short-term customer demands and generating equipment characteristics. A small superconducting magnet that can help in meeting customer peak needs at the far end of a transmission line could increase the effective load that the line can serve by as much as 25%, producing cost savings that could offset in whole or part the additional costs of expanding the transmission line capability.

2.5 THERMAL ENERGY STORAGE (TES)

2.5.1 WHY THERMAL STORAGE

- Primary energy source -Hydro, Gas, Coal and Nuclear fuels transformed directly into Electricity as a power source for industrial and household appliances.
- In principle, electricity generation has to be balanced with the exact time of the consumption to satisfy the fluctuating demand at the lowest possible cost.
- Fluctuating seasonal and specific time demands outside their control .

- Utility companies generate electricity using different types of primary energy sources to offset peak.
- Almost every modern society has a mid-day or late evening peak electricity demand.
- This essential demand force utility companies to build new additional peak demand power stations -> considerable investment that operate only during peak demand periods and shut down the rest of the time.
- They use expensive primary energy sources and are subject to the standard cost of maintenance, consequently production cost per kWh is 3-4 times higher than the standard base load electricity production cost.

2.5.2 DEFINITION OF THERMAL STORAGE

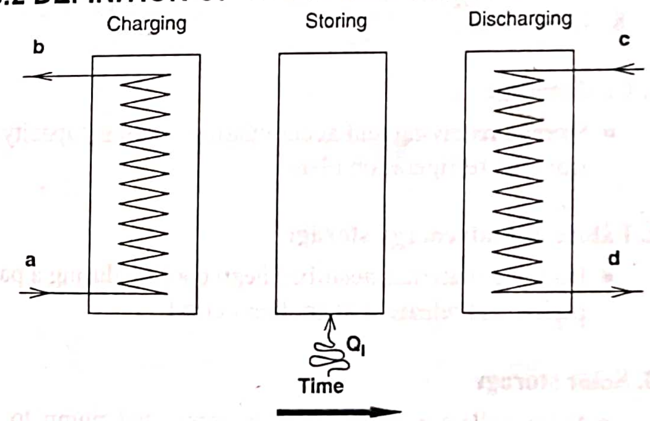

Fig 2.5 The three processes in a general TES system: charging (left), storing (middle), and discharging (right). Here the heat Ql is infiltrating and is positive in value for a cold thermal storage. If it is released, it will be toward the surroundings and Ql will be negative. The heat flow is illustrated for the storing process, but can occur in all three processes

- Thermal storage for HVAC applications Storage at various temperatures associated with heating or cooling.
- The collection of heat from solar energy for later use , hours, days or many months later , at individual building , multiuser building.

- Ex:energy demand can be balanced between day time and night time; summer heat from solar collectors can be stored inter seasonally for use in winter. And cold obtained from winter air can be provided for summer air conditioning.

2.5.3 TYPES OF THERMAL STORAGE SYSTEMS

1. Cold storage
2. Fabric and slab energy storage
3. Solar storage
4. Packed Rock Beds
5. Low Temperature CO2 Storage System
6. Thermo chemical Energy Storage
7. Sensible heat
8. Latent heat

1. Cold storage

- Storage receiving and accumulating cooling capacity output from the refrigeration plant.

2. Fabric & Slab energy storage

- Building materials absorbed heat/ cooling during a particular period and release it at another period.

3. Solar storage

- Solar collector along with its associated pump to convert solar radiation into heat.
- The store which receives the heated water from the collector delivers heated water to the space heating heat exchanger.
- It contribute to the building's hot water requirements of between 6% and 12%.

4. Packed Rock Beds

- A packed rock bed utilizes the available thermal energy by means of circulating through a packed rock bed to add heat or remove heat from the system for charging and discharging respectively.
- The energy can be transferred from a fluid but the most common systems utilize air due to the high heat transfer coefficient between air and rock.

5. Low Temperature CO_2 Storage System

- Carbon dioxide offers the most compact latent heat storage system due to the commercially obtainable triple point which allows the utilization of a single substance as static latent heat of fusion storage.
- Carbon dioxide can be stored at it's triple point of -57 Deg C and 518 kPa with solid fraction of 70-80 % by mass and the system can provide 140 kJ/kg thermal storage capacity.

6. Thermochemical Energy Storage

- Recent research shows that various alcohols and ketones are potential thermochemical storage media but due to the relative cost and complexity, no commercially viable systems have yet emerged.
- Typical examples are the mixture of Sulphuric Acid and water, and alternatively Sodium Hydroxide and water.
- Systems in which the water is separated by the heat input to the mixture and as soon as the two substance are mixed, the chemical reaction of the substances liberates heat.

7. Sensible heat storage:

A heat storage system that uses a heat storage medium, and where the additional or removal of heat results in a change in temperature.

Solar Pond Technology

The vertical configuration of salt-gradient solar pond consists of following three zones:

- Adjacent the surface there is a homogeneous convective zone that serves as a buffer zone between environmental fluctuations at the surface and conductive heat transport from the layer below. This is the upper convective zone (UCZ).
- At the bottom of the pond there is another convective zone, the lower convective zone or LCZ. This is the layer with the highest salt concentration and where the high temperature are built up.
- For given salinities and temperature in the upper and lower convective zones, there exists a stable intermediate gradient zone. This zone keeps the two convective zones apart and gives the solar pond its unique thermal performance. This intermediate zone provides excellent insulations for the storage layer, while simultaneously transmitting the solar radiation. To maintain a solar pond in this non-equilibrium stationary state, it is necessary to replace the amount of salt that is transported by molecular diffusion from the LCZ to the UCZ. This means that salt must be added to the LCZ, and fresh water to the UCZ whilst-brine is removed. The brine can be recycled, divided into water and salt (by solar distillation) and returned to the pond.

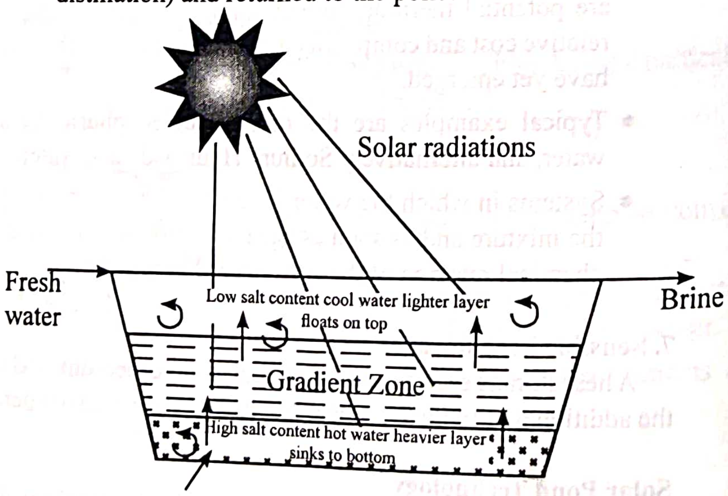

Fig. 2.6 Principle of solar pond

The major heat loss occurs from the surface of the small pond. This heat loss can be prevented by spreading a plastic grid over the ponds surface to prevent disturbance by the wind. Disturbed water tends to lose heat transfer faster than when calm.

8. Latent heat storage:

A heat storage system that uses the energy absorbed or released during a change in phase, without a change in temperature (isothermal).

Phase Change Materials (PCMs)

When a material melts or vaporizes, it absorbs heat; when it changes to a solid (crystallizes) or to a liquid (condenses), it releases this heat. This phase change is used for storing heat in PCMs. Typical PCMs are water/ice, salt hydrates, and certain polymers. The eutectic salt does not expand or contract when it freezes and melts; so, there is no fatigue on the plastic container. The eutectic salt-filled containers are placed in a tank, typically in a below-grade concrete or gunite structure. The containers occupy about two-thirds of the tank's volume, so that one-third of the tank is occupied by the water used as the heat-transfer medium. Since energy densities for latent TES exceed those for sensible TES, smaller and lighter storage devices and lower storage losses normally result.

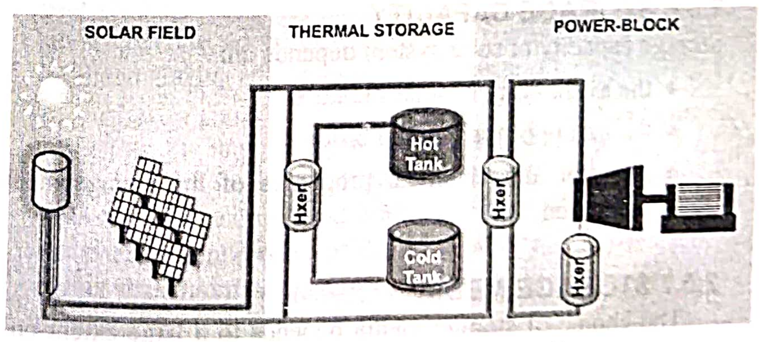

Fig. 2.7 Principle of use of PCM

Other early applications of PCMs included "eutectic plates" used for cold storage in trucking and railroad transportation applications. Another important application of PCMs is association with space technology, with NASA sponsoring a project on PCM applications for thermal control of electronic packages.

2.5.4 SITUATIONS FAVOR THE USE OF THERMAL STORAGE SYSTEMS

The storage systems are most likely to be cost-effective in situations when :-

- A facility's maximum cooling load is much greater than the average load.
- Limited electric power is available at the site;
- Backup cooling capacity is desirable;
- Loads are of short duration, infrequently, cyclical in nature
- Loads are not well matched to the availability of the energy source

2.5.5 WHY STORE SOLAR ENERGY

- solar energy is a time-dependent energy resource
- load does not match available energy
- cost consideration (avoid peak use)
- short term or long term storage

2.5.6 STORAGE CAPACITY

Storage capacity of solar system depends on:

- the availability of solar radiation.
- the nature of the thermal process.
- physical and chemical properties of the storage medium employed.

2.5.7 STORAGE MEDIA

The choice of storage media depends to a large extent on the nature of the solar thermal process.

- water storage.
- air based thermal storage (e.g., packed-bed storage).
- storage walls and floors. buried earth thermal storage.

2.5.8 WATER STORAGE

Water is the ideal material in which to store useable heat because it is low in cost and has a high specific heat.

The use of water is particularly convenient when water is used also as the mass and heat transfer medium in the solar collector and in the load heat exchanger.

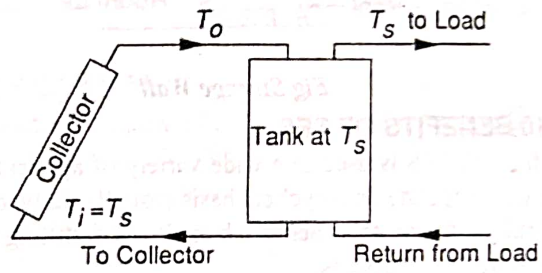

Fig A typical system using water tank storage, with water circulation through collector to add energy and through the load to remove energy

2.5.9 STORAGE WALL

A storage wall (Storage Walls e.g. Trombe wall) is a sun-facing wall built from material that can act as a thermal mass (such as stone, concrete, adobe or water tanks), combined with an air space, insulated glazing and vents to form a large solar thermal collector.

During the day, sunlight would shine through the glazing and warm the surface of the thermal mass. At night, if the glazing insulates well enough, and outdoor temperatures are not too low, the average temperature of the thermal mass will be significantly higher than room temperature, and heat will flow into the house interior.

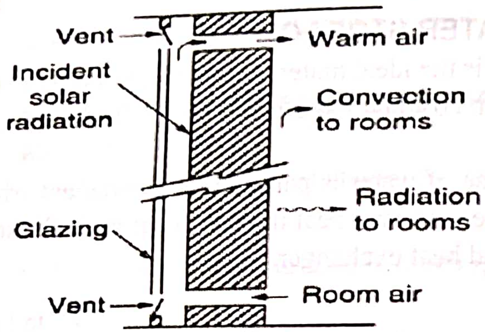

Fig Storage Wall

2.5.10 BENEFITS OF TES

Although TES is used in a wide variety of applications, all are designed to operate on a cyclical basis (usually daily, occasionally, seasonally). The systems achieve benefits by fulfilling one or more of the following purposes:

- **Increase generation capacity.** Demand for heating, cooling, or power is seldom constant over time, and the excess generation available during low-demand periods can be used to charge a TES in order to increase the effective generation capacity during high-demand periods. This process allows a smaller production unit to be installed (or to add capacity without purchasing additional units), and results in a higher load factor for the units.
- **Enable better operation of cogeneration plants.** Combined heat and power, or cogeneration, plants are generally operated to meet the demands of the connected thermal load, which often results in excess electrical generation during periods of low electricity use. By incorporating TES, the plant need not be operated to follow a load. Rather, it can be dispatched in more advantageous ways (within some constraints).
- **Shift energy purchases to low-cost periods.** This measure constitutes the demand-side application of the first purpose listed, and allows energy consumers subject to time-of-day pricing to shift energy purchases from high- to low-cost periods.

- **Increase system reliability.** Any form of energy storage, from the uninterruptable power supply of a small personal computer to a large pumped storage project, normally increases system reliability.
- **Integration with other functions.** In applications where on-site water storage is needed for fire protection, it may be feasible to incorporate thermal storage into a common storage tank. Likewise, equipment designed to solve power-quality problems may be adaptable to energy storage purposes.

2.6 ENERGY SAVINGS

Thermal energy storage (TES) is a key component of many successful thermal systems. TES should allow for the minimum reasonable thermal energy losses and the corresponding energy savings, while permitting the highest appropriate extraction efficiency of the stored thermal energy.

TES systems are an important element of many energy-saving programs in a variety of sectors, residential, commercial, industrial, and utility, as well as in the transportation sector.

TES can be employed to reduce energy consumption or to transfer an energy load from one period to another. The consumption reduction can be achieved by storing excess thermal energy that would normally be released as waste, such as heat produced by equipment and appliances, by lighting, and even by occupants. Energy-load transfer can be achieved by storing energy at a given time for later use, and can be applied to TES for either heating or cooling capacity.

2.7 ENERGY MANAGEMENT AND AUDIT

2.7.1 DEFINITION & OBJECTIVES OF ENERGY MANAGEMENT

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

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

"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"

(Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press inc. 1997)

Another comprehensive definition is

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

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

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

2.7.2 ENERGY AUDIT: TYPES AND METHODOLOGY

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management

programme. As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

2.7.3 NEED FOR ENERGY AUDIT

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

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

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

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

2.8 TYPE OF ENERGY AUDIT

The type of Energy Audit to be performed depends on:

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

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

i) Preliminary Audit
ii) Detailed Audit

2.8.1 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

2.8.2 DETAILED ENERGY AUDIT METHODOLOGY

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of

energy use. This estimated use is then compared to utility bill charges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre Audit Phase
Phase II - Audit Phase
Phase III - Post Audit Phase

A Guide for Conducting Energy Audit at a Glance

Industry-to-industry, the methodology of Energy Audits needs to be flexible.

A comprehensive ten-step methodology for conduct of Energy Audit at field level is presented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types.

2.8.3 TEN STEPS METHODOLOGY FOR DETAILED ENERGY AUDIT

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	Phase I – Pre Audit Phase	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning. Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation
	Phase II – Audit Phase	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc. - Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
	Phase III – Post Audit phase	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

2.8.4 PHASE I -PRE AUDIT PHASE ACTIVITIES

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

Initial Site Visit and Preparation Required for Detailed Auditing

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

- During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -
- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyse the major energy consumption data with the relevant personnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are: -

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

2.8.5 PHASE II- DETAILED ENERGY AUDIT ACTIVITIES

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

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

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

1. Energy consumption by type of energy, by department, by major items of process equip ment, by end-use
2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
3. Energy cost and tariff data
4. Process and material flow diagrams
5. Generation and distribution of site services (eg.compressed air, steam).
6. Sources of energy supply (e.g. electricity from the grid or self-generation)