MODULE -1

ENERGY:

It is great word, which is defined as the ability or capacity to do work. We use energy to do work and make all movements. When we eat, our body's transform the food into energy to do work. When we run or walk or do some work, we ―burn" energy in our bodies. Cars, planes, boats machinery etc. also transform energy into work. Work means moving or lifting something, warming or lifting something, warming or lighting something. There are many sources of energy that help to run the various machines invented by man.

Energy is measured in BLU (British Thermal Unit) or Joule (Named after the English Physicist type of energy). One Joule after the amount of energy required to lift 1 pound (approx 400g) about 9 inches (23cm). It takes 1000 Joules to equal a Btu. It would take 2 million Joules to make a pot of coffee. A price of buttered tarts contains 315 kilo Joules of energy.

Kinds of energy

Kinetic energy: it is the energy of motion

Potential energy: It is the energy due to position or energy stored.

Types of energy

Light, chemical. Mechanical, heat, electric, atomic, sound.

All these forms of energy can be broken down either into kinetic or potential energy.

Sources of energy

Primary Energy Sources:

Energy resources are mined or otherwise obtained from the environment.

Ex. a. Fossil fuels: coal, lignite, crude oil, Natural gas etc.

b. Nuclear fuels: Uranium, Thorium, other nuclear used in friction reaction.

c. Hydro energy: It is energy of falling water, used to turn a turbine.

d. Geo thermal: The heat from the underground stream.

e. Solar energy: Electromagnetic radiation from the Sun.

f. Wind energy: The energy from moving air used by wind mills.

g. Tidal energy: The energy associated with the rise and fall of the tidal waters.

Global energy consumption patterns

Transportation consumes about 24% of the energy, 40% for industry, 30% for domestic and commercial purposes and remaining 6% for other uses including agriculture. The top 20 richest countries of the world consume 80 of the natural gas 65% of the oil and 50 of the coal produced every year while these countries have only one fifth of the world's population. One third of the world's population is about two billion people, lack access to adequate energy supplies, they mainly depend on fuel wood, dung, coal, charcoal and kerosene for cooking and heating. U.S.A is the largest energy consumer in the world.

Table 1: **Different Sources of Energy**

Energy Source	**Percentage of total energy**	**Subtotal percentage**
Non- renewable Source		
Oil	32	
Coal	21	
Natural gas	23	
Nuclear	6	82
Renewable Sources		
Bio mass (mainly wood)	11	
Solar, wind, hydro and Geothermal power	7	18
Total		100

Energy Status of India

India's energy status is not promising. Presently, the country consumes about 100 million tons of coal and 32,5 million tons of oil annually. Official estimate report that 40 billion tons of coal are available but only one half this is recoverable which means it is less than the projected demand of 23 billion tons of coal till the year 2020. n the other hand the projected demand for hydroelectric power by 2020 is 12 times more than the present installed capacity of nearly 15, 000 MW.

India's oil deposits Is about 400 million tonnes as against the world oil reserve of 750,000 million tonnes. Gas reserves of our country are about 100 million cubic meters, as against

World's reserves of 63,000 million cubic meters. Here, one can conclude that the energy Scenario of India is blank.

Renewable and Non- Renewable Energy Sources

Renewable or inexhaustible energy sources:

These are the resources that can be generated continuously. These are mostly biomass based which are renewed over relatively short period of time and then available in unlimited amount in nature. These include conventional energy sources like: firewood, petrol plants, plant biomass, animal dung, water energy etc.

Non-conventional energy sources like solar energy, wind energy, tidal energy, geothermal energy and dendro thermal energy etc. These can reproduce themselves in nature and can be harvested continuously through a sustained planning and proper management.

Non- renewable or exhaustible energy sources:

These are available in limited amount and develop over a longer period of time. Hence, they cannot be replenished in the quantities they are being consumed in a given period of time. Non-Conventional energy sources like nuclear energy etc. Development of modern technological civilizations is chiefly based on the non-renewable sources. These reserves are fast depleting and within a few decades they will get exhausted. The unwise and exploitative use of renewable energy sources have forced these resources in the category of non- renewable energy sources as the rate of production of these sources become much less than the rate of their utilization.

ELECTROMAGNETIC RADIATION

An electromagnetic radiation is energy in the form of a wave due to changing electric and magnetic fields. There are different forms of electromagnetic radiation, each with different wavelengths (i.e., Distance between successive peaks or troughs in the wave) and energy content. Such radiation travels through space at the speed of light, which is about 3, 00 000 kilometers/sec. Cosmic rays, gamma rays, x-rays and ultra violet radiation are known as Ionizing radiation because they have energy to knock electrons from atoms and change them to positively charged ions. The resulting highly reactive electrons and ions can disrupt living cells, interfere with body processes and cause many types of sickness, including various cancers. The other forms of electromagnetic radiation do not contain enough energy to form ions and are known as non-ionizing radiation.

The visible light that can be detected by our eyes is a form of non- ionizing radiation that occupies only a small portion of full range or spectrum of different types of electromagnetic radiation.

HYDRO ELECTRICAL ENERGY

Electricity produces from waterpower is known as hydroelectric energy. The potential energy of falling water captured and converted to mechanical energy by water wheel powered the start of industrial revolution. Wherever head or change in elevation could be found, river and stream were dammed and mills were built.

Large Scale Hydro power: in this case a high dam is built across a large river to create a reservoir, water is allowed to flow to through huge pipes laid along the steep hill slopes (falling) at controlled rates, thus spinning turbines (prime movers) and in turn generators producing electricity.

Small hydropower: In this case a low dam with no reservoir (or only a small one) is built across a small stream and the water used to spin turbine to produce electricity.

Pumped Storage hydropower: In this case the surplus electricity conventional power plant is used to lift water from a lake or tail race to another reservoir at a higher elevator, water in the upper reservoir is released to spin the turbine for generating electricity.

In 2001, hydro power supplied about 7% of the world"s total commercial energy, 20% of the world's electricity. It supplies 99% of the electricity in Norway, 75% in New Zealand and 50% in developing countries and 25% in China.

In India the generation of hydroelectricity has been emphasized right from the beginning of the First Five Year plan. By the end of Fourth plan, India was able to generate 6.9 thousand MW of hydroelectricity, contributing 42% of the total power generation capacity. But due to increase in demand, by the end of Eighth plan it fell down to 25% only. The hydropower potential of India is estimated to be 4 X 10 11k w –hours. Till now we have utilized only a little move than 11% of this potential. Because of increasing concern about the harmful environment and social consequences of large dams, there has been growing pressure on the World Bank and other development agencies to stop funding new large scale hydro power projects.

According to a study by world commission on Dams, hydropower in tropical countries is a major emitter of greenhouse gases. This occurs because reservoirs that power the dams can trap rotting vegetation, which can emit greenhouse gases such as Carbon dioxide and Methane. Small-scale hydropower projects eliminate most of the harmful environmental effects of large-scale projects. However, their power output can vary with seasonal changes in the stream flow.

Advantages	Disadvantages
Moderate to high net energy.	High construction cost
High efficiency (80%)	High environmental impact
Low cost electricity emission from biomass decay in shallow tropical reservoirs	High carbon dioxide
Long life span	Floods natural areas.
No carbon dioxide emission during operation	Coverts land habitat to lake habitat.
May provide flood control below dam.	Danger of collapse
Provides water for year-round Irrigation.	Uproots People
Reservoir is useful for fishing and recreation	Decreases fish harvest Below dam

Above are the advantages of and disadvantages of using large-scale hydropower plants to generate electricity

According to the United Nations, only about 13% of the World's exploitable potential for hydropower has been developed. Much its un trapped potential is in South Asia, (China), South America and parts of Russia.

FOSSILS FUELS

Fossils fuels (oil, coal, natural gas) are energy rich substances that have formed from the remains of organisms that lived 200 to 500 million years ago. During the stage of the Earth's evolution, large amount of dead organic matter had collected. Over millions of years, this matter was buried under layers of sediment and converted by heat and pressure into coal, oil and natural gas.

Chemically, fossil fuels largely consist of hydrocarbons, which are compounds of hydrogen and carbon. Some fossils fuel also contains smaller quantities of other compounds. After the accumulating sediments exerted increasing heat and pressure for millions of years on the ancient organisms' hydrocarbons were formed. Most common among them are petroleum, coal and natural gas. However, Geologists have identified other types of hydrocarbon rich deposits, which can serve as fuels. Such deposits are: oil shale, tar sands and gas hydrates. However, they are not widely used due to the fact that they are very costly to extract and refine. Majority of fossil fuels are being used in transportation, industries heating and generation of electricity.

Crude petroleum is refined into gasoline; diesel and jet fuel that power the world's transportation system. Coal is mostly used in the generation of electricity (thermal power). Natural gas is used for commercial and domestic purposes like heating, air conditioning and as fuels for stoves and for other heating appliances.

Once we discovered the fossil fuel, we began consuming them at an increasing rate. From 1859 to 1969, total oil production was227 billion barrels (1 barrel=159 lts). 50% of this total was extracted during the first 100 years, while the next 50% was extracted in next 10 years. Today, fossil fuels are considered to be non-renewable for the reason that their consumption rate is far in excess of the rate of their formation.

Coal:

About 250 to 350 million years ago coal was formed on earth in hot, damped regions. Almost 27350 billion metric tons of known coal deposits occur on our planet. Out of which about 56% are located in Russia, 28% in USA and Canada. India has about 5% of world's coal reserve and that too not of vary good quality in term of heat capacity. West Bengal, Jharkhand, Orissa, Andhra Pradesh, Madya Pradesh and Maharastra are the major coal producing states of India. Mainly, there are three types of coal: Anthracite or hard coal (90% carbon content) Bituminous or soft coal (85% carbon content) Lignite or brown coal (70% carbon content). The present annual extraction rate of coal is about 3000 million metric tons, at this rate coal reserves may last for about 200 hundred years and if its use is increased by 2% per year then it will last for another 65 years.

Petroleum:

Convenience of petroleum or mineral oil and its greater energy content as compared to coal on weight basis has made it the lifeline of global economy. Petroleum is cleaner fuel when compared to wood or coal as it burns completely and leaves no residue. Petroleum is unevenly distributed like any other mineral. There are 13 countries in the world having 67% of the petroleum reserves which together form the OPEC (Organization of petroleum exporting countries). Six regions in the world are rich in petroleum – USA, Mexico, Russia and West Asian countries. Saudi Arabia oil producing has one fourth of the world oil reserves. The total oil reserves of our planet is about 356.2 billion metric tons out of this annually we are exporting about 28% million metric tons. Hence the existing reserves would last for about 40 – 50 years. About 40% of the total energy consumed in the entire world is now contributed by oil.

The oil-bearing potential of India is estimated to be above one million square kilometers is about one third of the total geographic area. Northern plains in the Ganga-Brahmaputra

Valley, the coastal strips together with their off-shore continental shelf (Bobay Hihgh), the plains of Gujarat, the Thar Desert and the area around Andaman and Nicobar Islands.

Natural gas:

Natural gas mainly consists of Methane (CH4) along with other inflammable gases like Ethane and propane. Natural gas is least polluting due to its low Sulphur content and hence is clearest source of energy. It is used both for domestic and industrial purposes. Natural gas is used as a fuel in thermal plants for generating electricity as a source of hydrogen gas in fertilizing industry and as a source of carbon in tyre industry.

The total natural gas reserves of the world is about 600 000 billion meters, out of this Russia has 34%, Middle East 18%, North America 17%, Africa and Europe 9% each and Asia 6%. Annual production of natural gas is about 1250 billion cubic meters and hence it is expected to last for about 50-100 years. In India gas reserves are found in Tripura, Jaisalmer, off shore areas of Bombay and Krishna-Godavari Delta.

Environmental effects of Using Fossil Fuels:

Acid rain: When fossil fuels are buried, Sulphur, Nitrogen and Carbon combine with oxygen to form compounds known as oxide. These oxides when released into the atmosphere, they react with water form and result in the formation of Sulfuric acid, Nitric acid and Carbonic acid. These acids can harm biological quality of forests, soils, lakes and streams.

Ash particles: Ash particles are the un burnt fuel particles. However with strict imposition of Government regulations, perubben are provided to trap these particles. Petro and natural gas generate less ash particles than coal, diesel or gasoline.

Global warming: Carbon dioxide is a major byproduct of fossil combustion and this gas is known as green hour gas. Green hour gas absorbs solar heat reflected off the earth’s surface and retains this heat, keeping the Earth warm and habitat for living organisms. Rapid industrialization between 19th and 20th centuries however has resulted in increasing fossils fuel emissions, raining the percentage of carbon dioxide by about 28%. This drastic increase has led to global warming that could cause environmental problems, including disrupted weather patterns and polar ice cap melting. Metal hydra rides, charcoal powders, graphite nano fibers and glass micro spheres containing hydrogen will not explode or burn of a vehicle’s tank is ruptured in an accident. Such tanks would be much safer than current gasoline tanks.

Advantages and Disadvantages of various fossil fuels

a. Conventional oil

Advantages	**Disadvantages**
Amply supply for 40-90years	Need to find substitute within 50 years
Low cost (with huge substitute)	Artificially low price encourages waste and discourages search for alternative
High net energy yield	Air pollution when burnt
Easily transported within and between countries	Released carbon dioxide when burnt
Low land use	Moderate water pollution
Technology is well developed	
Efficient distribution system	

b. Heavy oils from oil shale and Tar sand

Advantages	**Disadvantages**
Moderate existing supplies	High costs
Large potential supplies	Low net energy yield
Easily transport within and between countries	Large amount of water needed to process
Efficient distribution system in place	Severe land disruption
Technology is well developed	Water pollution from mining residues
Air pollution when burnt	
Carbon dioxide emissions when burnt	

c. Conventional Natural gas

Advantages	**Disadvantages**
Ample supplies (125 years)	Non-renewable resources
High net energy yield	Releases carbon dioxide when burnt
Low cost (with huge subsidies) can leak from pipelines	Methane (a greenhouse gas)
Less air pollution than other fossil fuels	Shipped across ocean as highly explosive LNG
Moderate environmental import at wells because of low prices	Sometimes burnt off and wasted
Easily transported by pipelines	Requires pipelines
Low land use turbines	

Coal

Advantages	**Disadvantages**
Ample supplies (225-900 years)	Very high environmental impact
Air pollution can be reduced with	Several land disturbance air
High net energy yield pollution and water pollution	High land use (including mining)
Low cost (with huge substitutes)	Severe threat to human health
Mining and combustion technology well developed	High carbon dioxide emissions developed when burnt
Releases radio-active particles and mercury into air.	

NUCLEAR ENERGY

Nuclear energy is non- renewable source of energy, which is released during fission (disintegration) or fusion (union) of selected radioactive materials. Nuclear power appears to be the only hope for large scale energy requirements when fossil fuels are exhausted. The reserves of nuclear fuels is about ten times more than fossil fuels and its major advantage is that even small quantities can produce enormous amounts of energy. For example, a ton of uranium –235 can produce an energy equivalent 3 million tons of coal or 12 million barrels of oil. Nuclear energy has been successfully used in the generation of electricity in spaceships, marine vessels, chemical and food-processing industry.

Nuclear fission: nuclear fission reaction are based on the fission of U235 nuclei by thermal neutrons 92 U235 The energy from these nuclear reactions is used to heat water in the reactor and generates steam to drive a stream turbine. High temperature gas-cooled reactors and Fast Breeder reactors convert non fissionable Pu 239 and U233 Nuclear fusion It is based on deuterium-deuterium and deuterium-tritium reaction. The deuterium-deuterium re actions promise an unlimited source of energy will take several more years due to the technical problem. Nuclear fusion is also known as thermo nuclear reaction.

Environmental impact: nuclear fission power reactor generates large quantities of radioactive fission waste products, which may remain dangerous for thousands of years. In addition, these are no safe disposal methods.

SOLAR ENERGY

The solar energy originates from the thermonuclear fusion reaction taking place in the Sun. It is one of the potential non-conventional energy sources. The earth continuously receives energy from the Sun, part of which is absorbed while the remaining is emitted back into space. Out of the solar radiations reaching the earth 92% consists radiations in the range of 315 to 1400 mm. 45% of this is in the visible range and emits radiations in the infra-red region (2u to 40u). The heat equivalent of the solar radiation reaching the earth is estimated to be about 2,68x 10 Joules per year.

Solar energy being non- polluting and non-depletes is considered as renewable energy and thus fills into the principle of sustainability. But only 0,25 to 0.5 % of the solar energy reaching the earth is utilized for photosynthesis. Utilisation of solar energy is to gain popularity among the masses due to expensive nature. In India, solar photovoltaic systems are being installed by Department of Non- Conventional energy resources for lighting, running of TV sets, water pumping etc. In India, there has been steady rise in demand for solar photovoltaic system.

Solar cells are used to convert the impinging solar radiation directly of this method is that no mechanical movement of parts is need. The reliability of the operation is extraordinarily high. Even under severe space conditions a maintenance free life span of ten or more years has been achieved. Only disadvantage is that, its cost is very high for a solar power station with a capacity of 1000 Mw, a land of surface of about 12 km2 is required.

Advantages of solar energy

Solar energy is free and it is available locally in abundance. Solar energy is pollution free. Systems are easy to install, generate and maintain. System can be specifically designed according to individual requirements. Supply of hot water is instant and un interrupted Recurring fuel costs are zero Heating 100 liters of water to 60o c by solar system results in an energy saving of 1200-1500 units (kilowatts hours) of electricity per year.

BIOMASS

Biomass is the term used to describe the organic matter produced by photo synthesis that exists on the Earth's surface. The source of all energy in biomass is the Sun, the biomass acting as a kind of chemical energy store. Traditionally the extraction of energy from biomass is split into three distinct categories:

Solid biomass: The use of trees, crop residues animal and human waste, house hold or industrial residues for direct combustion to provide heat.

Biogas: it is obtained an aerobically (without air) digesting the organic material to produce ethane. Animal waste and municipal waste are two common feed stocks for anaerobic digestion.

Liquid bio-fuels: They are obtained by subjecting organic materials to one of the various chemical or physical processes to produce a usable, combustible liquid fuel. Bio fuels such as vegetable oils or ethanol are often processed from industrial or commercial residues such as biogas or from energy crops grown specially for these purposes.

Biomass use in the development world

More than two billion people in the developing world use biomass for the majority of their household energy needs. Biomass is also used widely used for non-domestic appliances. Biomass is available in varying quantities throughout the developing world. In recent decades, with the threat of global deforestation much focus has been given to the efficient use of biomass.

Biomass resources: They are renewable energy recourses**.** Natural Biomass resources vary in type and content depending upon the geographical location. World's biomass producing areas are classifieds into three distinctive regions.

Temperate regions: Produce wood, crop residues like straw, vegetable leaves, human and animal waste. Arid and Semi-arid regions: Produce very little excess vegetation for fuel. People living in these areas are often the most affected by desertification and have differently in finding sufficient wood fuel. Humid tropical regions: Produce abundant wood supplies, crop produces, animal and human

Wastes, commercial industrial agro and food processing residues. Many of the world's poorer countries are found in these regions and hence there is a high incidence of domestic biomass use. Tropical areas are currently the most seriously affected by deforestation, logging and land clearance for agriculture.

Activities including Commercial utilization of Biomass- Biomass can be used for a variety of commercial tobacco curing praising direct heat for brick burning, for lime burning and cement kilns.

In India, sugar mills are rapidly turning to bagasse, the leftover of cane after it is crushed and its juice extracted to generate electricity. This is mainly done to clean up the environment, cut down power cost and additional revenue. According to current estimates, about 3500 MW of power can be generated from bagasse in the existing 430 sugar mills of the country. Around 270 MW of power has already been commissioned and more are under construction. The advantages of biomass are that it can be locally sourced.

Biomass **energy and environment:** Concern for the environment was one of the major inspirations for early research and development work on improved stoves. Initially, one environment concern dominated the improved stove work, saving trees. Today, this is considerably downplayed. At the same time, other environmental issues have become dominant. Large scale combustion of biomass is only environmentally feasible if carried out on a sustainable basis. For obvious continual large-scale exploitation of biomass resources without care for its replacement and regeneration will cause environmental damage and also Jeopardize the fuel source itself.

Benefits of Biomass energy:

* Renewable or recyclable energy source (Stored solar energy)
* Less waste directed to landfills.
* Decrease reliance on imported energy sources.
* Potential rural development and job creation.
* Can generate renewable electricity when the Sun is not shining and the wind is not blowing.

BIOGAS

Biogas is obtained by an aerobically (without air) digesting organic material to produce a combustible gas known as methane. Animal waste and municipal waste are two common feed stocks for an aerobic digestion. At present biogas technology provides an alternative source of energy in rural India for cooking. It is particularly useful for village households that have their own cattle. Through a simple process cattle dung is used to provide the gas. The residual dung is used as manure. India has world’s largest cattle population - 400 million, thus offering tremendous potential for biogas plants. Biogas production has the capacity to provide us with about half of our energy needs either burned for electricity production or piped into current gas lines for use. It just has to be done and made a priority. Though about 3.71 million biogas plants in India up to March 2003 are successfully in operation but still it is utilizing only 31% of the total estimated potential of 12 million plants. The payback period of the biogas plant is only 2 to 3 years. Rather in the case of community and industrial Biogas plants is even less. Therefore, biogas electrification at Community Panchayat level is required to be implemented. Sixty cubic feet approx. 2 m3 biogas plant can serve the needs of one average family.

The charge for the biogas generation consists of dung and waste in the form of slurry. The fermentation is carried out between 35 to 500C. About 160 liters of gas is produced per kg of cow dung and heating value of the gas is 490 kilocalories on 160 liters basis. The average composition of biogas is methane 55%. Hydrogen 7.4%, Carbon dioxide 39%, Nitrogen 2.6%, Waster- traces. The average gross calorific value of the gas is 5300 kilo cals /cubic meters.

HYDROGEN AS AN ALTERNATIVE FUTURE SOURCE OF ENERGY

Alternative energy sources

Other alternative source of energy for future is the nuclear energy derived from nuclear fission or nuclear fusion processes. The use of nuclear energy mainly requires its conversion into electrical energy. Out of the world's total energy requirement only 20% constitutes electrical energy. The rest of the 80% requirement is energy in the form of heat. Conversion of nuclear energy into chemical energy for storage and transportation and disposal of nuclear waste are the problems of this technique.

Hydrogen as fuel

Hydrogen is an important alternative energy source. Some advantages of hydrogen are:

Hydrogen is abundantly available in the combined form as water.

• Use of hydrogen as fuel provides pollution free atmosphere because its combustion product is water. Time required for regeneration of hydrogen is short. Automobile’s engine burning hydrogen is about 25 to 50% more efficient than an automobile engine burning gasoline (petrol). Heat of combustion per gram of hydrogen is more than twice that of jet fuel. Hydrogen-oxygen fuel cells provide other possibilities of powering motor vehicles. Hydrogen is excellent reducing agent and produces less atmospheric pollution than carbon. So it can replace coal in many industrial processes.

The changes in our way of life by adopting widespread uses of hydrogen are referred to as 'hydrogen economy'.

Hydrogen economy

Although hydrogen looks as very good future fuel, the problems associated with its economy are:

Availability

Hydrogen is not available as such. It does not occur in a free state in nature. The cheap production of hydrogen is a basic requirement of hydrogen economy. The source of hydrogen is water and using nuclear energy or solar energy might generate it.

Transportation

Hydrogen gas has explosive flammability and so is difficult to handle. This causes problem to its storage and transportation. A solution for this is the use of Fe-Ti alloy, which absorbs hydrogen and results in the formation of fine silvery powder. Heating the powder safely releases hydrogen gas. Such storage system is safer than storage of hydrogen as gas or liquid.

Platinum scarcity

Platinum is required as catalyst in oxygen-hydrogen fuel cells. The demand of platinum exceeds the supply. This will cause problems for fuel cells, which are highly promising energy source for automobiles.

Cost

Hydrogen is an expensive fuel because its cost of production is high.

Use of liquid hydrogen as fuel

Liquid hydrogen is used as an important rocket fuel because of its low mass and high enthalpy of combustion. The chemical reaction involved is:

$$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_l + 286\ KJ$$

Both reactants H2 and O2 are stored as liquids in separate tanks. The advantage of using hydrogen as a rocket fuel is: The product of combustion is water.

There is no emission of environmental pollutants such as CO, SO2, oxides of nitrogen, hydrocarbons, etc. Although during the 'lift off operations, these propellants power shuttle's main engine for about 8.5 min, liquid hydrogen cannot be used much because the extraction of it from water is an expensive procedure

Advantages and disadvantages of hydrogen

Advantages

- Can be produced from water.
- Low environmental impact.
- No carbon dioxide emissions if produced from water.
- Good substance for oil.
- Competitive price if environmental and social costs are included in cost comparisons.

- Easier to store than electricity.
- Safer than gasoline a natural gasoline.
- High efficiency 65-95% in full cells.

Disadvantages

- Not found in nature.
- Energy is needed to produce fuel
- Negative net energy.
- Carbon dioxide emission if produced from carbon containing compounds.
- Non- renewable if generates by fossil fuels or nuclear power.
- High costs.
- Short driving range for current fuel cells cars.
- No fuel distribution system in place
- Excessive hydrogen leaks may deplete ozone.

Key energy trends in India

Demand

- India has been responsible for almost 10% of the increase in global energy demand since 2000. Its energy demand in this period has almost doubled, pushing the country’s share in global demand up to 5.7% in 2013 from 4.4% at the beginning of the century. While impressive, this proportion is still well below India’s near 18% current share of global population, a strong indicator of the potential for further growth.
- Expressed on a per-capita basis, energy demand in India has grown by a more modest 46% since 2000 and remains only around one-third of the world average, slightly lower than the average for the African continent (refer fig.1).
- One reason is that a significant part of the Indian population remains without modern and reliable energy: despite a rapid extension of the reach of the power system in recent years, around 240 million people in India lack access to electricity.

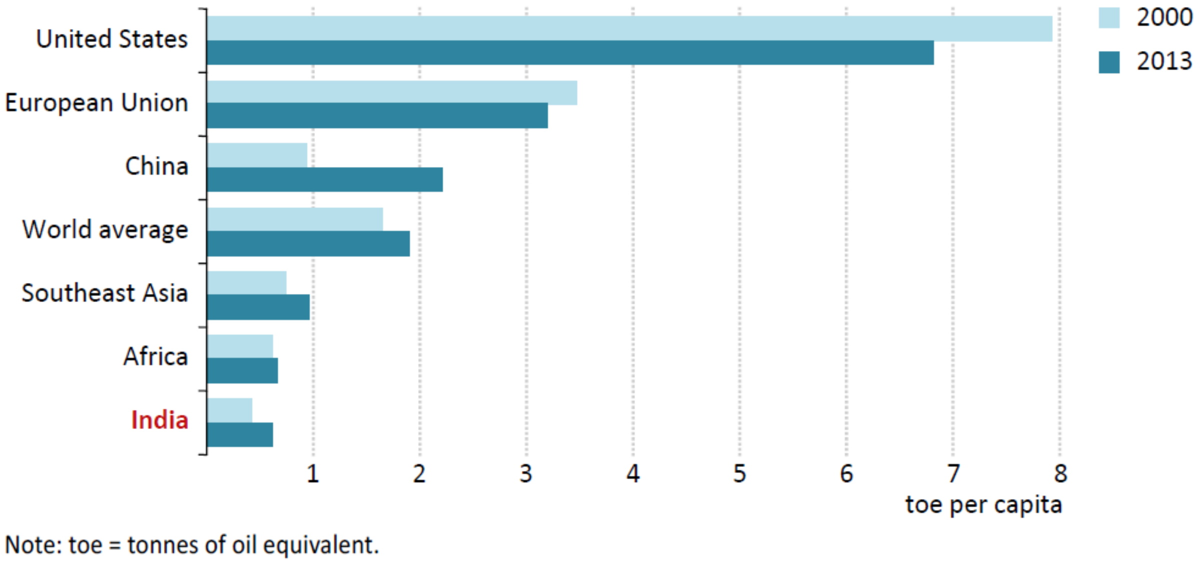


Fig. 1: Per-capita energy consumption in India and selected regions

The widespread differences between regions and states within India necessitate looking beyond national figures to fully understand the country's energy dynamics. This is true of all countries, but it is particularly important in India, both because of its size and heterogeneity, in terms of demographics, income levels and resource endowments, and also because of a federal structure that leaves many important responsibilities for energy with individual states.

Energy demand has almost doubled since 2000, but this is slower than the rate of economic growth over the same period (fig.2). This is due in part to the shift away from bioenergy3 consumption in the residential sector, the rising importance of the services sector in the Indian economy and increased policy efforts directed at end-use energy efficiency.

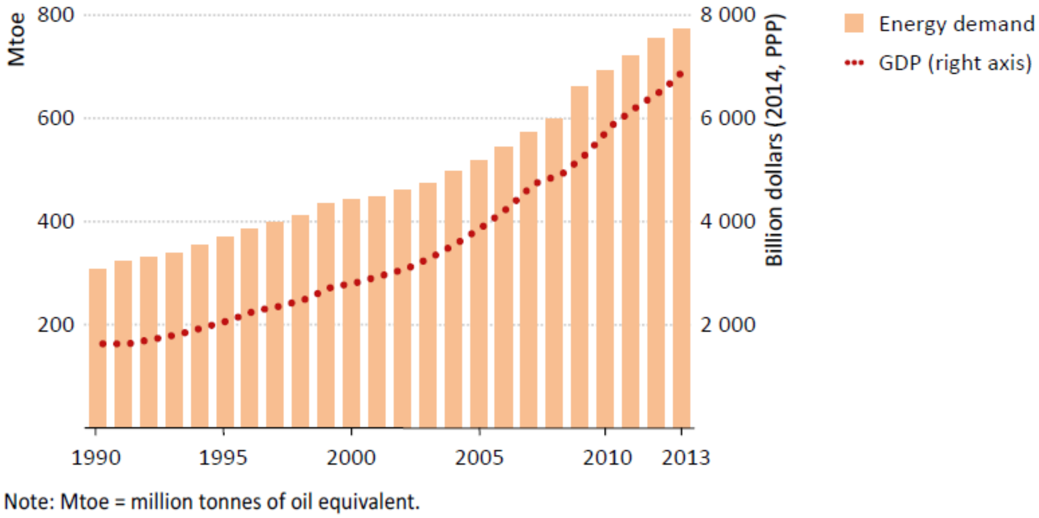


Fig.2: Primary energy demand and GDP in India

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 and a decreasing role for bioenergy, as

Households move away from the traditional use of solid biomass for cooking (Fig.3). Coal now accounts for 44% of the primary energy mix (compared with under a third globally) – mainly because of the expansion of the coal-fired power generation fleet, although increased use of coking coal in India's steel industry has also played a part. The availability and affordability of coal relative to other fossil fuels has contributed to its rise, especially in the power sector. Demand for bioenergy (consisting overwhelmingly of solid biomass, i.e., fuel wood, straw, charcoal or dung) has grown in absolute terms, but its share in the primary energy mix has declined by almost ten percentage points since 2000, as households moved to other fuels for cooking, notably liquefied petroleum gas (LPG).

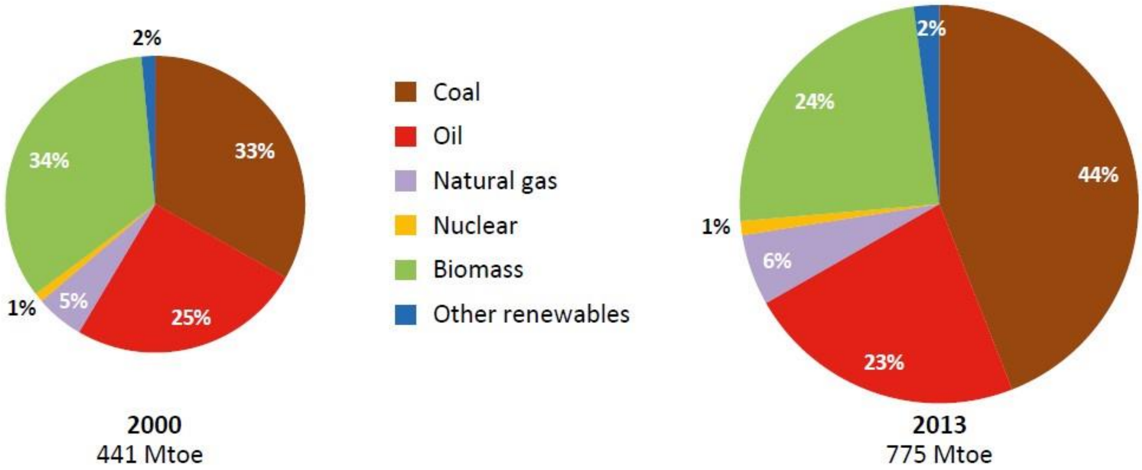
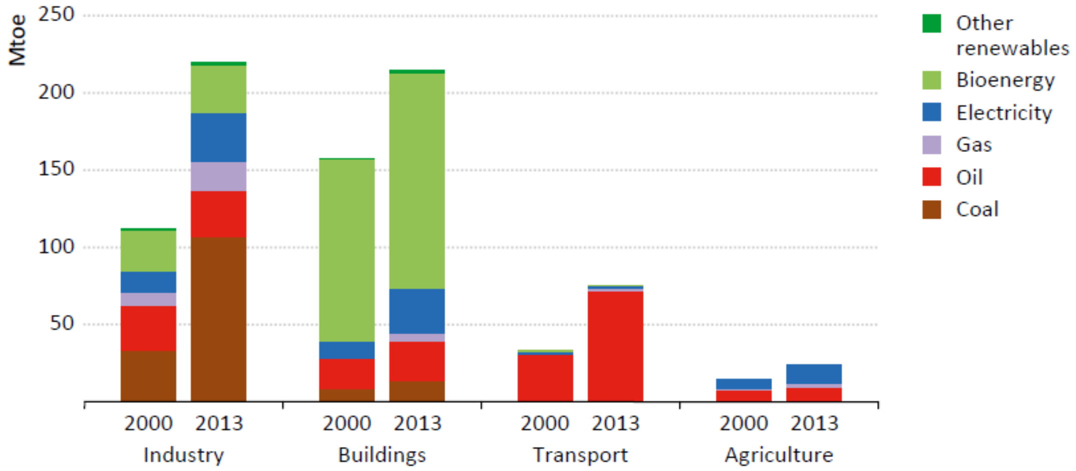


Fig.3: Primary energy demand in India by fuel

Oil consumption in 2014 stood at 3.8 million barrels per day (mb/d), 40% of which is used in the transportation sector. Demand for diesel has been particularly strong, now accounting for some 70% of road transport fuel use. This is due to the high share of road freight traffic, which tends to be diesel-powered, in the total transport use and also to government subsidies that kept the price of diesel relatively low (this diesel subsidy was removed at the end of 2014; gasoline prices were deregulated in 2010). LPG use has increased rapidly since 2000, reaching over 0.5 mb/d in 2013 (LPG is second only to diesel among the oil products, pushing gasoline down into an unusually low third place). The rise in LPG consumption also reflects growing urbanization, as well as continued subsidies. Natural gas makes up a relatively small share of the energy mix (6% in 2013 compared with 21% globally). It is used mainly for power generation and as a feedstock and fuel for the production of fertilizers, although it also has a small, but growing role in the residential sector and as a transportation fuel. 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.

Energy demand had traditionally been dominated by the buildings sector (which includes residential and services) (Fig.4), although demand in industry has grown more rapidly since 2000, overtaking buildings as the main energy user in 2013. In the buildings sector, a key driver of consumption in both rural and urban areas has been rising levels of appliance ownership, especially of fans and televisions, and an increase in refrigerators and air conditioners in urban areas over the latter part of the 2000s. As a result, electricity demand in the buildings sector grew at an average rate of 8% per year over 2000-2013. The share of bioenergy in the buildings sector (mostly the traditional use of biomass for cooking and heating) has declined from 75% of the sector's total consumption in 2000 to two-thirds in 2013, as electricity and oil products have gained ground.



Notes: Other renewables includes solar photovoltaics (PV) and wind. Industry includes energy demand from blast furnaces, coke ovens and petrochemical feedstocks.

Fig.4: Energy demand by fuel in selected end-use sectors in India

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity. Large expansion in the energy-intensive sectors, including a tripling in steel production, is one component. Nonetheless, consumption levels of cement and steel are still relatively low for a country of India's size and income levels: consumption of cement is around 220 kilograms (kg) per capita, well behind the levels seen in other fast-growing economies and a long way behind the elevated levels seen in China in recent years (up to 1 770 kg per capita). The agricultural sector, though a small part of energy demand, is a key source of employment and since 2000 has accounted for roughly 15% of the increase in total final electricity demand as more farmers obtained electric pumps for irrigation purposes.

Over 90% of energy demand in the transport sector in India is from road transport. The country's passenger light-duty vehicle (PLDVs) stock has increased by an average of 19% per year

Since 2000, rising to an estimated 22.5 million in 2013, with an additional 95 million motorbikes and scooters (two/three-wheelers). Yet ownership levels per capita are still very low compared with other emerging economies and well below ownership levels of developed countries (Fig.5). Poor road infrastructure is a major constraint to broader vehicle ownership; according to the World Bank, one-third of the rural population lacks access to an all-weather road, making car ownership impractical – even in cases where it is affordable (World Bank, 2014).

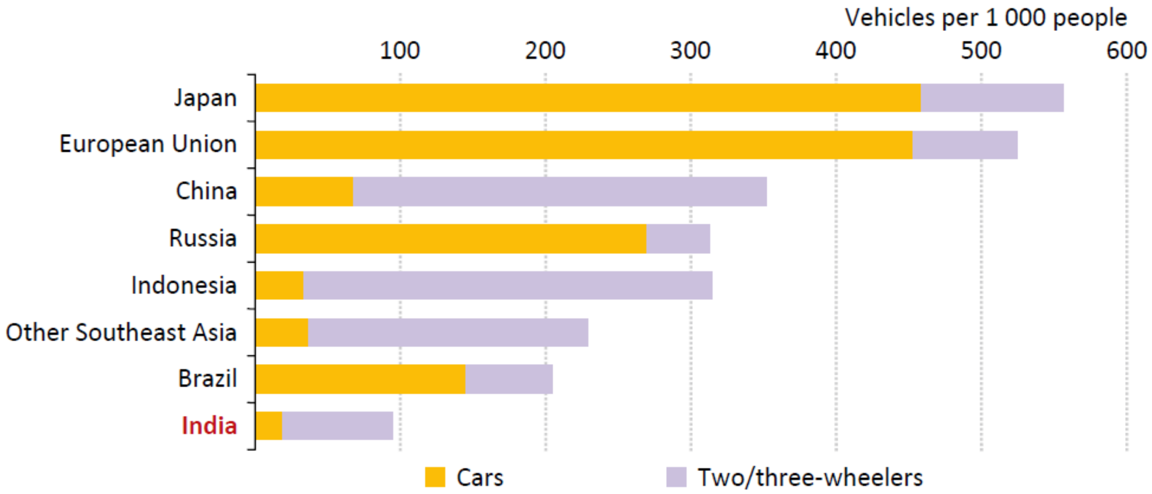


Fig.5: Vehicle ownership in India and selected regions, 2013

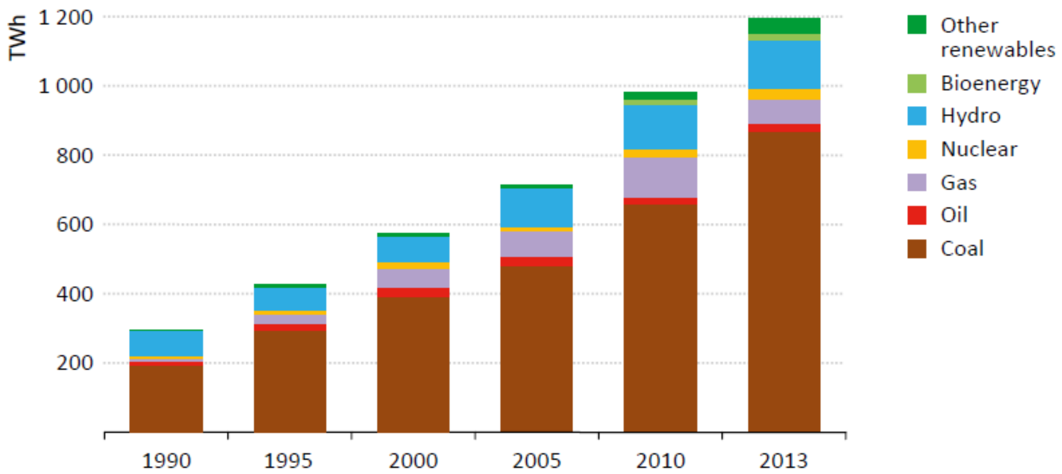
Electricity

The provision of electricity is critical to India's energy and economic outlook and is a major area of uncertainty for the future. 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, an increase of around four percentage points since 2000. As with all other demand sectors, further rapid growth is to be expected: around one-sixth of the world's population in India consumes about one-twentieth of global power output. With continued economic expansion, expanding access to electricity, urbanization, an ever-larger stock of electrical appliances and a rising share of electricity in final consumption, pressures on the power system will persist and increase.

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 (see section on energy prices below). The consequent financial problems faced by local distribution companies are often exacerbated by shortfalls in subsidy compensation payments due from state governments and by poor metering and inefficient billing and collection, creating a spiral of poor performance, Inadequate investment, high transmission and distribution losses and regular power outages. This is a key structural weakness for the energy sector as a whole.

On the supply side, India has some 290 gigawatts (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.6). But, despite the increase in generation, India faces a structural shortage of power. For residential consumers, this constraint is most evident during periods of peak demand, typically in the early evenings as demand for lighting, cooling and other appliances surges (with the result that, where they can afford it, households often invest in small diesel generators or batteries and inverters as back-up).

Industrial consumers are also affected by unreliable and unpredictable power supply: around half of the industrial firms in India have experienced power cuts of more than five hours each week (FICCI, 2012). Elevated end-use industrial tariffs, allied to unreliable supply, lead many industrial and commercial consumers to produce their own electricity, using back-up diesel generators or larger plants (albeit not utility-scale). Energy-intensive industries, such as steel, cement, chemicals, sugar, fertilizers and textiles are key auto-producers, with cement producers, for example, estimated to produce around 60% of the electricity that they consume. This capacity has been growing steadily and is often coal-fired, relatively inefficient compared with utility-scale generation units and under-utilized (many companies need less electricity than their captive plants can produce, but there are obstacles to feeding this excess power into the grid). The increased use of captive generators, both at household and industrial levels, often worsens local air pollution.



Note: Other renewables includes solar PV and wind.

Fig.6: Total electricity generation in India by fuel

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 (Table 1). The population without access is concentrated in a relatively small number of states: almost two-thirds are in two populous northern and north-eastern states, Uttar Pradesh and Bihar. In large swathes of India, including the majority of southern states, electrification rates are already well above 90%. Of the total without access, the large majority – some 220 million people – 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, especially in India's large peri-urban slum areas that are home to around 8.8 million households (National Sample Survey Office, 2014b). 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, as well as questions over the definition of access.

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. Among the issues that have held up progress with electrification is the need to find local solutions adapted to the specific circumstances of the remote settlements without access, and a variety of problems in securing authorization for the necessary projects (e.g., land acquisition and rights-of-way for transmission lines and roads).

Table 2: Number and share of people without access to electricity by state in India, 2013

	Population without access (million)			Share of population without access		
	Rural	Urban	Total	Rural	Urban	Total
Uttar Pradesh	80	5	85	54%	10%	44%
Bihar	62	2	64	69%	19%	64%
West Bengal	17	2	19	30%	7%	22%
Assam	11	0	12	45%	9%	40%

Rajasthan	10	0	11	22%	2%	17%
Odisha	10	0	11	32%	4%	27%
Jharkhand	8	1	9	35%	4%	27%
Madhya Pradesh	7	1	8	16%	3%	12%
Maharashtra	6	2	6	11%	2%	7%
Gujarat	2	0	3	7%	6%	6%
Chattisgarh	2	0	3	14%	6%	12%
Karnataka	1	2	1	5%	1%	3%
Other states	3	16	6	2%	2%	2%
Total	221	16	237	26%	4%	19%

Source: National Sample Survey Office, (2014); Central Electricity Authority, (2014a); IEA analysis.

Aside from those without electricity, India also has the largest population in the world relying on the traditional use of solid biomass for cooking: an estimated 840 million people – more than the populations of the United States and the European Union combined. There is a host of issues associated with the traditional use of solid biomass for cooking, including the release of harmful indoor air pollutants that are a major cause of premature death, as well as environmental degradation as a result of deforestation and biodiversity loss. The government has made a major effort to address these issues, primarily through the subsidized availability of LPG as an alternative cooking fuel (see section below on energy prices).

Energy production and trade

Fossil fuels supply around three-quarters of India's primary energy demand and, in the absence of a very strong policy push in favour of alternative fuels, this share will tend to increase over time as households move away from the traditional use of biomass. This high – and potentially growing – reliance on fossil fuels comes with two major drawbacks. India's domestic production of fossil fuels, considered on a per-capita basis, is by far the lowest among the major emerging economies (Fig.7), meaning that India has a structural dependence on imported supply. In addition, combustion of coal and oil products contributes to pressing air quality problems in many areas, as well as to global greenhouse gas (GHG) emissions.

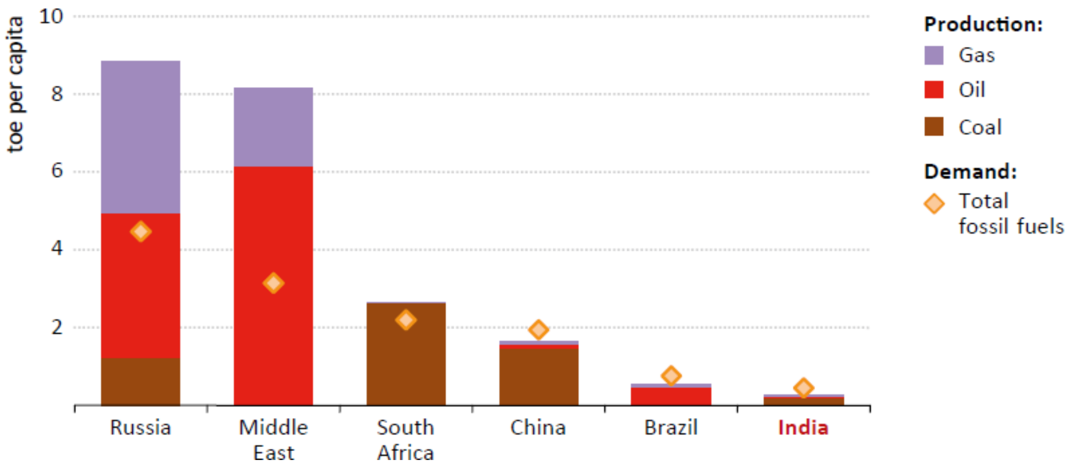


Fig.7: Fossil-fuel production and demand per capita by selected countries, 2013

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 a way that keeps pace with burgeoning domestic needs. In 2013, India produced almost 340 million tonnes of coal equivalent (Mtce), but it also imported some 140 Mtce – roughly 12% of world coal imports (61% from Indonesia, 21% from Australia, 13% from South Africa). With a view to limiting reliance on imports, the government announced plans in early 2015 to more than double the country's coal production by 2020.

The coal sector in India is dominated by big state-owned companies, of which Coal India Limited (CIL) is the largest, accounting for 80% of India's output. CIL has an unwieldy structure and is characterized by poor availability of modern equipment and infrastructure, an over-reliance on surface mining and very low productivity from a very large workforce. Around 7% of national production comes from captive mining, i.e. large coal-consuming companies that mine for their own use; private companies are not at present allowed to mine and market coal freely, though there are now some moves to open the coal market. At present, more than 90% of coal in India is produced by open cast mining. This method has relatively low production costs and is less dangerous than deep mining, but has a large, adverse environmental footprint in the form of land degradation, deforestation, erosion and acid water runoff.

Among the other problems facing the Indian coal sector is a mismatch between the location of hard coal reserves and mines, which are concentrated in eastern and central India, and the high-demand centres of the northwest, west and south. A ton of coal must travel on average more than 500 kilometres (km) before it is converted to electricity, straining the country's rail network. There are also challenges related to the quality of the coal reserves. Most of the hard coal has low to medium calorific values and high ash content. The low heat value means that more coal must be burned per unit of electrical output, leading to higher local emissions. The ash content increases the cost of transporting coal, is corrosive and lowers the efficiency and load factor of coal-fired power plants. In addition, most power plants are designed for a specific coal quality; if not available, operators may choose to blend different coal types, which can adversely impact the performance of the power plant, as the properties of blends can vary widely.

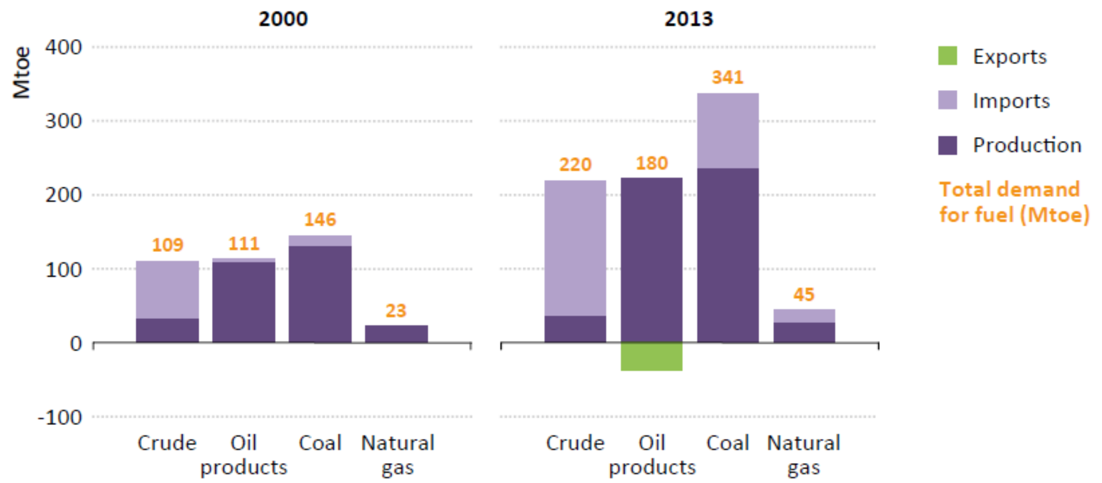
The difficulty in expanding coal production in recent years has been related to a number of factors, including delays in obtaining environmental permits, land acquisition and rehabilitation and resettlement issues, infrastructure constraints (limited transport capacity to connect mines, dispatch centres and end-use destinations), insufficient coal-washing facilities to remove the ash and technological limitations (notably for underground mining). Other questions concerning future supply have arisen as a result of a Supreme Court decision in 2014 to annul the award of almost all of the coal blocks allocated since 2003 on the grounds that these awards had not been made on a transparent and competitive basis, although this has also opened an unexpected opportunity for the government to reform the coal sector in order to comply with the judgement. Two successful rounds of bidding have already been held to re-allocate some blocks and there is a possibility that private companies may be invited to participate in future rounds.

Oil and oil products

India is one of the few countries in the world (alongside the United States and Korea) that rely on imports of crude oil while also being significant net exporters of refined products (Fig.8). Domestic crude oil production of just over 900 thousand barrels per day (kb/d) is far from enough to satisfy the needs of 4.4 mb/d of refinery capacity. The output from the refinery sector, in turn, is more than enough to meet India’s current consumption of oil products, at around 3.8 mb/d (with the exception of LPG, for which India imports about half of domestic consumption).

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. The Assam-Arakan basin in the northeast is also an oil-producing basin and contains nearly a quarter of total reserves. Despite efforts to bolster oil production, including the opening of India’s upstream sector to non-state investors, the sector has underperformed. Key impediments to investment include the complex regulatory environment (including uncertainty over contract terms and pricing arrangements), and a resource base that is still not well-explored and appraised. The upstream is still dominated by a few state-owned companies: about two-thirds of crude oil is produced by the Oil and Natural Gas Corporation Limited (ONGC) and Oil India Limited (OIL) under a pre-liberalization nomination regime. Most of the remaining production comes from joint ventures with the national oil and gas companies and from blocks awarded under successive licensing rounds held under the New Exploration Licensing Policy introduced in 1999.

By contrast, the refining sector continues to strengthen. 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 from companies such as Reliance and Essar (India is now fourth in the world in terms of total refining capacity, behind only the United States, China and Russia). India's refinery assets include the largest refinery in the world, Reliance's Jamnagar complex, with over 1.2 mb/d of throughput capacity (more than India's domestic crude production). These capacity additions have given India a surplus of refined products, as the growth in oil product demand growth, even at an impressive 4.2% average annual rate, has been slower than the capacity boom.



Note: Demand for crude oil shows refinery intake.

Fig.8: Fossil-fuel balance in India

The refining capacity expansion, along with stagnant domestic crude oil output, means that India has become the third-largest crude oil importing country, behind the United States and China, with about 3.7 mb/d of import requirements (overall, India must import feedstock to meet 80% of its refinery needs for crude oil). The majority of ports that handle imported crude oil are located on the western side of India to accommodate oil tankers from the Middle East (the largest source of imports), Latin America and Africa. India has sought to diversify its sources of supply, especially as disruptions have plagued several of its suppliers such as Iran, Libya and Nigeria. The government announced in March 2015 a strategic aim to reduce reliance on imported crude by as much as 10% by 2022. The fall in the price of crude oil has also offered a cost-effective opportunity to build up emergency stockpiles of crude. With the expected completion of additional storage facilities for the

Strategic petroleum reserve expected in late 2015, India will have a combined storage capacity of about 37 million barrels, or roughly ten days' worth of crude imports. With refinery output exceeding total demand by roughly 1 mb/d, India is a net exporter of all refined products except LPG. India has been an important supplier of diesel to Europe and a regular supplier of transport fuel to Asia-Pacific and Middle Eastern countries. Its exports come mainly from the private sector refiners Reliance and Essar, while the public sector refiners supply the domestic market. Growing product exports from India have contributed to refinery capacity rationalisation in both European and Asia-Pacific markets, as India's more modern, privately owned refineries, which are capable of efficiently processing Middle Eastern oil into high quality products, were able to gain market share from less complex refineries in Europe and Japan.

Natural gas

Natural gas has a relatively small share (6%) of the domestic energy mix. Optimism about the pace of expansion, fueled by some large discoveries in the early 2000s, has been dashed by lower-than-expected output from offshore domestic fields. The main onshore producing fields are in the states of Assam in the northeast, Gujarat in the west and Tamil Nadu and Andhra Pradesh in the south. Some of the most promising areas are offshore, including the Krishna Godavari basin off the east coast. The production record in recent years has been strongly affected first by the start of production at the much-awaited KG-D6 offshore field in 2009, and then by it's faster than expected decline because of reported subsurface complexity. This has contributed to an overall decrease in Indian gas output since 2011. Production of conventional gas reached 34 bcm in 2013 and was supplemented by LNG imports via four regasification terminals. The majority state-owned gas company, GAIL, is the largest player in the midstream and downstream gas market.

In addition to conventional gas resources, India also has large unconventional potential, both from coal bed methane (CBM) and shale gas. Commercial production at scale is still some way off, although CBM activity is starting to gain momentum, with a number of private companies, including Reliance and Essar, stepping up their involvement. In the case of shale gas, the government approved in 2013 an exploration policy that allows the two national companies – ONGC and OIL – to drill for shale resources in their existing blocks. However, upstream gas development in India continues to face a number of significant hurdles: a key issue is the price available to domestic producers.

Hydropower

India has significant scope to expand its use of hydropower: its current 45 GW of installed capacity (of which over 90% is large hydro) represents a little under a third of the assessed resource. Much of the remaining potential is in the north and northeast. A further 14 GW are under construction, although some of these plants have been delayed by technical or environmental problems and public opposition. If developed prudently, hydropower can bring multiple benefits as a flexible source of clean electricity, and also as a means of water management for flood control, irrigation and domestic uses. It can also enable variable renewables to make a greater contribution to the grid. However, its development has lagged well behind thermal generation capacity, leading to a consistent decline in its share of total electricity output. Capacity additions and generation have routinely fallen short of the targets set in successive government programmes, while the objective of bringing in private investors has likewise proved difficult to realise.

High upfront costs, the need for long-term debt (which is quite limited in India's capital markets) and consequent difficulties with financing have been a major impediment to realising India's hydropower potential. Much of the potential is in remote areas, necessitating new long-distance transmission lines to bring power to consumers. Adequate and efficient project planning and supervision is another hurdle, notably the challenge of evaluating and monitoring environmental impacts (including long-term water availability and potential seismic risks), ensuring adequate public involvement and acceptance, and assessing the effect of multiple projects (often in different states) on individual river systems. Some hydropower projects have faced very long environmental clearance and approval procedures, as well as significant public opposition arising largely from resettlement issues and concern over the impact on other water users. Some of these concerns can be reduced by undertaking small-scale projects: India has an estimated potential 20 GW of small hydro projects (up to 25 megawatt [MW] capacity) (MNRE, 2015). As of 2014, 2.8 GW of small hydro (less than 10 MW) had been developed.12 Such projects are particularly well-suited to meet power requirements in remote areas.

Bioenergy

Bioenergy accounts for roughly a quarter of India's energy consumption, by far the largest share of which is the traditional use of biomass for cooking in households. This reliance gives rise to a number of problems, notably the adverse health effects of indoor air pollution. India is also deploying a range of more modern bioenergy applications, relying mainly on residues from its large agricultural sector. There was around 7 GW of power generation capacity fuelled by biomass in

2014, the largest share is based on bagasse (a by-product of sugarcane processing) and a smaller share is cogeneration based on other agricultural residues. The remainder produce electricity via a range of gasification technologies that use biomass to produce syngas, including small-scale thermal gasifiers that often support rural small businesses. Although modern bioenergy constitutes only a small share of energy use at present, Indian policy has recognised – with the launch of a National Bioenergy Mission – the potential for modern bioenergy to become a much larger part of the energy picture especially in rural areas, where it can provide a valuable additional source of income to farmers, as well as power and process heat for consumers.

Biofuels are another area of bioenergy development in India, supported by an ambitious blending mandate, dating back to 2009, that anticipates a progressive increase to a 20% share for bioethanol and biodiesel by 2017. Implementation has thus far been slower than planned: the present share of bioethanol – mostly derived from sugarcane – remains well under 5% and progress with biodiesel has been even more constrained. The main concern over biofuels – and some other forms of bioenergy – is the adequacy of supply: land for biofuels cultivation can compete with other uses, as well as requiring water and fertilisers that may be limited and is required in other sectors.

Wind and solar

From a low base, modern renewable energy (excluding hydropower) is rapidly gaining ground in India's energy mix as the government has put increasing emphasis on renewable energy, including grid-connected and off-grid systems. Wind power has made the fastest progress and provides the largest share of modern non-hydro renewable energy in power generation to date. India has the fifth-largest amount of installed wind power capacity in the world, with 23 GW in 2014, although investment has fluctuated with changes in subsidy policies at national and state level. Key supporting measures have included a generation-based financial incentive (a payment per unit of output, up to certain limits) and an accelerated depreciation provision. A scheme of renewable purchase obligations also exists, requiring that a certain percentage of all electricity should be sourced from wind, solar and other renewables, but the operation of this scheme has been undercut (and not enforced in some cases) by the financial state of many distribution companies.

Solar power has played only a limited role in power generation thus far, with installed capacity reaching 3.7 GW in 2014, much of this added in the last five years. However, India began to put a much stronger emphasis on solar development with the launch in 2010 of the Jawaharlal Nehru National Solar Mission, the target of which was dramatically upgraded in 2014 to 100 GW of solar installations by 2022, 40 GW of rooftop solar photovoltaic (PV) and 60 GW of large- and medium-scale grid-connected PV projects (as part of a broader 175 GW target of installed renewable power capacity by 2022, excluding large hydropower). The dependence of national targets on supportive actions taken at state level is underlined by the fact that four states (Gujarat, Rajasthan, Madhya Pradesh and Maharashtra) account for over three-quarters of today's installed capacity. Rooftop solar also has the potential to become a more important part of India's solar portfolio, particularly where it can minimize or displace expensive diesel-powered back-up generation.

While the promise is undeniable, renewable energy faces, like other energy source, structural, governance and institutional challenges. Though costs for solar and wind are declining, in most cases the technologies do not yet warrant investment in India (as in most other countries) without some form of subsidy. Fiscal incentives and policy support are strong at the moment, but this is a source of uncertainty, especially when juxtaposed with the financial difficulties faced by local distribution companies that are often obliged to absorb the extra cost. The need for land and additional transmission and distribution infrastructure (which India is trying to address via the concept of "green energy corridors") could likewise constrain progress. Given the priority in Indian policy to develop the domestic manufacturing sector, the outlook is also contingent to a degree on the local availability of equipment, such as solar panels and wind turbines, where India has lost

Ground to lower cost producers. In China, for example, the cost of locally produced solar modules and cells is 25-50% lower than in India.

Nuclear power

India has twenty-one operating nuclear reactors at seven sites, with a total installed capacity close to 6 GW. Another six nuclear power plants are under construction, which will add around 4 GW to the total. The operation of the existing nuclear fleet has been constrained in the past by chronic fuel shortages, in 2008 the average load factor was as low as 40%. This constraint was eased after India became a party to the Nuclear Suppliers' Group agreement in 2008, allowing access not only to technology and expertise but also reactor parts and uranium. The average plant load factor rose to over 80% in 2013 (DAE, 2015).

Though the current share of nuclear power in the generation mix is relatively small at 3%, India has ambitious plans to expand its future role, including a long-term plan to develop more complex reactors that utilize thorium – a potential alternative source of fuel for nuclear reactors. India has limited low-grade uranium reserves, but it has the world's largest reserves of thorium: developing a thorium fuel cycle will though require a range of tough economic, technical and regulatory challenges to be overcome.

The nuclear industry in India is also subject to the broader challenges that are facing the worldwide nuclear industry, including project economics, difficulties with financing and the implications of the Fukushima Daiichi accident in Japan for public acceptance of new projects. India has struggled to attract the necessary investment and to gain access to reactor technology and expertise, with the Civil Liability Nuclear Damage Act of 2010 widely seen as deterring potential suppliers (especially Japanese and US companies). However, the United States and India reached an understanding on nuclear liability issues early in 2015 that may facilitate US investment in Indian nuclear projects.

Factors affecting India's energy development

Economy and demographics

The pace of economic and demographic change is a vitally important driver of India's energy sector. Since 1990, 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 (if both these countries are excluded). This propelled India beyond Japan in 2008, to become the third-largest economy in the world, measured on a PPP basis. India alone has accounted for over 9% of the increase in global economic output since 1990.

In the period since the early 1990s, the poverty rate (measured as the proportion of the population making less than $1.25/day in PPP terms14) fell by more than half, from almost 50% to less than 25%. In the eight years 2004-2011, more than 180 million people in India were lifted out of extreme poverty. Despite this progress, income per capita is still low and a gap has emerged between India and its counterparts among the BRICS (Brazil, Russia, India, China and South Africa). Though starting off at similar levels in the early 1990s (in PPP terms), average income per capita in China is now more than double that in India (Fig.9). Furthermore, although extreme poverty has been reduced, income inequality has increased in India, with the poorest quartile of society earning a smaller share of total income than they did in 1990.

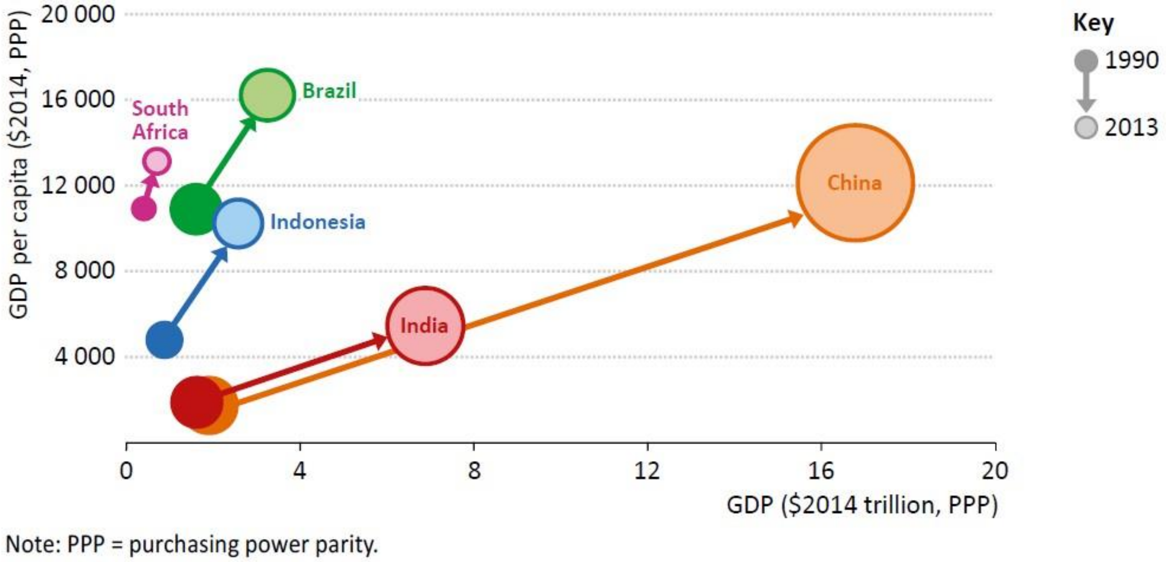


Fig.9: GDP per capita and total GDP for selected countries, 1990 and 2013

The 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. This is rooted both in a robust increase in the supply of services but, crucially, also in the increasing share of high-value segments including financial intermediation, information and communications technology, and professional and technical services, which have enabled total factor productivity in the services sector to more than double. However, despite its dominant share in the economy, 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 (Fig. 10).

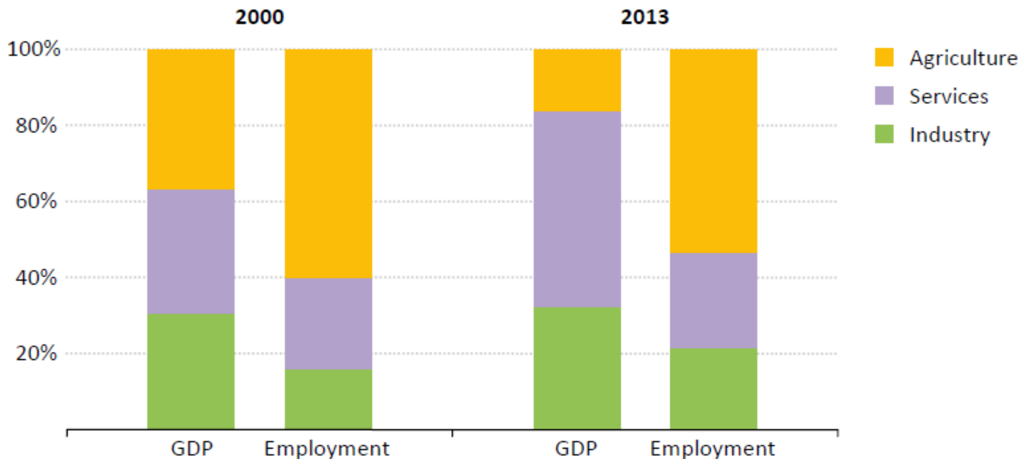


Fig.10: Composition of GDP and employment structure in India

The services-led growth that India has enjoyed since the early 1990s differs from the path of economic development in many other countries, since it was not preceded by an initial strong push from the manufacturing sector. The government has expressed its intention to re-balance the economy and in 2014 announced the "Make in India" initiative, with the intention of increasing the share of manufacturing in GDP to 25% by 2022, creating 100 million jobs in the process. The extent to which this objective is realised will affect India's energy development in two ways. First, mining, oil and gas, renewables and power generation have all been identified as clusters for industrial development, so any success will have implications for energy supply. Second, any change in the share of industry in the economy, and the materials-intensity of future economic growth, will have profound effects on the levels of energy demand. Urbanization and the build-up of a manufacturing base, including the necessary energy infrastructure, will require significant inputs from the basic materials industry, including steel, cement and chemicals, which are all highly energy-intensive.

Since 1990, India's population has grown by over 380 million people, a number greater than the total population of the United States and Canada together. This includes a near-doubling of the urban population, reflecting the transition away from agricultural employment. Population growth is expected to remain high; India is set to overtake China as the most populous country in the world before 2025 (UNPD, 2015). India's large and growing population is often regarded as one of its major assets; it is relatively young, with almost 60% (around 700 million people) under the age of 30, a large and potentially very vibrant workforce. The large domestic market can also act as a natural driver for economic growth, with levels of private consumption currently around two-and-a-half-times as large as exports. The flip side of this demographic dividend is the likely strain on the country's infrastructure and resources. Water stresses that are already evident in some regions will be exacerbated and create new challenges in relation to food and energy security, and there will be a need to create one million new jobs each month to absorb the new entrants to the labour market.

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. Clarity of vision for the energy sector is difficult to achieve in India, not least because of the country's federal system and complex institutional arrangements. However, the drive for a more coherent and consistent energy policy has been a long-standing priority, typified by the Integrated Energy Policy 2008, the National Action Plan on Climate Change and the co-ordination efforts of the Planning Commission (now the National Institution for Transforming India, [NITI Aayog]), all aided by consistent improvements in the quality of Indian energy data. An energy scenario modelling exercise has also been launched, the India Energy Security Scenarios, overseen by NITI Aayog. More recently, the submission of India's Intended Nationally Determined Contribution (INDC) on 1 October 2015 was a milestone in both India's energy and its environmental policy.

India shares the overarching aim of energy policy throughout the world: to provide secure, affordable and universally available energy as a means to underpin development, while addressing environmental concerns. The administration in place since 2014 has given greater definition to many aspects of energy policy, while also seeking to give more rights and responsibilities to the individual states. 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. In the power sector, the decision to increase the target for renewables to 175 GW by 2022 (including the expansion of solar generation capacity to 100 GW) has attracted a lot of attention; but there is also, for example, a volumetric target for India to produce 1.5 billion tonnes of coal by 2020. Efficiency gains as well as production increases underlie India's energy security objective of reducing reliance on fossil-fuel imports by 10%.

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. This is being accompanied by a reorientation of energy subsidy programmes, away from price controls and towards financial payments to the most vulnerable parts of society.

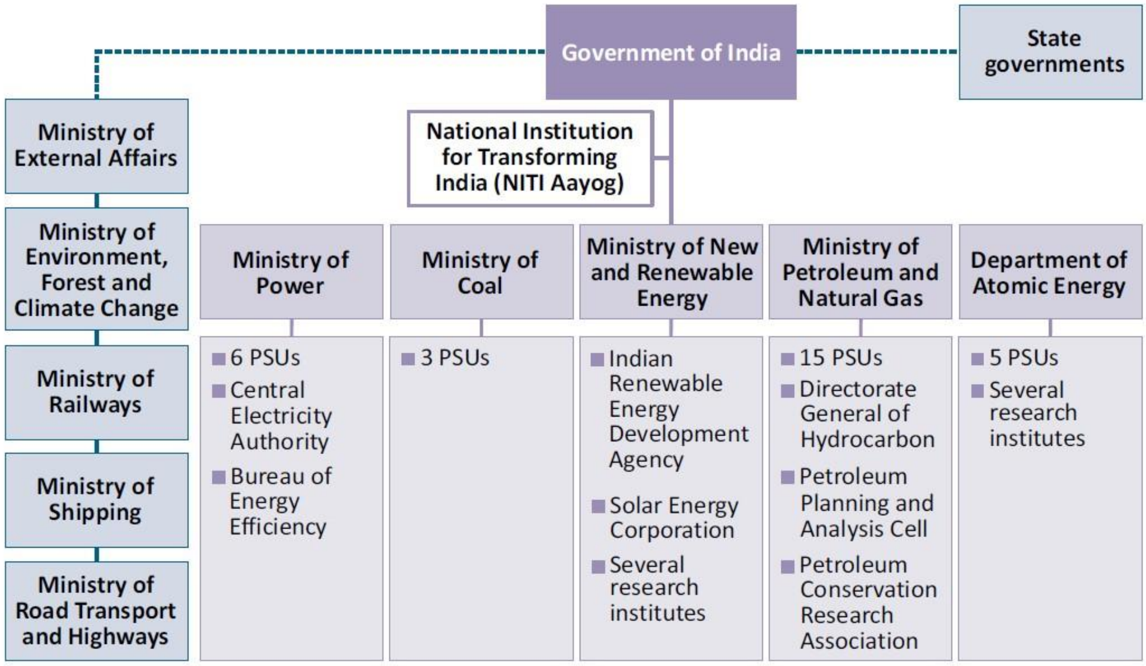
A drive for market-oriented solutions and increased private investment (including foreign investment) in energy, both through some energy-specific reforms (e.g., to licensing regimes) and via a general drive to simplify and deregulate the business environment. A pledge to pursue a more climate-friendly and cleaner path than the one followed thus far by others at corresponding levels of economic development. India's INDC includes the twin energy-related commitments to increase the share of non-fossil fuel power generation capacity to 40% by 2030 (with the help of transfer of

Technology and low-cost international finance) and to reduce the emissions intensity of the economyby 33-35% by the same date, measured against a baseline of 2005.

Achievement of these aims is naturally contingent on the broader political and institutional context. India is a federal, democratic country in which regional and local politics and governments play a very important role, via the 29 constituent states and 7 union territories (their role is reflected in the bi-cameral national parliamentary structure, where the lower house, elected by direct popular vote, sits alongside an upper house, representing the states and territories). The constitution divides power between the central and state governments, as well as defines a category of subject areas for which there are concurrent responsibilities. The central government has exclusive competence over inter-state trading and commerce, as well as mineral and oil resources, nuclear energy and some national taxes, e.g., on income. States have jurisdiction over water issues and land rights, natural gas infrastructure, and many specific areas of taxation, e.g., on mineral rights or the consumption or sale of electricity. Concurrent powers include electricity and forestry, as well as economic and social planning, and labour relations.

India's federal structure puts a premium on constructive relations between states and the central government, but also risks duplication and inconsistent decision-making. The model being promoted by the new administration is one of co-operative federalism, which involves increased devolution in certain areas (e.g., a higher regional share of hydrocarbon revenues in some cases) as well as a wider set of regional responsibilities (e.g., for timely implementation and approval of the state-level clearances required for investment projects). There is also a greater accent on tailoring policies and resource use, particularly in the power sector, to the specificities of individual regions and states. Maintaining independent regulatory bodies, free of political interference (for example, as envisaged in the 2003 legislation reforming the power sector), is a challenge at all levels.

The risk of fragmented decision-making also applies at the national level itself, as there is no single body charged with formulating and implementing a unified energy policy. India has several ministries and other bodies, each with partial responsibility for aspects of energy policy and the related infrastructure (Fig.11). Effective co-ordination has been improved by the appointment of a single Minister for Power, Coal, New and Renewable Energy, although the individual ministries themselves continue to exist as separate entities. The institutional structure requires constant effort – not always successful – to achieve co-ordination and resolve disputes.



Notes: PSU = Public sector undertaking (state-owned enterprise). Other ministries with responsibilities relevant to the energy sector include the Ministry of Urban Development, Ministry of Water Resources, Ministry of Agriculture, Ministry of Finance and the Department of Science and Technology.

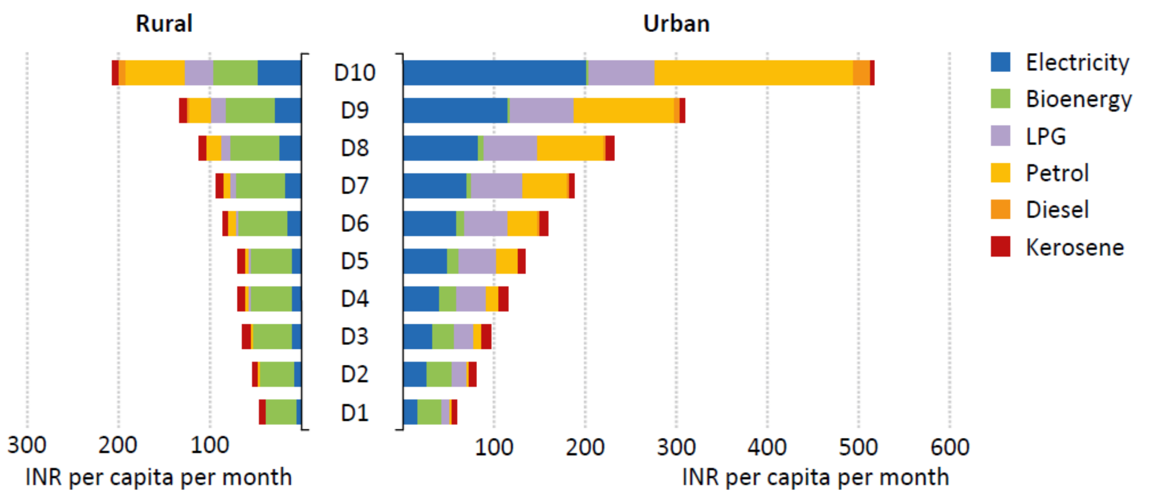
Source: Adapted from (IEA, 2012).

Fig.11: Main institutions in India with influence on energy policy

Energy prices and affordability

Expenditure

The relationship between income levels, energy prices and energy expenditure is fundamental to the evolution of India's energy system. As one would expect, energy consumption increases with income, with the wealthiest 10% of the population accounting for around a quarter of all household energy expenditure, although the poorest segments spend a greater proportion of their income on energy. But the 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, and the most affluent among the urban population spend more than eight-times as much on energy as the poorest, whereas in rural areas they spend four-and-a-half-times as much (Fig.12).



Notes: INR = Indian rupees. The income ranges are by decile (i.e. 10% slices) of the rural and urban population, with D10 being the most affluent 10% and D1 the poorest.

Source: Ministry of Statistics and Programme Implementation (2012).

Fig.12: Per-capita energy expenditure by location and income in India

The expenditure pattern across the income groups reflects both an increase in energy consumption as people become more affluent and a switch in fuels, away from bioenergy and kerosene and towards LPG and electricity. In urban areas, spending on bioenergy and kerosene decreases drastically higher up the income groups. Bioenergy and kerosene account for almost 60% of energy expenditure among the poorest income group, but only roughly 1% among the wealthiest group in which 85% of energy expenditure is for electricity and transport fuels.

The pattern is different in rural areas. Here, spending on bioenergy increases as income increases (for all but the wealthiest 20%), driven by a rise in consumption, but also because the poorer segments of society typically collect fuel wood rather than pay for it, an inclination that gradually decreases with increasing levels of wealth. The pattern of expenditure of the most affluent decile in rural areas is significantly different from that of lower income groups, resembling the switch that is observed in urban centres, albeit in a more limited way. Across income levels, rural spending on electricity accounts for around 20% of energy expenditure (compared with almost 40% in urban areas). Rural expenditure is constrained by a lack of access, particularly among the poorest segments of rural communities.

Energy prices

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, and successive governments have made efforts to ensure that electricity and natural gas prices better reflect market realities. End-use electricity tariffs for most consumers nonetheless remain below the cost of supply. Reform of kerosene and LPG pricing has been much slower, reflecting the role that these fuels play in providing

Lighting and cooking fuels to the poorest segments of society. As a major consumer and importer ofoil, India has also been one of the main beneficiaries of the fall in the oil price since 2014.

Diesel is the most widely consumed petroleum product in India, accounting for around 40% of total oil product consumption. In 2002-2010, the price of diesel was, on average, 70% that of gasoline and this price gap widened when gasoline prices were deregulated in 2010. Price differentials have recently lessened with the removal of diesel subsidies, resulting in diesel consumption flattening as consumer preferences shift towards gasoline (Fig.13). During the period in which transport fuels were subsidized, the benefits accrued disproportionately to the wealthiest strata of society: prior to the deregulation of diesel prices, the bottom two income deciles benefited to the tune of 20 Indian rupees (INR) per capita per month on average from subsidies, while the top two deciles received around INR 120 per capita per month (Anand, 2013). Where subsidies to oil product consumption remain, as in the case of LPG, the government is committed to make them more efficient: the "Aadhaar" system, coupled with recent efforts to spread banking service access to all, will increasingly allow the authorities to make a monetary payment directly to eligible consumers, after they have purchased gas cylinders at market prices. The government also launched a "Give it up" campaign to encourage the wealthiest consumers to abandon their LPG subsidy. As of September 2015, over three million Indians had voluntarily given up the subsidy.

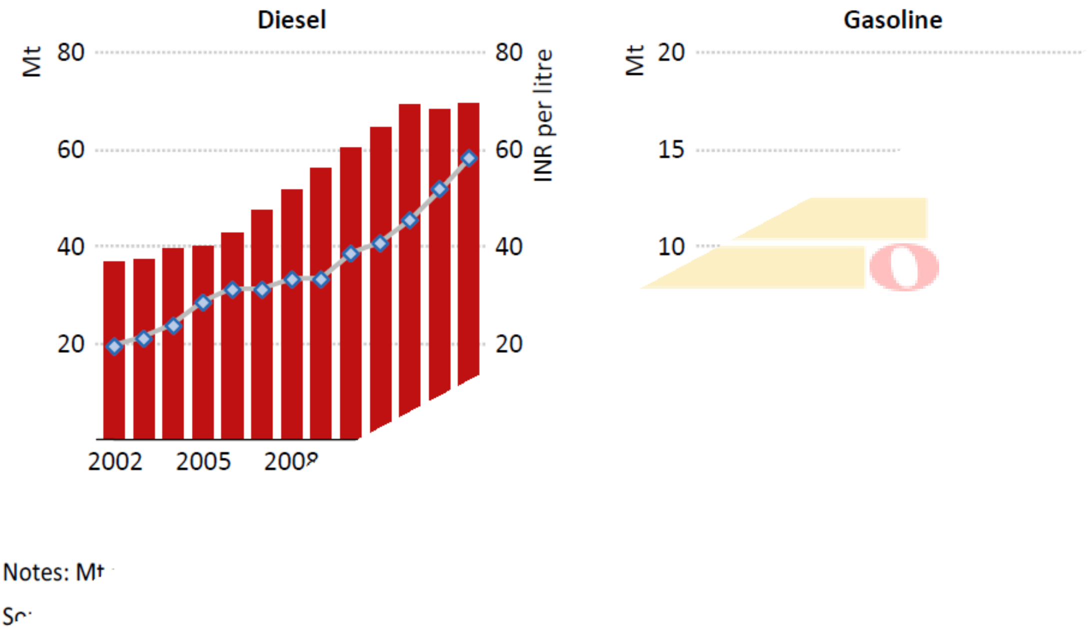


Fig.13: Diesel and gasoline prices and demand, 2002-2014

The Indian gas market consists of two segments: for domestically produced gas, the price is defined by the government, as are the priority uses (city gas for households and transport, fertiliser plants, grid-connected power plants) which are entitled to gas at this lower price. After a long debate, in October 2014 the government introduced a new pricing formula, linked to a basket of international prices and applicable to most domestically produced gas; this resulted in a price increase from the earlier $4.2 per million British thermal units (MBtu) to around $5.6/MBtu, although this has since come down because of the subsequent fall in the reference prices. The new arrangements have kept the price in a range acceptable to domestic gas-consuming sectors, but many gas-producing companies argue that they do not offer sufficient incentive to bring forward new investment in exploration and production in India, particularly in offshore blocks (see Chapter 3). Imported LNG is available at contracted prices that can be significantly higher; there have been proposals to pool LNG with domestically produced gas to make it more accessible to domestic users as well as a subsidy scheme to increase consumption of imported LNG in the power sector.

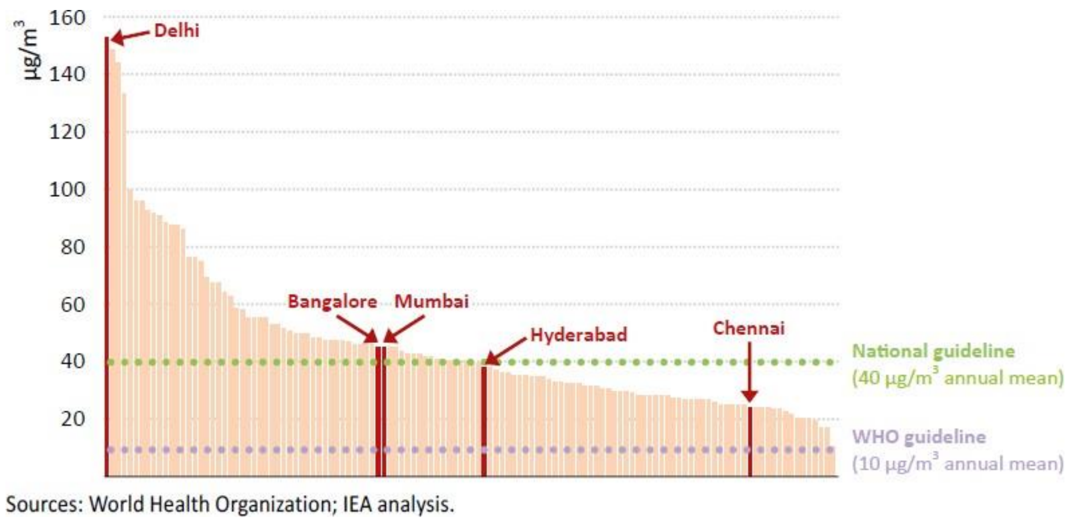
The consumption changes spurred by the recent increase in diesel prices relative to those of gasoline reflect the conventional wisdom that higher prices can act as a brake on demand, spurring consumers to switch fuels, reduce their consumption or opt for more efficient technologies. The inverse relationship, where low tariffs lead to inefficient use of both electricity and water, is evident in the agricultural sector, which accounts for more than one-fifth of final electricity consumption but only 8% of revenue for the utilities.

Social and environmental aspects

Local air pollution

Rapid economic growth and urbanisation create a number of pressures on communities and the wider environment. These can originate from the need to meet growing demand for energy and minerals that increase competition for land, water and other resources, as well as the polluting by-products of the subsequent growth. 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 (PM2.5) and Sulphur and nitrogen oxides, into the air.

In addition to the problem of indoor air pollution linked to the traditional use of biomass as a cooking fuel, the deteriorating air quality in growing urban centres is becoming an alarming issue for India (Fig.14). Of the 124 cities in India for which data exist, only one, Pathanamthitta (with a population of 38000), meets the World Health Organization guideline for PM2.5 concentrations. Delhi exceeds this guideline by fifteen-times. India has 13 of the world’s 20 most-polluted cities and an estimated 660 million people in areas in which the government’s own national air quality standards are not met. It is estimated that life expectancy, as a result, is reduced by 3.2 years for each person living in these areas.



$PM_{2.5}$ refers to particulate matter less than 2.5 micrometres in diameter; these fine particles are particularly damaging to health as they can penetrate deep into the lungs when inhaled.

Fig.14: Average annual particulate matter concentration in selected cities in India

Land

The welfare of India's rural population, which is 850 million strong and accounts for almost 70% of the total 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 fraught with social and political sensitivity. Legislative changes introduced in 2013 introduced stringent procedural requirements for land acquisition, defining compensation payments and rehabilitation and resettlement benefits and stipulated those potential developers in the private sector would need to secure the consent of 80% of affected families in the case of land acquisition (70% for acquisitions by public-private partnerships). There have since been attempts to amend this legislation, but finding an appropriate balance between the drive to push ahead with infrastructure projects, on the one hand, and the rights of local communities, especially farmers, on the other, is proving difficult. In the absence of a resolution to this issue, obtaining the required statutory clearances related to community rights, environmental protection and sustainable development has been a major cause of delay. At end-2014, infrastructure projects valued at around 7% of GDP were stalled for these reasons (OECD, 2014). Projects in the energy sector are particularly susceptible to delay: detailed analysis of projection applications showed that the clearance process for some 40-60% of projects in thermal power, hydropower, coal mining and nuclear power sectors went beyond the statutory time limits (Chaturvedi et.al, 2014).

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. With renewable water resources of some 1 130 cubic metres per capita in 2013, India has now passed the defined threshold for "water stress" (1 700 cubic metres per capita). This has major implications for the energy sector: more than 70% of India's power plants, for example, are located in areas that are water stressed or water scarce (WRI, 2014) and India's warm temperatures and the poor quality coal used in the bulk of its power plants add to their cooling requirements. Global climate change could exacerbate these stresses.

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: in 2010, more water was withdrawn in India for agricultural use alone than for all purposes in China. A number of national and state-level initiatives have sought to encourage more efficient water use, via metering, tariff reform (linked to more reliable supply) and changes to agricultural practices. Plans to introduce more efficient equipment, including solar-powered groundwater pumps, while relieving some pressures on the grid, could reduce incentives for water conservation unless they are accompanied by the introduction of systems that use water more efficiently, such as drip irrigation networks.

Carbon-dioxide emissions

India's CO_2 emissions can be seen through two lenses. Calculated on a per-capita basis, emissions are extremely low, standing at just one-quarter of China's and the European Union's and one-tenth the level in the United States (Fig.15), while India also accounts for only a small share of cumulative historical GHG emissions. On the other hand, India is the third-largest country in volume terms of CO_2 emissions in the world, behind only China and the United States. Heavy dependence on coal for power generation and the use of inefficient subcritical plants to burn it push up the carbon intensity of India's power sector to 791 grammes of carbon dioxide per kilowatt-hour (g CO_2/kWh), compared to a world average of 522 g CO_2/kWh.

Fig.15: Carbon intensity of GDP and energy-related CO_2 emissions per capita in selected regions, 2013

Investment

Since 2000, we estimate that investment in energy supply in India has increased substantially, reaching almost $77 billion on average since 2010 (Fig.16). The power sector absorbs the largest share, spurred by the rapid increase in demand as encouraged by the liberalisation agenda launched by the landmark Electricity Act in 2003. Maintaining a rising trend in infrastructure spending, especially energy sector spending, is a major government policy priority. India's government aims to increase investment in infrastructure (broadly defined, including communications, road, rail and energy networks, as well as social areas such as schools and hospitals) to 8.2% of GDP, from roughly 7.2% in 2007-2011. More than a third of this $1 trillion in infrastructure spending is to go to electricity, renewable energy, and oil and gas pipeline projects, with around half from private investment.19 Relieving infrastructure bottlenecks, particularly those related to poor road and rail infrastructure, inefficient ports and unreliable electricity supply, is widely recognised as essential to meet India's economic growth and development ambitions (IMF, 2015).

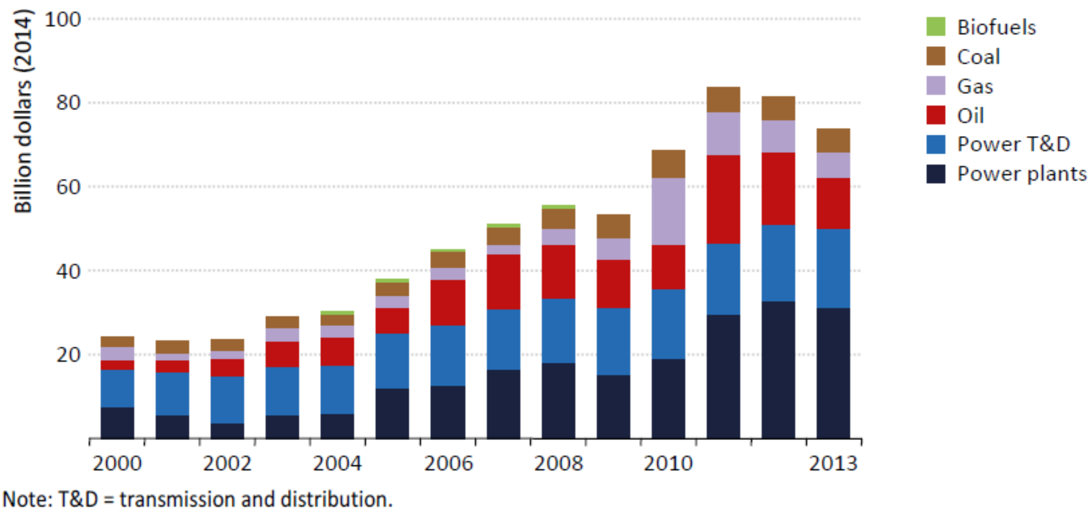
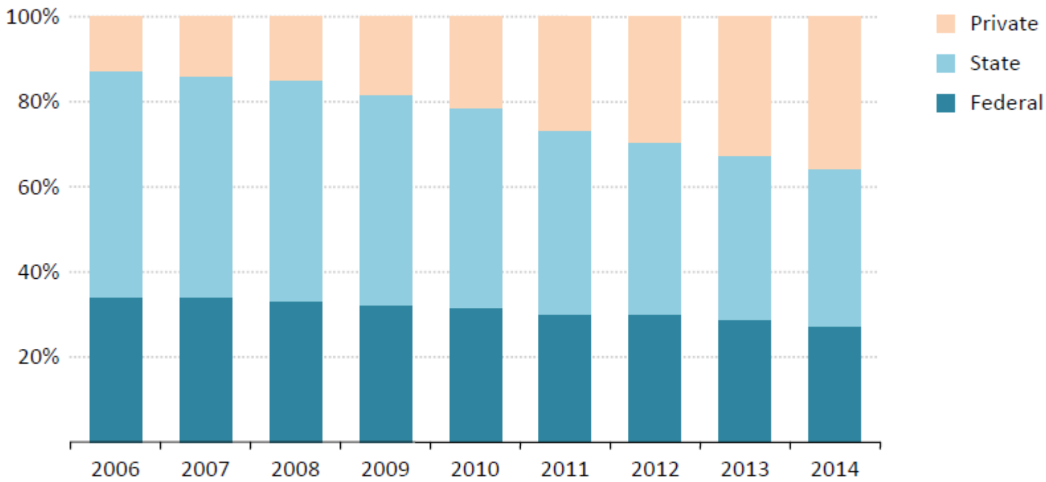


Fig.16: Energy supply investment by type, 2000-2013

As the Indian government has recognised, public funds sufficient to support the necessary investment projects in the energy sector cannot be taken for granted, in the face of increasing competition from other areas of public spending (including healthcare, pensions, education, etc.). So meeting the country's investment needs will require the mobilisation of increasing amounts of private capital, including foreign direct investment (FDI). Access to such investment opportunities by the private sector though is uneven across the Indian energy economy and a number of broader impediments to attracting investment persist, such as the complex regulatory environment, in relation to which the World Bank has ranked India 142 out of 189 countries in terms of ease of doing business. Despite these impediments, India's vast potential puts it high on the list of prospective destinations for foreign investment, ranking third behind China and the United States. Furthermore, 2014 saw a significant increase in FDI inflows, which rose by 22% compared to the previous year, to a total of over $34 billion (UNCTAD, 2015). Preliminary numbers for FDI in 2015 show a further substantial increase.

Since the late 1990s, steps have been taken to deregulate the oil and gas sectors, notably successive bidding rounds held under the New Exploration Licensing Policy, which have been open to a range of private players. However, these two sectors remain dominated, in practice, by a handful of state concerns and the process of opening the coal sector to private investment is only just beginning. The power generation sector has been open to private participation for some time and the government has offered a range of fiscal incentives to increase the attractiveness of projects. Since 2006, 6 GW out of every 10 GW of net capacity added to the grid has been financed by private investors, whose share of generation has increased quickly, to reach more than one-third of the total (Fig.17). Private sector involvement in the distribution side of the power system is much more limited. Presently the distribution utilities are largely state-controlled and administered, and the priority given to regional social sensitivities often contributes to the under-recovery of costs acrossthe sector.



Source: Central Electricity Authority.

Module – II

1. ENERGY STORAGE SYSTEMS

Energy storage (ES) has only recently been developed where it to a point 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. **Energy storage** is the capture of energy produced at one time for use at a later time to reduce imbalances between energy demand and energy production.

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 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.

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);
- Reduced pollutant emissions (e.g., CO_2, and chlorofluoro carbons (CFCs)).

1.1 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 process can be stored for use in preheating and other heating operation.

Cogeneration: Since the closely coupled production of heat and electricity by a cogeneration systemrarely 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 cloudydays or at night, ES systems can increase the capacity factor of solar energy systems.

2. Energy storage Systems

2.1 Mechanical and hydraulic Energy storage 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, butadvanced 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.

2.2 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.

2.3 Electrochemical ES systems have better turnaround efficiencies but very high prices. lntensive 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.

2.4 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 Europe. ln 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 energycan 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 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.

3. 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 and petrochemicals.

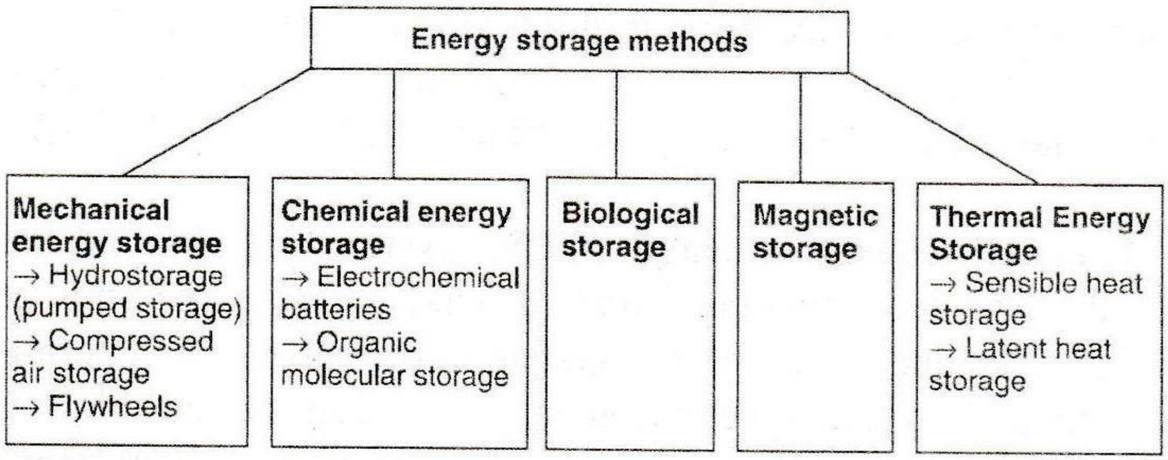


Fig: A classification of energy storage methods

3.1 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. tt 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 there are three main mechanical storage types that have discuss in this section: hydro storage. Compressed-air storage and flywheels.

3.1.1 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 other 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 peakconsumption.

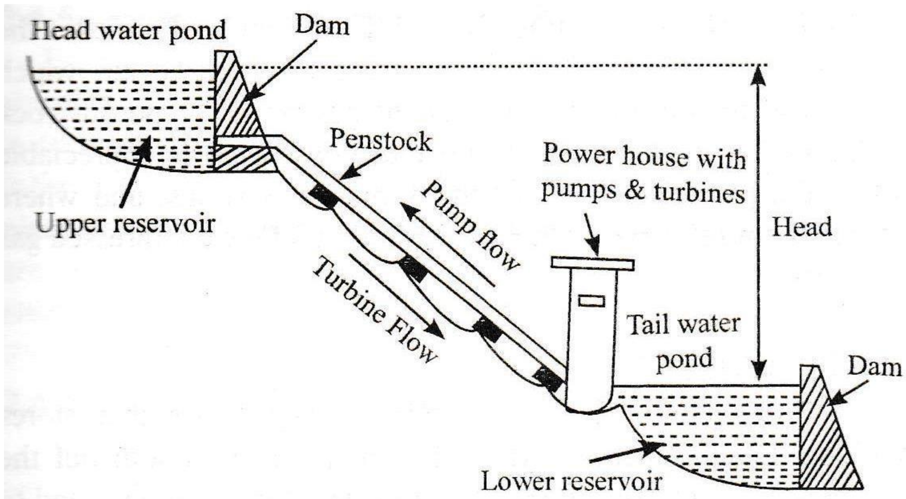


Fig: Pump Storage

3.1.2 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.

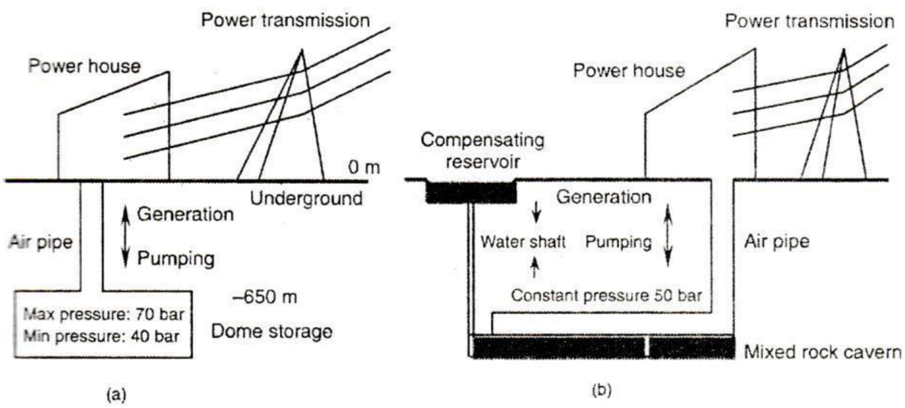


Fig: Compresses air ES systems (a) Sliding Pressure System (b) Compensated Pressure System

The technique used by such a system to compress air to store energy is relatively straightforward. ln 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 cavefish. 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 where suitable spent salt caverns make it easy to build the compressed gas reservoirs.

3.1.3 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 rework both as a motor when driven by electric power and as a generator when driven bymechanical power.

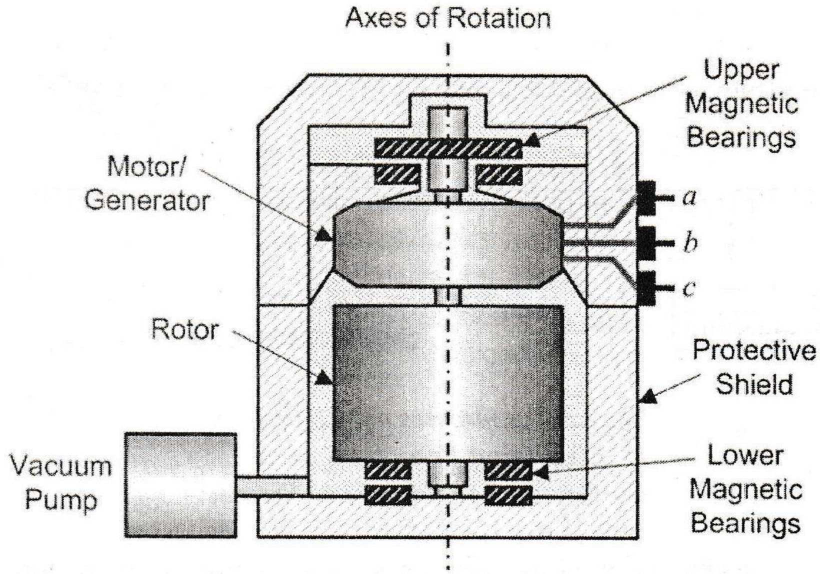


Fig: Flywheel Storage Energy

3.2 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 energy storage 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. Power to gas and Power to liquid are two methods of chemical ES system.

Power to gas: Power to gas is a technology that uses electric power to produce a gaseous fuel such as hydrogen or methane. When using surplus power (Excess electricity is surplus electrical energy that must be dumped (or curtailed) because it cannot be used to serve a load or charge batteries) from wind generation, the concept is sometimes called wind gas. The three commercial methods use electricity to reduce water into hydrogen and oxygen by means of electrolysis.

In the first method, hydrogen is injected into the natural gas grid or is used for transportation. The second method is to combine the hydrogen with CO2 to produce methane using a methanation reaction such as the Sabatier reaction, or biological methanation, resulting in an extra energy conversion loss of 8%. The methane may then be fed into the natural gas grid. The third method uses the output gas of a wood gas generator or a biogas plant, after the biogas upgrader is mixed with the hydrogen from the electrolyzer, to upgrade the quality of the biogas.

Hydrogen: The element hydrogen can be a form of stored energy. Hydrogen can produce electricity via a hydrogen fuel cell [A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions]. Underground hydrogen storage is the practice of hydrogen storage in caverns, salt domes and depleted oil and gas fields. Large quantities of gaseous hydrogen have been stored in caverns by Imperial Chemical Industries for many years without any difficulties.

Methane: Methane is the simplest hydrocarbon with the molecular formula CH_4. Methane is more easily stored and transported than hydrogen. Storage and combustion infrastructure (pipelines, gasometers, power plants) are mature. Synthetic natural gas (syngas or SNG) can be created in a multi-step process, starting with hydrogen and oxygen. Hydrogen is then reacted with carbon dioxide in a Sabatier process, producing methane and water. Methane can be stored and later used to produce electricity. The resulting water is recycled, reducing the need for water. In the electrolysis stage, oxygen is stored for methane combustion in a pure oxygen environment at an adjacent power plant, eliminating nitrogen oxides. Methane combustion produces carbon dioxide (CO_2) and water. The carbon dioxide can be recycled to boost the Sabatier process and water can be recycled for further electrolysis. Methane production, storage and combustion recycles the reaction products. The CO_2 has economic value as a component of an energy storage vector, not a cost as in carbon capture and storage.

Power to liquid: Power to liquid is similar to power to gas except that the hydrogen is converted into liquids such as methanol or ammonia. These are easier to handle than gases, and requires fewer safety precautions than hydrogen. They can be used for transportation, including aircraft, but also for industrial purposes or in the power sector.

3.2.1 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, 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.

3.2.2 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.

3.3 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.

3.4 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. Over all 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.

3.5 THERMAL ENERGY STORAGE (TES)WHY THERMAL STORAGE

- Primary energy source -Hydro, Gas, Coal and Nuclear fuels transformed directly into electricityas 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 shutdown the rest of the time.
- They use expensive primary energy stores 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.

DEFINITION OF THERMAL STORAGE

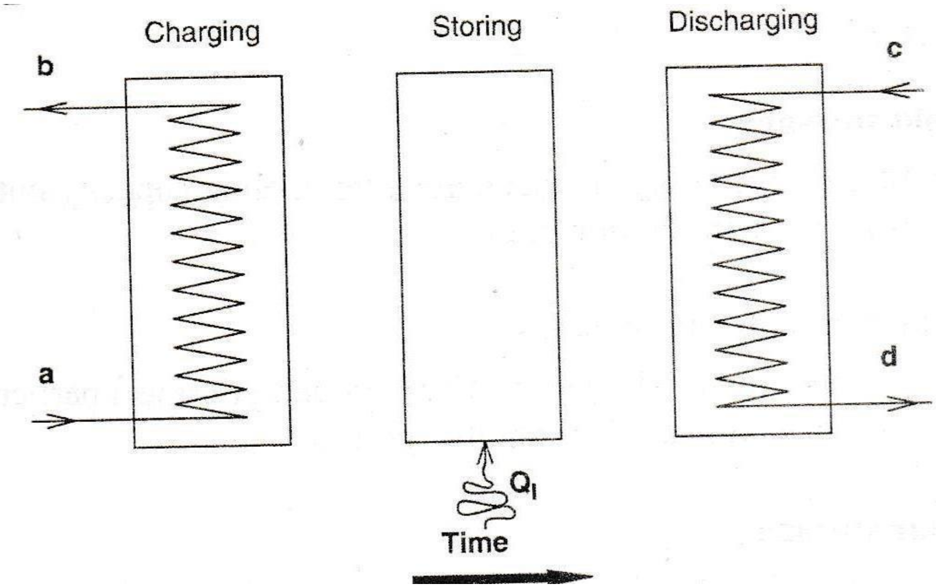


Fig: The Three processes in a general TES system

- Charging (left), storing (middle), and discharging (right). Here the heat Q_1 is infiltrating and is positive in value for a cold thermal storage. If it is released, it will be toward the surroundings and Q_1 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.

TYPES OF THERMAL STORAGE SYSTEMS

1. Cold storage
2. Fabric and slab energy storage
3. Solar storage
4. Packed Rock Beds
5. Low temperature CO_2 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 contributes 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 packedrock 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 tire highheat transfer coefficient between air and rock.

Advantages of packed bed storage

1) Solid material like rocks and oxides can be more easily contained than water.
2) Easily used for thermal storage at temperature above 100^0C.
3) The heat transfer between air and solid is high and hence the efficiency of the unit is high.
4) The cost of storage material and unit is low
5) Conductivity of bed is low, hence heat losses are less.

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 its triple point of -57^0C 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 alliteratively Sodium Hydroxide and water.
- Systems in which the water is separated by the heat input to the mixture and as soon as the two substances 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. Tirisis 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 transpired by rnolecular diffusion from the LCZ to the UCZ. This means that salt must be added to the LCZ, and fresh waier to the UCZ whilst- brine is removed. The brine can be recycled, divided into water and salt (by solar distillation) and retuned to the 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 tendsto lose heat transfer faster than when calm.

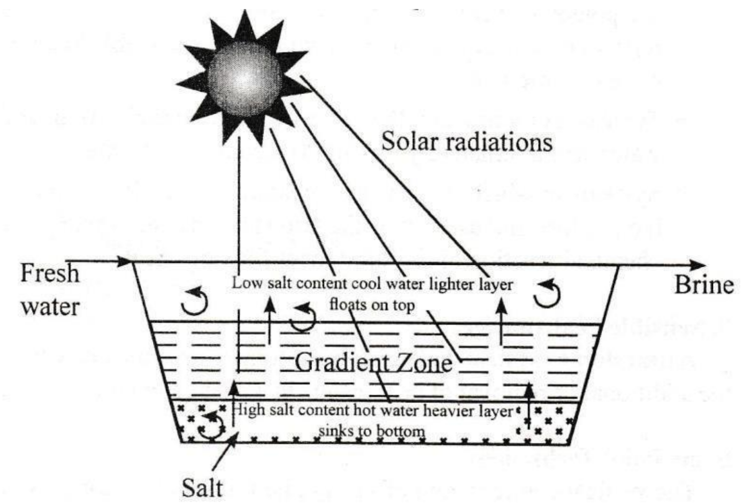


Fig: Principle of solar pond

8. Latent heat storage:

A heat storage system that uses the energy absorbed or released during a change in phase, withouta 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 ice, salt hydrates, and certain polymers. The eutectic salt does not expander 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 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.

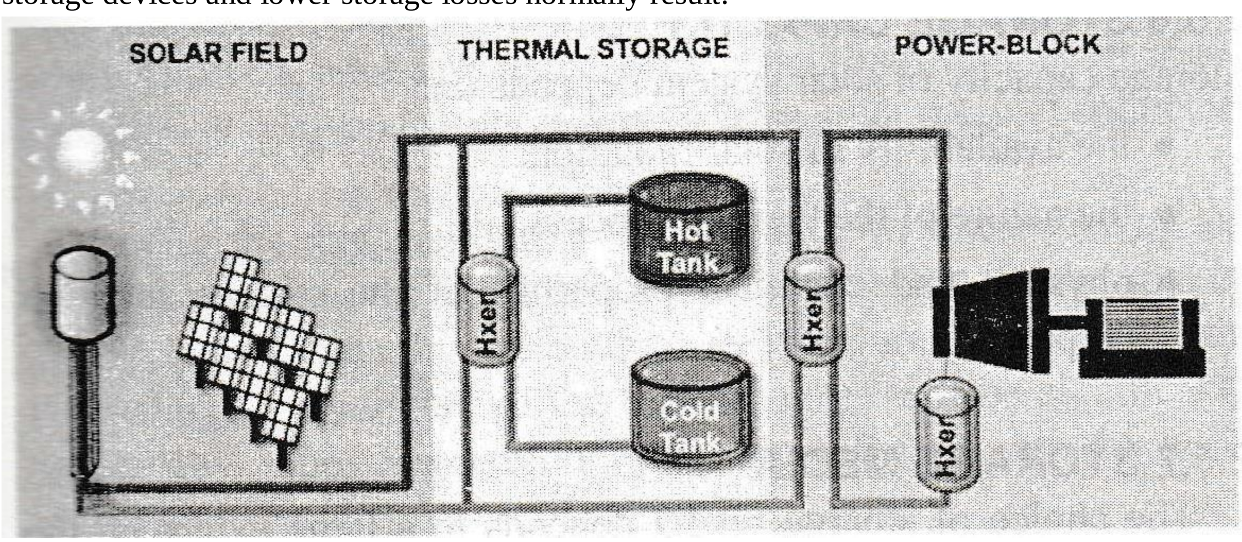


Fig: Principle of use of PCM

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.

Advantages of latent heat storage systems

1) More compact storage systems as compared to sensible heat storage systems.
2) Energy stored per unit volume is high.
3) Variety of materials are available to suit the applications.

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

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

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.

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.

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 load heat exchanger.

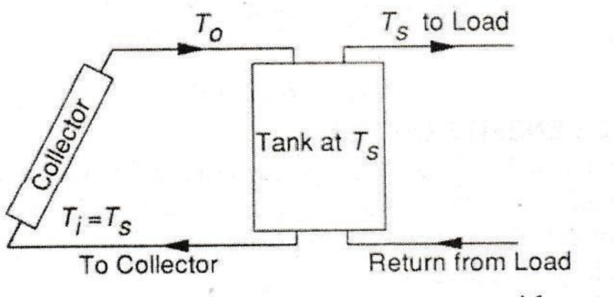


Fig : Water storage System

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

3.5.1 Benefits of Thermal Energy Storage

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 prover-quality problems may be adaptable to energy storage purposes.

4. 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.

4.1 STORAGE WALL

A storage wall (Storage Walls e.g. Trombe wall) is a sun-facing wall built from material that acts 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.

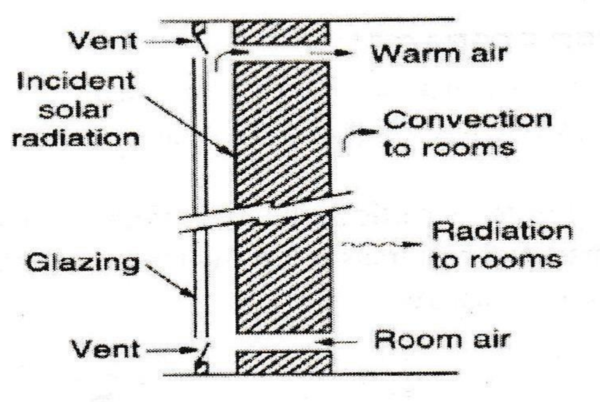


Fig: Storage Wall

- **5. Energy management**

Business, industry and government organizations have all been under tremendous economic and environmental pressures in the last few years. Being economically competitive in the global marketplace and meeting increasing environmental standards to reduce air and water pollution have been the major driving factors in most of the recent operational cost and capital cost investment decisions for all organizations.

Energy management has been an important tool to help organizations meet these critical objectives for their short-term survival and long-term success. The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

One definition of energy management 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 utilization throughout the organization and a) to minimize energy costs/waste without affecting production & quality. B) To minimize environmental effects

5.1 WHAT IS ENERGY MANAGEMENT

Utilization of minimum quantity of energy for a task at an appropriate quality neither better nor worse than needed. "Task in energy use"

- To minimize the energy cost without effecting production & quality.

- Energy forms of high-quality grade shouldn't use for low grade applications.
- The fundamental goal of energy management is to produce goods and provide services with the least

cost and least environmental effect.

5.2 PRINCIPLES OF ENERGY MANAGEMENT

- Historical Energy Use
- Energy Audits
- Housekeeping & maintenance
- Analysis of Energy use
- More efficient equipment's
- more efficient process
- Energy containment -confine energy, reduce losses & recover heat
- Substitute materials
- Aggregation of Energy sources
- Alternative Energy Sources
- Construction of new facilities.
- Manage the energy at the highest energy efficiency.
- Reuse and recycle energy by cascading.
- Use most appropriate technology.
- Reduce the available losses.
- Economic Evaluation

5.3 Energy demand estimation

Energy Demand estimation (EDE) means managing of the demand for power by utilities distribution companies, among some or all its customers to meet current or future needs. EDE programs result in energy and / or demand reduction. For example. under this process, the demand can be shifted from peak to off peak hours thereby reducing the need for buying expensive imported power during peak hours. EDE also enables end users to better manage their load curve and thus improves the profitability" potential energy saving through EDE is treated same as new additions on the supply side in MWs. EDE can reduce the capital needs for power capacity expansion.

6 ENERGY PRICING

Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information. Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year, which gives a base-line for future reference
- Energy invoices may indicate the potential for savings when related to production requirements orto air conditioning requirements/space heating etc.
- When electricity is purchased on the basis of maximum demand tariff
- They can suggest where savings are most likely to be made.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures.

6.1 POWER COSTS

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Energy Charges, kWh (i.e., How much electricity is consumed?)
- TOD Charges, Peak/Non-Peak Period(i.e. When electricity is utilized?)
- Power factor Charge, P.F (i.e., Real power use versus Apparent power use factor)
- Other incentives and penalties applied from time to time
- High tension tariff and low-tension tariff rate changes
- Slab rate cost and its variation.
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, Government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/States
- Tax holiday for new Projects

7 Energy audit

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".

7.1 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.

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 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.

The type of Energy Audit to be performed depends on

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

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

i) **Preliminary Audit**

ii) **Detailed Audit**

Preliminary Energy Audit Methodology

- Preliminary energy audit is a relatively quick exercise to:
- Establish energy consumption in the organization
- Estimate the scope for saving

- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/ savings

- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

Detailed Energy Audit Methodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost. In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use is estimated then compared to utility bill charges.

The detailed energy auditing is carried out in three phases:

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

Phase I -Pre Audit Phase Activities

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

Initial Site Visit and Preparation Required for Detailed Auditing

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

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyze the major energy consumption data with the relevant personnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are: -

- To finalize Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit eg. kWh, steam,oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame

- To collect macro data on plant energy resources, major energy consuming centers

- To create awareness through meetings/programme

Phase II- Detailed Energy Audit Activities

- Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out.
- Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.
- The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process.
- Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected 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.

Phase –III- Post Audit Phase

On completion of energy audit, energy action plan should be prepared. The energy action plan list the ENCONs which should be implemented first, and suggest an overall implementation schedule. Energy audit is incomplete without monitoring and its associated feedback. Monitoring consists of collecting and interpreting data. The data to be collected depends upon goals chosen in the energy action plan. Electrical power consumption and fuel consumption must be evaluated and monitored.

The monitoring data should provide direct feedback to those most able to implement the changes. often additional instruments should be installed in various department in addition to main metering.

7.2 Energy Audit Reporting Format

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation in a typical energy audit report format. This format may vary with the type of the company also format can be suitably modified for specific requirement applicable for a particular type of industry.

7.3 Organizing Energy management in Industries

Following are the guidelines for carrying out energy management in industries

- Developing ideas and plans for enlisting employee support and participation
- Planning and participation in energy audits
- Surveying and literature on the ways to conserve energy and communicating these ideas and suggestions.
- Establishing realistic and achievable energy conservation goals.
- Developing uniform record keeping, reporting and energy auditing.

- Planning and conducting continuing program of activities to stimulate interest in energy conservation efforts.

7.4 Duties and responsibilities of energy manager

- Creation of a data base related to inputs and outputs of the manufacturing process. For this purpose, extensive metering instrumentation at various points of energy and material flows through the plant might be required.
- To carry out energy audits from the data base on a regular basis and to reconcile energy audits with financial audits.
- To analyze energy consumption centers such as boilers, furnaces, electric motor driven instruments like compressors, pumps etc and to identify the energy conservation opportunities.
- To report plant's energy conservation progress to the top management.
- To advise the top-level management as the ways of long-term energy conservation opportunities.
- To coordinate energy consumption between energy consuming centers.
- To build thorough inventory of all machines, equipment and facilities which consume energy – their capacity, time worked since installation, parts and components repaired or replaced and other working specifications.
- To survey and review the literature on energy development and to properly disseminate this information.
- To develop and communicate energy saving technique and ideas to divisional heads.

Step No	**PLAN OF ACTION**	**PURPOSE/RESULTS**
Step 1	Phase I- Pre Audit Phase Plan and organize Walk through Audit Informal Interview with Energy Manager,Production/Plant Manager	Resource planning, Establish/organize a Energyaudit team • Organize Instruments& time frame. Macro Data collection (suitable to type o industry.) • Familiarization of process/plantactivities. • First hand observation &Assessment of current level operation and practices.

Step 2	Conduct of brief meeting/awareness programme withall 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 chart Al service utilities system diagram (Example Single line power distribution diagram water, compressed air & steam distribution. Design, operating data and schedule o 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 selectedenergy guzzlers	Trials/ Experiments: 24 hours power monitoring (MD,PF, kWh etc.) Load variations trends in pumps, fan compressors etc. Boiler/Efficiency trails for (4-8hours) Furnace efficiency trials. Equipment/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 energy audit if any Use brainstorming and value analysis techniques Conduct vendors for new/efficient technology
Step 8	Cost benefit analysis	Assess technical feasibility, economic viability andprioritization of ENCON options for implementation Select the most promising projects Prioritise by low, medium, long term measures
Step 9	Reporting and presentation to the top management	Documentation, Report presentation to the top management.
Step10	**<u>Phase III- Post Audit Phase</u>** Implementation and follow up	Assist and Implement ENCON recommendation measures and Monitor the performance Action plan, Schedule for implementation Follow-up and periodic review

8. Economic Analysis

Among the most important indicators of the success of an engineering enterprise are the profit achieved and the return on investment. Therefore, economic considerations play a very important role in the decision-making processes that govern the design of a system. It is generally not enoughto make a system technically feasible and to obtain the desired quality of the product. The costs incurred must be taken into account to make the effort economically viable. It is necessary to finda balance between the product quality and the cost.

Because of the crucial importance of economic considerations in most engineering decisions, it is necessary to understand the basic principles of economics and to apply these to the evaluation of investments, in terms of costs, returns, and profits.

- **Simple interest**

If the interest is calculated only on the principal over a given duration, without considering the change in investment due to accumulation of interest with time and without including the interest with the principal for subsequent calculations, the resulting interest is known as *simple interest*. Then, the simple interest on the principal sum P invested over n years is simply Pni, and the final amount F consisting of the principal and interest after n years is given by $F = P(1 + ni)$.

- **Compound interest**

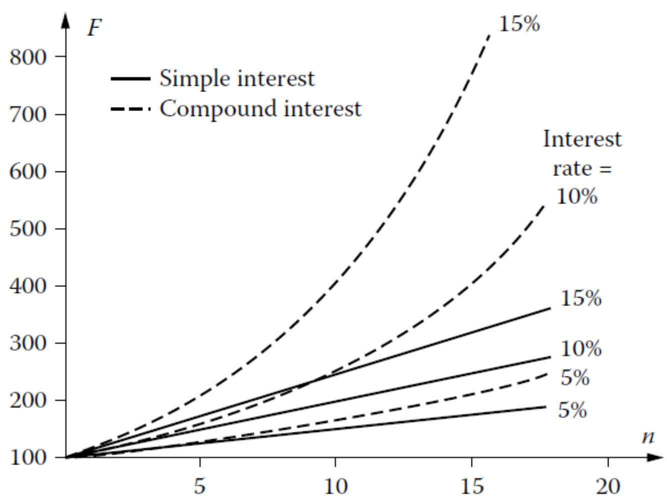
The interest may be calculated several times a year and then added to the amount on which interest is computed in order to determine the interest over the next time period. This procedure is known as compounding and interest is called as compound interest.

If the interest is compounded m times a year, the interest on a unit amount in the time between two compounding is i/m. Then the final sum F, which includes the principal and interest, is obtained after n years as

$$F = P\,(\frac{1}{m} + i)^{mn}$$

For monthly compounding m =12, daily compounding m =365 etc.

Variation of sum F consisting of the principal, and accumulated interest as a function of number of years for simple and compounding at different rates of interests are shown in the graph.



Two approaches that are commonly used for bringing all financial transactions to a common timeframe are the present and future worth of an investment, expenditure, or payment.

- **Present worth**

Present worth (PW) of a lumped amount given at a particular time in the future is its value today.Thus, it is the amount that, if invested at the prevailing interest rate, would yield the given sum atthe future date. If we consider the resulting sum F after n years at a nominal interest rate i, Then $P$is the present worth of sum F for the given duration and interest rate. Therefore, the present worth of a given sum F may be written, for yearly compounding,

$$\mathbf{PW = P = F(1+i)^{-n} = (F)\,(P/F,\ i,\ n)}$$

Where P/F is known as present worth factor and is given by

$$\boldsymbol{P/F = (1 + i)^{-n}}$$

—

The **future worth** of a lumped amount *P*, given at the present time, may similarly be determined after a specified period of time. Therefore, the future worth (FW) of *P* after *n* years with an interest rate of *i*, compounded yearly or *m* times yearly, are given, respectively, by the following equations:

FW= F= P(1+i)^n = (P) (F/P, I, n)

$$\mathbf{FW = F = P\left(1+\frac{i}{m}\right)^{mn} = (P)\ (F/P,\ \frac{i}{m},\ mn)}$$

Where *F/P* is known as the *future factor worth* or *compound amount factor*

- **SERIES OF PAYMENTS**

A common circumstance encountered in engineering enterprises is that of a series of payments. Frequently, a loan is taken out to acquire a given facility and then this loan is paid off in fixed payments over the duration of the loan. Recurring expenses for maintenance and labor may be treated similarly as a series of payments over the life of the project. Both fixed and varying amountsof payments are important, the latter frequently being the result of inflation, which gives rise to increasing costs. The series of payments is also brought to a given point in time for consideration with other financial aspects. As before, the time chosen may be the present or a time in the future.

- **FUTURE WORTH OF UNIFORM SERIES OF AMOUNTS**

Let us consider a series of payments, each of amount *S*, paid at the end of each year starting with the end of the first year. The future worth of this series at the end of *n* years is to be determined. This can be done easily by summing up the future worths of all these individual payments. The first payment accumulates interest for *n* – 1 years, the second for *n* – 2 years, and so on, with the second-to-last payment accumulating interest for 1 year and the last payment accumulating no interest. Therefore, if *i* is the nominal interest rate and yearly compounding is used, the future worth *F* of the series of payments is given by the expression

$$F = S\,(\frac{(1+i)^{n-1}}{(1+i)-1}) = S\,(\frac{(1+i)^{n-1}}{i}) = S\,(\frac{F}{s}, i, n)$$

Where F/S is often known as the series future worth factor or the series compound amount factor. It yields the future worth of a series of payments of equal amount *S* when *S* is multiplied by this factor. The amount *S* of a series of payments to pay off an amount *F*.

- **Taxes**

Government depends heavily on taxes to finance its operations and to provide services. It is necessary to include taxes in the evaluation of the overall return on the investment in an engineering enterprise and also for comparing different financial alternatives for a venture. There are two main forms of taxation thatare of concern to an engineering company: income tax and real estate, or property, tax.

The overall profit made by a given company is the income that is taxed by the federal, state, and local governments. Though the federal taxation rate remains unchanged with location, the state and local taxes are strongly dependent on the location, varying from close to zero to as high as 20% across the country. However, the federal tax may vary with the size of the company and the nature of the industry. Since the amount paid in taxes is lost by the company, diligent efforts are made to reduce this payment by employing different legal means. Certainly, locating and registering the company at aplace where the local taxes are low is a common approach. Similarly, providing bonuses and additional benefits to the employees, expanding and upgrading facilities, and acquisition of new facilities or enterprises increase the expenses incurred and reduce the taxes owed by the company.

- **Real estate and local taxes**

Taxes are also levied on the property owned by the company. These may simply be real estate taxes on the value of the buildings and land occupied by the company or may include charges by the local authorities to provide services, such as access roads, security, and solid waste removal. All these are generally included as expenses in the operation of the company. Different alternatives involve different types of expenses and, therefore, the design of the system may be affected by these taxes. For instance, a system that involves a smaller floor area and, therefore, a smaller building and lower real estate taxes is more desirable than one that requires a large floor area. Similarly, the raw materials needed and the resulting waste are important in determining expenses for transportation and disposal, possibly making one system more cost effective than another.

- **Depreciation**

The decrease in the value of the power plant equipment and building due to constant use is known as depreciation. An important concept with respect to the calculation of taxes is that of depreciation. Since a given facility has a finite useful life, after which it must be replaced, it is assumed to depreciate in value as time elapses until it is sold or discarded at its salvage value. In essence, an amount is allowed to be put aside each year for its replacement at the end of its useful life. This amount is the depreciation and is taken as an expense each year, thus reducing the taxes to be paid by the company. There are several approaches to calculating depreciation, as allowed by the federal government.

The book value of the item is the initial cost minus the total depreciation charged up to a given pointin time. Therefore, the book value *B* at the end of the *j* th year is given by

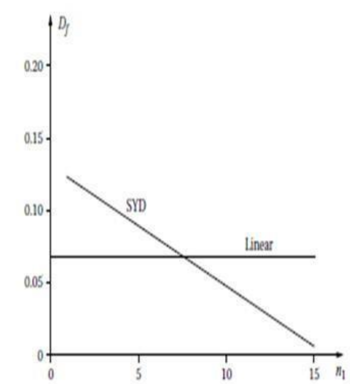
$$B = P - \frac{J}{n}(P - Q)$$

In actual practice, most facilities depreciate faster in the initial years than in later years, as anyone who has ever bought a new car knows very well. This is largely because of the lower desirability and unknown maintenance of the used item. As time elapses and the wear and tear are well established, the depreciation usually becomes quite small. Different distributions are used to represent this trend of greater depreciation rate in the early years. These include sum of-years digits (SYD), the declining balance, Modified accelerated cost recovery methods.

- **SYD method (Sum of the Years digits)**

$$\mathbf{D = \left[\frac{-n1+1}{n(n+1)/2}\right] (P-Q)}$$

Where the denominator is the sum n(n+1)/2 of the digits representing the years, 1,2,3….n. the numerator is the digit corresponding to the given year when the digits are arranged in reverse order,as n,n-1,n-2. And so on. By using this calculation procedure, the depreciation is larger than that obtained by the linear method in the early years and smaller in the later years.



Variation of the fractional depreciation D_j with the number of years under consideration n_1 for the linear and SYD depreciation calculation methods.

➢ **GENERAL CHARACTERISTICS OF CAPITAL INVESTMENTS**

When companies spend money, the outlay of cash can be broadly categorized into one of two classifications; expenses or capital investments. Expenses are generally those cash expenditures those are routine, on-going, and necessary for the ordinary operation of the business.

Capital investments, on the other hand, are generally more strategic and have long term effects. Decisions made regarding capital investments are usually made at higher levels within the organizational hierarchy and carry with them additional tax consequences as compared to expenses. Three characteristics of capital investments are of concern when performing life cycle cost analysis. First, capital investments usually require a relatively large initial cost. “Relatively large” may mean several hundred dollars to a small company or many millions of dollars to a large company. The initial cost may occur as a single expenditure such as purchasing a new heating system or occur over a period of several years such as designing and constructing a new building. It is not uncommon that the funds available for capital investments projects are limited. In other words, the sum of the initial costs of all the viable and attractive projects exceeds the total available funds. This creates a situation known as capital rationing which imposes special requirements on the investment analysis.

The second important characteristic of a capital investment is that the benefits (revenues or savings) resulting from the initial cost occur in the future, normally over a period of years. The period between the initial cost and the last future cash flow is the life cycle or life of the investment.It is the facts that cash flows occur over the investment’s life that requires the introduction of time value of money concepts to properly evaluate investments. If multiple investments are being evaluated and if the lives of the investments are not equal, special consideration must be given tothe issue of selecting an appropriate planning horizon for the analysis.

The last important characteristic of capital investments is that they are relatively irreversible. Frequently, after the initial investment has been made, terminating or significantly altering the nature of a capital investment has substantial (usually negative) cost consequences.
This is one of the reasons that capital investment decisions are usually evaluated at higher levels of the organizational hierarchy than operating expense decisions.

Capital Investment Cost Categories

In almost every case, the costs which occur over the life of a capital investment can be classified into one of the following categories:

- Initial Cost,
- Annual Expenses and Revenues,
- Periodic Replacement and Maintenance, or
- Salvage Value.

As a simplifying assumption, the cash flows which occur during a year are generally summed and regarded as a single end-of-year cash flow. While this approach does introduce some inaccuracy in the evaluation, it is generally not regarded as significant relative to the level of estimation associated with projecting future cash flows. Initial costs include all costs associated with preparing the investment for service. This includes purchase cost as well as installation and preparation costs. Initial costs are usually nonrecurring during the life of an investment. Annual expenses and revenues are the recurring costs and benefits generated throughout the life of the investment. Periodic replacement and maintenance costs are similar to annual expenses and revenues except that they do not (or are not expected to) occur annually. The salvage (or residual) value of an investment is the revenue (or expense) attributed to disposing of the investment at the end of its useful life.

Cash Flow Diagrams

A convenient way to display the revenues (savings) and costs associated with an investment is a cashflow diagram. By using a cash flow diagram, the timing of the cash flows are more apparent and the chances of properly applying time value of money concepts are increased. With practice, different cash flow patterns can be recognized and they, in turn, may suggest the most direct approach for analysis.

It is usually advantageous to determine the time frame over which the cash flows occur first. This establishes the horizontal scale of the cash flow diagram. This scale is divided into time periods which are frequently, but not always, years. Receipts and disbursements are then located on the time scale in accordance with the problem specifications. Individual outlays or receipts are indicated by drawing vertical lines appropriately placed along the time scale. The relative magnitudes can be suggested by the heights, but exact scaling generally does not enhance the meaningfulness of the diagram. Upward directed lines indicate cash inflow (revenues or savings) while downward directed lines indicate cash outflow (costs).

Theory questions:

1. List the difference types of thermal energy storage systems. Explain any two of them.

2. Elaborate the different phases involved in detailed energy audit methodology

3. What are the general characteristics of capital investment?

4. Explain in detail various phases of energy audit methodology

5. List the various thermal energy storage methods. Explain sensible heat and latent heat storagemethods.

6. Define energy audit. Explain the need for energy audit.

7. Write a short note on energy demand estimation

8. Elaborate the benefits of thermal energy storage.

Module – III

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.

- **Environment**

Definition

Environmental studies deals with every issue that affects an organism. It is essentially a multidisciplinary approach that brings about an appreciation of our natural world and human impacts on its integrity. It is an applied science as it's seeks practical answers to making human civilization sustainable on the earth's finite resources.

- **Scope**

As our surroundings were originally natural landscapes such as a forest, a river, a mountain, a desert, or a combination of these elements. Most of us live in landscapes that have been heavily modified by human beings, in villages, towns or cities. But even who live in cities get our food supply from surrounding villages and these in turn are dependent on natural landscapes such as forests, grasslands, rivers, seashores, for resources such as water for agriculture, fuel wood, fodder, and fish. Thus our daily lives are linked with our surroundings and inevitably affects them. All peoples are using water to drink and for other day-to-day activities. Air for breath, use resources for food, depends on the community of living plants and animals which form a web of life, of which we are also a part.

Our dependence on nature is so great that we cannot continue to live without protecting the earth's environmental resources. Thus most traditions refer to our environment as 'Mother Nature' and most traditional societies have learned that respecting nature is vital for their livelihoods. This has led to many cultural practices that helped traditional societies protect and preserve their natural resources.

- **Importance**

Environment is not a single subject. It is an integration of several subjects that include both Science and Social Studies.

In a world natural resources are limited. Water, air, soil, minerals, oil, the products are get from forests, grasslands, oceans and from agriculture and livestock, are all a part of our life support systems. Without them, life itself would be impossible. As keep increasing in numbers and the quantity of resources uses also increases, the earth's resource base must inevitably shrink. The earth cannot be expected to sustain this expanding level of utilization of resources. Added to this is misuse of resources. Wasting or polluting large amounts of nature's clean water, Creating more and more material like plastic that discard after a single use and wasting colossal amounts of food, Which is discarded as garbage is polluting the environment. Manufacturing processes create solid waste by products that are discarded, as well as chemicals that flow out as liquid waste and pollute water, and gases that pollute the air. Increasing amounts of waste cannot be managed by natural processes. These accumulate in our environment, leading to a variety of diseases and other adverse environmental impacts now seriously affecting all our lives. Air pollution leads to respiratory diseases, water pollution to gastro-intestinal diseases, and many pollutants are known to cause cancer.

Improving this situation will only happen if each of us begins to take actions in our daily lives that will help preserve our environmental resources. Cannot expect Governments alone to manage the safeguarding of the environment, nor expect other people to prevent environmental damage.

- **NEED FOR PUBLIC AWARENESS**

As the earth's natural resources are diminishing gradually and environment is being increasingly degraded by human activities, it is evident that something needs to be done to save environment. Along with government support also needed to save environment. It is the prevention of environment degradation in which all take part that must become a part of all our lives. Just as for any disease, prevention is better than cure. To prevent ill-effects on our environment by our actions is economically more viable than cleaning up the environment once it is damaged. Individually play a major role in environment management. Reduce wasting natural resources and act as watchdogs that inform the Government about sources that lead to pollution and degradation of our environment.

This can only be made possible through mass public awareness. Mass media such as newspapers, radio, television, strongly influence public opinion. However, someone has to bring this about. If each of us feels strongly about the environment, the press and media will add to our efforts. Politicians in a democracy always respond positively to a strong publicly supported movement. Thus if you join an NGO that supports conservation, politicians will make green policies.

- **Institutions in Environment**

There have been several Government and Nongovernment organizations that have led to environmental protection in our country. They have led to a growing interest in environmental protection and conservation of nature and natural resources. The traditional conservation practices that were part of ancient India's culture have however gradually disappeared. Public awareness is thus a critical need to further environmental protection. Among the large number of institutions that deal with environmental protection and conservation, a few well-known organizations include government organizations such as the BSI and ZSI, and NGOs such as BNHS, WWF-I, etc.

- **People in Environment**

There are several internationally known environmental thinkers. Among those who have made landmarks, the names that are usually mentioned are Charles Darwin, Ralph Emerson, Henry Thoreau, John Muir, Aldo Leopald, Rachel Carson and EO Wilson. Each of these thinkers looked at the environment from a completely different perspective.

- **Ecosystem**

An 'Ecosystem' is a region with a specific and recognizable landscape form such as forest, grassland, desert, wetland or coastal area. The nature of the ecosystem is based on its geographical features such as hills, mountains, plains, rivers, lakes, coastal areas or islands. It is also controlled by climatic conditions such as the amount of sunlight, the temperature and the rainfall in the region. The geographical, climatic and soil characteristics form its non-living (abiotic) component. These features create conditions that support a community of plants and animals that evolution has produced to live in these specific conditions. The living part of the ecosystem is referred to as its biotic component.

The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem.

Understanding ecosystems

Natural ecosystems include the forests, grasslands, deserts, and aquatic ecosystems such as ponds, rivers, lakes, and the sea. Man modified ecosystems include agricultural land and urban or industrial land use patterns.

- **Ecosystem degradation**

Ecosystems are the basis of life itself. The natural ecosystems in the wilderness provide a variety of products and are regions in which a number of vital ecological processes are present, without human civilization would not be able to exist.

Ecosystems are however frequently disrupted by human actions which lead to the extinction of species of plants and animals that can live only in the different natural ecosystems. Some species if eliminated seriously affect the ecosystem.

These are called 'keystone' species. Extinction occurs due to changes in land use. Forests are deforested for timber, wetlands are drained to create more agricultural land and semi arid grasslands that are used as pastures are changed into irrigated fields. Pollution from industry and waste from urban settings can also lead to extinction of several species.

The reason for the depletion of natural resources is twofold – our rapidly exploding population that needs to sustain itself on resources, and the growth of affluent societies, which consume and waste a very large proportion of resources and energy. Increasing extraction of resources is at the cost of natural ecosystems, leading to a derangement of their important functions. Each of us in our daily lives uses a variety of resources.

If tracked back to their source, one finds that the resources were originally obtained from nature and natural ecosystems. Our insensitivity to using resources carefully has produced societies that nature can no longer sustain. If one thinks before wasting resources such as water, reusing and recycling paper, using less plastic that are non-degradable, ruminatively this can have positive implications on the integrity of our natural resource base and conserve the resources that nature provides.

- **Resource utilization**

Most traditional societies used their environment sustainably. Though inequality in resource utilization has existed in every society, the number of individuals that used a large proportion of

resources was extremely limited. In recent times the proportion of 'rich' people in affluent societies, grew rapidly. Inequality thus became a serious problem. Whereas in the past many resources such as timber and fuel wood from the forest were extracted sustainably, this pattern has drastically changed during the last century.
The economically better off sections began to use greater amounts of forest products, while those people who lived in the forest became increasingly poor. Similarly the building of large irrigation projects led to wealth in those areas that had canals, while those who hand to remain dependent on a constant supply of water from the river itself, found it difficult to survive.

- **STRUCTURE AND FUNCTIONS OF AN ECOSYSTEM**

Structural aspects

Components that make up the structural aspects of an ecosystem include:

1) Inorganic aspects – C, N, CO_2, H_2O.
2) Organic compounds – Protein, Carbohydrates, Lipids – link abiotic to biotic aspects.
3) Climatic regimes – Temperature, Moisture, Light & Topography.
4) Producers – Plants.
5) Macro consumers – Phagotrophs – Large animals.
6) Micro consumers – Saprotrophs, absorbers fungi.

Functional aspects

1) Energy cycles.
2) Food chains.
3) Diversity-inter linkages between organisms.
4) Nutrient cycles-biogeochemical cycles.
5) Evolution.

Since each ecosystem has a non-living and a living part that are linked to each other, one needs to look around us and observe this closely. This is an important aspect that is a vital part of our lives. The non-living components of an ecosystem are the amount of water, the various inorganic substances and organic compounds, and climatic conditions such as rainfall and temperature, which depend on geographical conditions and location which is also related to the amount of sunlight. The living organisms in an ecosystem are inseparable from their habitat.
The living component of plant life ranges from extremely small bacteria, which live in air, water and soil, algae which live in fresh and salt water, to the terrestrial plants which range from grasses and herbs that grow after the monsoon every year, to the giant long-lived trees of the forest. The plants convert energy from sunlight into organic matter for their growth. They thus function as producers in the ecosystem. The living component of the animal world ranges from microscopic animals, to small insects and the larger animals such as fish, amphibia, reptiles, birds and mammals. Man is just one of the 1.8 million species of plants and animals that inhabit the earth.

- **ENERGY FLOW IN THE ECOSYSTEM**

Every ecosystem has several interrelated mechanisms that affect human life. These are the water cycle, the carbon cycle, the oxygen cycle, the nitrogen cycle and the energy cycle. While every ecosystem is controlled by these cycles, in each ecosystem its abiotic and biotic features are distinct from each other.

All the functions of the ecosystem are in some way related to the growth and regeneration of its plant and animal species. These linked processes can be depicted as the various cycles. These processes depend on energy from sunlight.

During photosynthesis carbon dioxide is taken up by plants and oxygen is released. Animals depend on this oxygen for their respiration.

The water cycle depends on the rainfall, which is necessary for plants and animals to live. The energy cycle recycles nutrients into the soil on which plant life grows. Our own lives are closely linked to the proper functioning of these cycles of life. If human activities go on altering them, humanity cannot survive on our earth.

- **The Water Cycle**

When it rains, the water runs along the ground and flows into rivers or falls directly into the sea.

A part of the rainwater that falls on land percolates into the ground. This is stored underground throughout the rest of the year. Water is drawn up from the ground by plants along with the nutrients from the soil. The water is transpired from the leaves as water vapour and returned to the atmosphere. As it is lighter than air, water vapour rises and forms clouds. Winds blow the clouds for long distances and when the clouds rise higher, the vapour condenses and changes into droplets, which fall on the land as rain. Though this is an endless cycle on which life depends, man’s activities are making drastic changes in the atmosphere through pollution which is altering rainfall patterns. This is leading to prolonged drought periods extending over years in countries such as Africa, while causing floods in countries such as the US. El Nino storms due to these effects have devastated many places in the last few years.

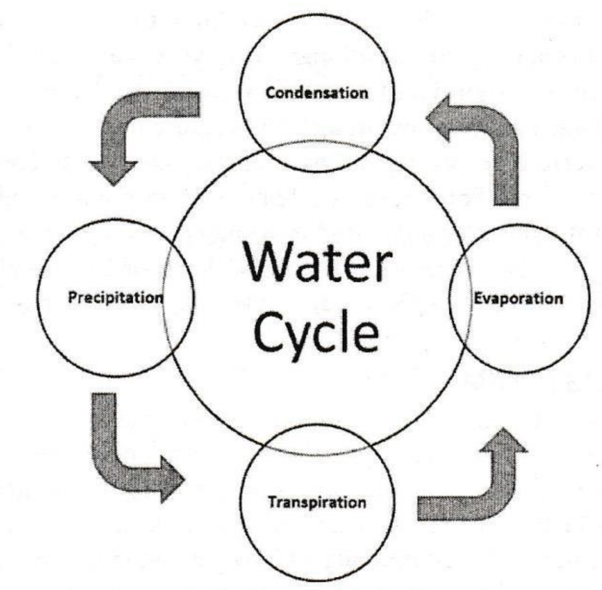


Fig: Water Cycle

- **The Carbon cycle**

The carbon, which occurs in organic compounds, is included in both the abiotic and biotic parts of the ecosystem.
Carbon is a building block of both plant and animal tissues.
In the atmosphere, carbon occurs as carbon dioxide (CO_2). In the presence of sunlight, plants take up carbon dioxide from the atmosphere through their leaves. The plants combine carbon dioxide with water, which is absorbed by their roots from the soil. In the presence of sunlight they are able to form carbohydrates that contain carbon.
This process is known as photosynthesis. Plants use this complex mechanism for their growth and development. In this process, plants release oxygen into the atmosphere on which animals depend for their respiration. Plants therefore help in regulating and monitoring the percentage of Oxygen and Carbon dioxide in the earth's atmosphere. All of mankind thus depends on the oxygen generated through this cycle. It also keeps the CO_2 at acceptable levels.
Herbivorous animals feed on plant material, which is used by them for energy and for their growth. Both plants and animals release carbon dioxide during respiration. They also return fixed carbon to the soil in the waste they exerted.
When plants and animals die they return their carbon to the soil. These processes complete the carbon cycle.

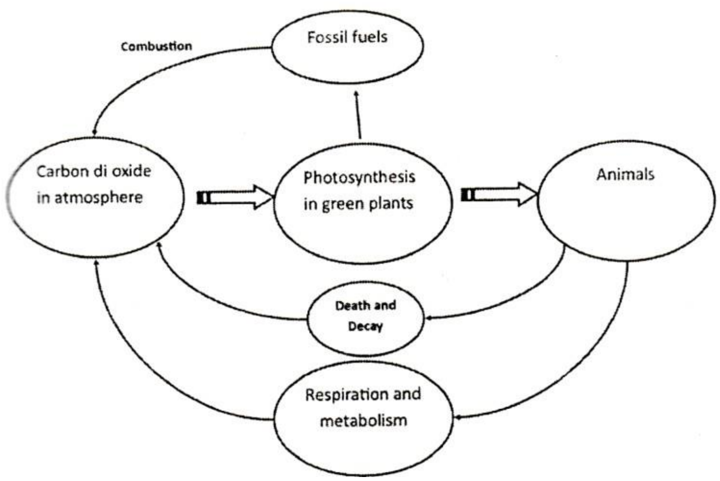


Fig: Carbon Cycle

- **The Nitrogen Cycle**

Carnivorous animals feed on herbivorous animals that live on plants. When animals defecate, this waste material is broken down by worms and insects mostly beetles and ants. These small 'soil animals' break the waste material into smaller bits on which microscopic bacteria and fungi can act. This material is thus broken down further into nutrients that plants can absorb and use for their growth. Thus nutrients are recycled back from animals to plants. Similarly the bodies of dead animals are also broken down into nutrients that are used by the plants for their growth. Thus the nitrogen cycle on which life is dependent is completed.
Nitrogen fixing bacteria and fungi in soil gives this important element to plants, which absorb it as nitrates. The nitrates are a part of the plant's metabolism, which help in forming new plant proteins.

This is used by animals that feed on the plants. The nitrogen is then transferred to carnivorous animals when they feed on the herbivores. Thus our own lives are closely interlinked to soil animals, fungi and even bacteria in the soil. When we think of food webs, we usually think of the large mammals and other large forms of life. But we need to understand that it is the unseen small animals, plants and microscopic forms of life that are of great value for the functioning of the ecosystem.

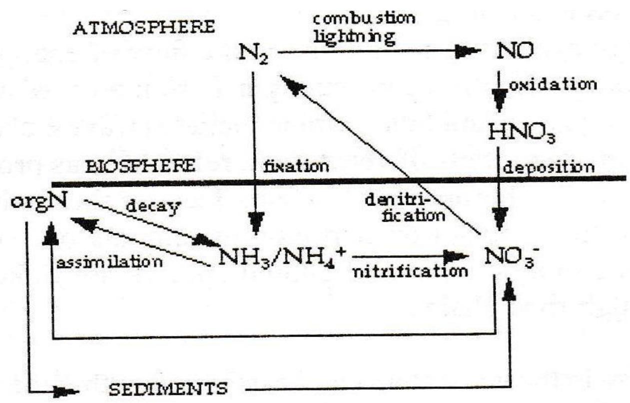


Fig: Nitrogen Cycle

- **The Oxygen Cycle**

Oxygen is taken up by plants and animals from the air during respiration. The plants return oxygen to the atmosphere during photosynthesis. This links the Oxygen Cycle to the Carbon Cycle. Deforestation is likely to gradually reduce the oxygen levels in our atmosphere. Thus plant life plays an important role in our lives which we frequently do not appreciate. This is an important reason to participate in afforestation programs.

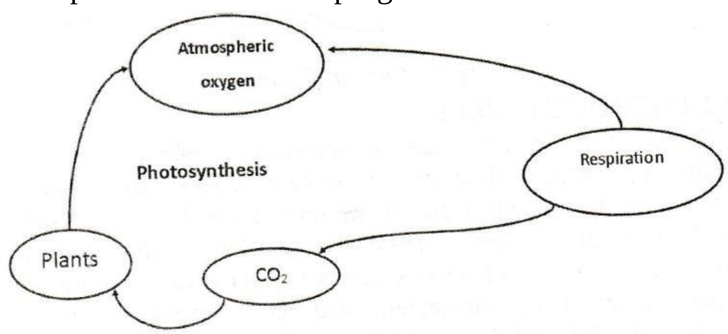


Fig: Oxygen Cycle

- **The Energy Cycle**

The energy cycle is based on the flow of energy through the ecosystem. Energy from sunlight is converted by plants themselves into growing new plant material which includes leaves, flowers, fruit, branches, trunks and roots of plants.

Since plants can grow by converting the sun's energy directly into their tissues, they are known as producers in the ecosystem. The plants are used by herbivorous animals as food, which gives them energy. A large part of this energy is used up for day to day functions of these animals such as breathing, digesting food, supporting growth of tissues, maintaining blood flow and body temperature. Energy is also used for activities such as looking for food, finding shelter, breeding and bringing up young ones. The carnivores in turn depend on herbivorous animals on which they feed. Thus the different plant and animal species are linked to one another through food chains. Each food chain has three or four links. However as each plant or animal can be linked to several other plants or animals through many different linkages and these inter-linked chains can be depicted as a complex food web. This is thus called the 'web of life' that shows that there are thousands of interrelationships in nature.

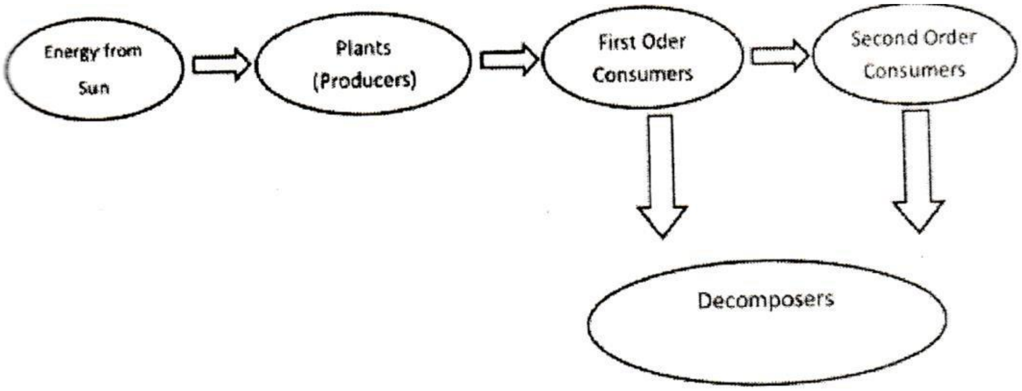


Fig: Energy Cycle

- **Integration of cycles in Nature**

These cycles are a part of global life processes.
These bio geochemical cycles have specific features in each of the ecosystems. These cycles are however linked to those of adjacent ecosystems.
Their characteristics are specific to the plant and animal communities in the region. This is related to the geographical features of the area, the climate and the chemical composition of the soil. Together the cycles are responsible for maintaining life on earth. If mankind disturbs these cycles beyond the limits that nature can sustain, they will eventually break down and lead to a degraded earth on which man will not be able to survive.

- **The food chains**

The transfer of energy from source in plants through a series of organisms by eating and being eaten constitutes **food chain.**The most obvious aspect of nature is that energy must pass from one living organism to another. When herbivorous animals feed on plants, energy is transferred from plants to animals. In anecosystem, some of the animals feed on other living organisms, while some feed on dead organicmatter. At each linkage in the chain, a major part of the energy from the food is lost for dailyactivities.Each chain usually has only four to five such links. However a single species may be linked to alarge number of species.

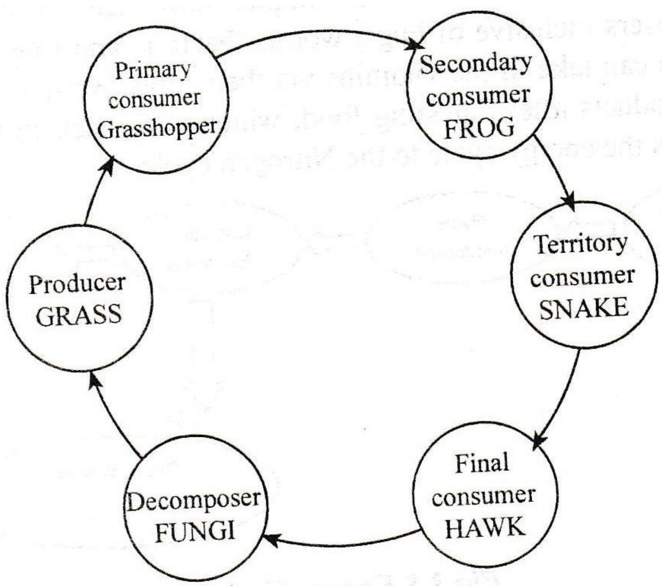


Fig: Food Chain

- **The food webs**

These food chain are not isolated sequences, but are interconnected with each other. This interlocking pattern is called as **food web.**

In an ecosystem there are a very large number of interlinked chains. This forms a food web. If the linkages in the chains that make up the web of life are disrupted due to human activities that lead to the loss or extinction of species, the web breaks down.

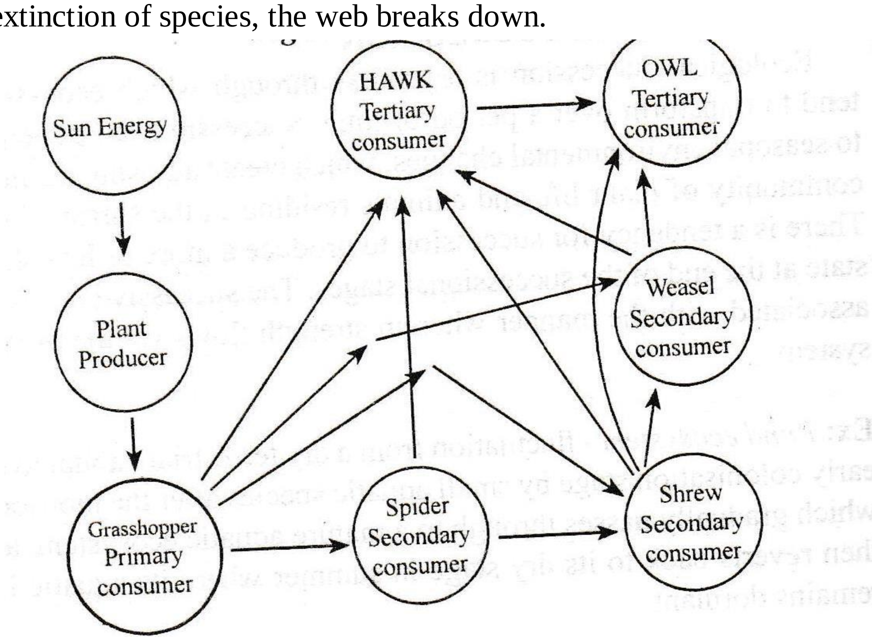


Fig: Food Web

- **The ecological pyramids**

Each step of the food web is called a trophic level. These trophic level together form the **ecological pyramid.**

In an ecosystem, green plants – the producers, utilize energy directly from sunlight and convert it into matter. A large number of these organisms form the most basic, or first 'trophic level' of the food pyramid. The herbivorous animals that eat plants are at the second trophic level and are called primary consumers. The predators that feed on them form the third trophic level and are known as secondary consumers.

Only a few animals form the third trophic level consisting of carnivores at the apex of the food pyramid. This is how energy is used by living creatures and flows through the ecosystem from its base to the apex. Much of the energy is used up in activities of each living organism.

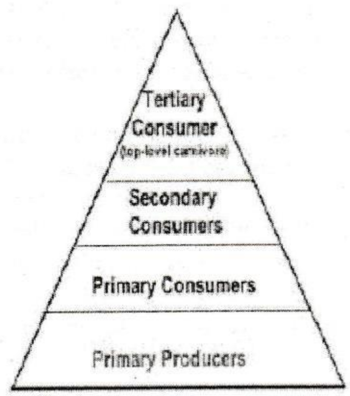


Fig : Energy pyramid

- **ECOSYSTEMS**
- **Forest ecosystem**

Forests are formed by a community of plants which is predominantly structurally defined by its trees, shrubs, climbers and ground cover.

Natural vegetation looks vastly different from a group of planted trees, which are in orderly rows. The most 'natural' undisturbed forests are located mainly in our National Parks and Wildlife Sanctuaries. The landscapes that make up various types of forests look very different from each other. Their distinctive appearance is a fascinating aspect of nature. Each forest type forms a habitat for a specific community of animals that are adapted to live in it.

The non-living or abiotic aspects of the forest:

The type of forest depends upon the abiotic conditions at the site. Forests on mountains and hills differ from those along river valleys. Vegetation is specific to the amount of rainfall and the local temperature which varies according to latitude and altitude. Forests also vary in their plant communities in response to the type of soil.

The living or the biotic aspects of the forest:

The plants and animals form communities that are specific to each forest type.

For instance coniferous trees occur in the Himalayas. Mangrove trees occur in river deltas. Thorn trees grow in arid areas. The snow leopard lives in the Himalayas while the leopard and tiger live in the forests of the rest of India. Wild sheep and goats live high up in the Himalayas. Many of the birds of the Himalayan forests are different from the rest of India. Evergreen forests of the Western Ghats and North East India are most rich in plant and animal species.

- **Types of forest ecosystem**

Forests in lndia can be broadly divided into Coniferous forests and Broad leaved forests.

Coniferous forests: Grow in the Himalayan mountain region. where the temperatures are low. These forests have tall stately trees with needle like leaves and downward sloping branches so that the snow can slip off the branches.

Broadleaved forests: They have several types, such as evergreen forests, deciduous forests, thorn forests, and mangrove forests. Broadleaved forests have large leaves of various shapes.

Evergreen forests grow in the high rainfall areas of the Western Ghati Nofth Eastem India and the Andaman and Nicobar Islands. These- forests grow in areas where the monsoon lasts for several months. There is no dry leafless phase as in a deciduous forest. An evergreen forest thus looks green throughout the year. The trees overlap with each other to form a continuous canopy. Thus very little light penetrates down to the forest floor.

Deciduous forests are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months.The deciduous trees shed their leaves during the winter and hot summer months. The forest frequently has a thick undergrowth as light can penetrate easily onto the forest floor.

Thorn forests are found in the semi- arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas. Thomy plants are able to conserve water.

Mangrove forests grow along the coast especially in the river deltas. These plants are able to grow in a mix of saline and fresh water. They grow luxuriantly in muddy areas covered with silt that the rivers iuve brought down. The mangrove trees have breathing roots that emerge from the mud banks.

Conservation of forest ecosystem: The forests can be conseryed only when its resources are used carefully. This can be done by using alternate sources of energy instead of fuel wood. There is a need to grow more trees than are cut down from forests every year for timber. Afforestation needs to be done continuously from which fuel wood and timber can be judiciously used. The natural forests with all their diverse species must be protected as National Parks and wildlife sanctuaries where all the plants and animals can be preserved.

- **Forest types in India**

The forest type depends upon the abiotic factors such as climate and soil characteristics of a region. Forests in India can be broadly divided into Coniferous forests and Broadleaved forests.

They can also be classified according to the nature of their tree species – evergreen, deciduous, xerophytic or thorn trees, mangroves, etc.

They can also be classified according to the most abundant species of trees such as Sal or Teak forests. In many cases a forest is named after the first three or four most abundant tree species.

Coniferous forests grow in the Himalayan mountain region, where the temperatures are low.

These forests have tall stately trees with needlelike leaves and downward sloping branches so that the snow can slip off the branches. They have cones instead of seeds and are called gymnosperms.

Broadleaved forests have several types, such as evergreen forests, deciduous forests, thorn forests, and mangrove forests. Broadleaved forests have large leaves of various shapes. Evergreen forests grow in the high rainfall areas of the Western Ghats, North Eastern India and the Andaman and Nicobar Islands. These forests grow in areas where the monsoon lasts for several months. Some even get two monsoons, such as in Southern India. Evergreen plants shed a few of their leaves throughout the year. There is no dry leafless phase as in a deciduous forest. An evergreen forest thus looks green throughout the year. The trees overlap with each other to form a continuous canopy.

Thus very little light penetrates down to the forest floor. Only a few shade loving plants can grow in the ground layer in areas where some light filters down from the closed canopy.The forest is rich in orchids and ferns.The barks of the trees are covered in moss. The forest abounds in animal life and is most rich in insect life.Deciduous forests are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months.

Most of the forests in which Teak trees grow are of this type. The deciduous trees shed their leaves during the winter and hot summer months. In March or April they regain their fresh leaves just before the monsoon, when they grow vigorously in response to the rains. Thus there are periods of leaf fall and canopy regrowth. The forest frequently has a thick undergrowth as light can penetrate easily onto the forest floor.

Thorn forests are found in the semi- arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas. Thorny plants are called xerophytic species and are able to conserve water. Some of these trees have small leaves, while other species have thick, waxy leaves to reduce water losses during transpiration. Thorn forest trees have long or fibrous roots to reach water at great depths. Many of these plants have thorns, which reduce water loss and protect them from herbivores.

Mangrove forests grow along the coast especially in the river deltas.These plants are able to grow in a mix of saline and fresh water. They grow luxuriantly in muddy areas covered with silt that the rivers have brought down. The mangrove trees have breathing roots that emerge from the mud banks.

- **Grassland ecosystems**

A wide range of landscapes in which the vegetation is mainly formed by grasses and small annual plants are adapted to India’s various climatic conditions. These form a variety of grassland ecosystems with their specific plants and animals.

Grasslands cover areas where rainfall is usually low and/or the soil depth and quality is poor.

The low rainfall prevents the growth of a large number of trees and shrubs, but is sufficient to support the growth of grass cover during the monsoon. Many of the grasses and other small herbs become dry and the part above the ground dies during the summer months. In the next monsoon the grass cover grows back from the root stock and the seeds of the previous year. This change gives grasslands a highly seasonal appearance with periods of increased growth followed by a dormant phase.

A variety of grasses, herbs, and several species of insects, birds and mammals have evolved so that they are adapted to these wide-open grass covered areas. These animals are able to live in conditions where food is plentiful after the rains, so that they can store this as fat that they use during the dry period when there is very little to eat. Man began to use these grasslands as pastures to feed his livestock when he began to domesticate animals and became a pastoralist in ancient times.

TYPES OF GRASSLANDS

The Himalayan -pasture belt: It extends up to the snowline. The grasslands at a lower level form patches along with coniferous or broadleaved forests. These Himalayan pastures have a large variety of grasses and herbs. There are also a large number of medicinal plants.

TheTerai:This consists of patches of tall grasslands interspersed with a Sal forest ecosystem. The patches of tall elephant grass are located in the low-lying waterlogged areas. The Sal forest patches cover the elevated region and the Himalayan foot hills.TheTerai also includes marshes in low-lyingdepressions. This ecosystem exteuds as a belt south of the Himalayan foothills.

The Semi-arid plains: This is located in Western India. Central India and the Deccan are covered by grass land tracts with patches Of thorn forest and are covered with seasonal grasses and herbs on which its fauna is dependent.

The Shola grasslands: It consist of patches on hillslopes along with the Shola forests on the western Ghats, Nilgiri and Annamalai ranges. This forms a patchwork of grassland on the slopes and forest habitats along the streams and low lying ares.

- **Desert ecosystem**

Desert and semi arid lands are highly specialized and sensitive ecosystems that are easily destroyed by human activities. The species of these dry areas can live only in this specialised habitat.

Deserts and semi arid areas are located in Western India and the Deccan Plateau. The climate in these vast tracts is extremely dry. There are also cold deserts such as in Ladakh, which are located in the high plateaus of the Himalayas.

The most typical desert landscape that is seen in Rajasthan is in the Thar Desert. This has sand dunes. There are also areas covered with sparse grasses and a few shrubs, which grow if it rains.

In most areas of the Thar the rainfall is scanty and sporadic. In an area it may rain only once every few years. In the adjoining semi arid tract the vegetation consists of a few shrubs and thorny trees such as kher and babul.

The Great and Little Rann of Kutch are highly specialised arid ecosystems. In the summers they are similar to a desert landscape. However as these are low-lying areas near the sea, they get converted to salt marshes during the monsoons.

During this period they attract an enormous number of aquatic birds such as ducks, geese, cranes, storks, etc. The Great Rann is famous, as it is the only known breeding colony of the Greater and

Lesser Flamingos in our country. The Little Rann of Kutch is the only home of the wild ass in India. Desert and semi arid regions have a number of highly specialized insects and reptiles. The rare animals include the Indian wolf, desert cat, desert fox and birds such as the Great Indian Bustard and the Florican. Some of the commoner birds include partridges, quails and sand grouse.

- **Aquatic ecosystems**

The aquatic ecosystems constitute the marine environments of the seas and the freesh water systems in lakes. rivers, ponds and wetlands. These ecosystems provide human beings with a wealth of narural resources. The aquatic ecosystems are classified into freshwater, brackish and marine ecosystems. which are based on the salinity levels.

The fresh rvater ecosystems: They have running water are streams and rivers. Ponds, tanks and lakes are ecosystems where water does not flow and have expenses of shallow water with aquatic vegetation, which forms anideal habitat for flsh, crustacean and water birds.

Marine ecosysterns are highly saline, while brackish areas have less saline water such as in river delta.

Brackish water ecosystems in river deltas are covered by mangrove forests and are among the world's most productive ecosystems in terms of biomass production. The largest mangrove swamps are in the Sundar bans in the delta of the Ganges.

- **ECOLOGICAL SUCCESSION**

Ecological succession is a process through which ecosystems tend to change over a period of time. Succession can be related to seasonal environmental changes, which create changes in the community of plants and animals living in the ecosystem. Other successional events may take much longer periods of time extending to several decades. If a forest is cleared, it is initially colonized by a certain group of species of plants and animals, which gradually change through an orderly process of community development.

One can predict that an opened up area will gradually be converted into a grassland, a shrubland and finally a woodland and a forest if permitted to do so without human interference.

There is a tendency for succession to produce a more or less stable state at the end of the successional stages. Developmental stages in the ecosystem thus consist of a pioneer stage, a series of changes known as several stages, and finally a climax stage. The successive stages are related to the way in which energy flows through the biological system. The most frequent example of successional changes occur in a pond ecosystem where it fluctuates from a dry terrestrial habitat to the early colonization stage by small aquatic species after the monsoon, which gradually passes through to a mature aquatic ecosystem, and then reverts back to its dry stage in summer where its aquatic life remains dormant.

Theory Questions

1. **Enumerate the utilization of carbon in ecosystem.** ***(December 2017)***
2. **Describe grassland ecosystem. What are its types? How conservation of grassland can be made.** ***(December 2017)***

3. **Discuss how oxygen cycle utilized in the eco system.** ***(December 2015)***
4. **Define environment. Mention its scope. Discuss the need for public awareness.** ***(December 2015)***
5. **What is an eco system? Discuss Forest ecosystem. Explain how conservation of forest can be done.** ***(December 2015)***
6. **Discuss how oxygen cycle is utilized in the ecosystems.** ***(December 2015)***
7. **Write a short note on**
   i. **Ecological succession**
   ii. **Food chain, food web and ecological pyramid.(*June 2015)***
   iii. **Elaborate how the nitrogen cycle ecosystem operates.**

MODULE IV

ENVIRONMENTAL POLLUTION

1.0 Pollution

Pollution is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. This occurs when only short-term economic gains are made at the cost of the long-term ecological benefits for humanity. No natural phenomenon has ledto greater ecological changes than have been made by mankind. During the last few decadeswe have contaminated our air, water and land on which life itself depends with a variety of waste products.

From an ecological perspective pollutants can be classified as follows:

Degradable or non-persistent pollutants: These can be rapidly broken down by natural processes. Eg: domestic sewage, discarded vegetables, etc.

Slowly degradable or persistent pollutants: Pollutants that remain in the environment for many years in an unchanged condition and take decades or longer to degrade. Eg: DDT and most plastics.

Non-degradable pollutants: These cannot be degraded by natural processes. Once they are released into the environment they are difficult to eradicate and continue to accumulate. Eg: toxic elements like lead or mercury.

1.1 Air pollution

Air pollution occurs due to the presence of un- desirable solid or gaseous particles in the air in quantities that are harmful to human health and the environment. Air may get polluted by natural causes such as volcanoes, which release ash, dust, sulphur and other gases, or by forest fires that are occasionally naturally caused by lightning. However, unlike pollutants from human activity, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change. Pollutants that are produced in the atmosphere when certain chemical reactions take place among the primary pollutants are called secondary pollutants. Eg: sulfuric acid, nitric acid, carbonic acid, etc.

Carbon monoxide is a colourless, odorless and toxic gas produced when organic materials such as natural gas, coal or wood are incompletely burnt. Vehicular exhausts are the single largest source of carbon monoxide. The number of vehicles has been increasing over the years all over the world. Vehicles are also poorly maintained and several have inadequate pollution control equipment resulting in release of greater amounts of carbon monoxide. Carbon monoxide is however not a persistent pollutant. Natural processes can convert carbon monoxide to other compounds that are not harmful. There- fore the air can be cleared of its carbon monoxide if no new carbon monoxide is introduced into the atmosphere.

Sulfur oxides are produced when sulfur containing fossil fuels are burnt

Nitrogen oxides are found in vehicular exhausts. Nitrogen oxides are significant, as they are involved in the production of secondary air pollutants such as ozone.

Hydrocarbons are a group of compounds consisting of carbon and hydrogen atoms. They either evaporate from fuel supplies or are remnants of fuel that did not burn completely. Hydrocarbons are washed out of the air when it rains and run into surface water. They cause an oily film on the surface and do not as such cause a serious issue until they react to form secondary pollutants. Using higher oxygen concentrations in the fuel-air mixture and using valves to prevent the escape of gases, fitting of catalytic converters in automobiles, are some of the modifications that can reduce the release of hydrocarbons into the atmosphere.

Particulates are small pieces of solid material (for example, smoke particles from fires, bits of asbestos, dust particles and ash from industries) dispersed into the atmosphere. The effects of particulates range from soot to the carcinogenic (cancer causing) effects of asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure to particulates can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases

Lead is a major air pollutant that remains largely unmonitored and is emitted by vehicles. High lead levels have been reported in the ambient air in metropolitan cities. Leaded petrol is the primary source of airborne lead emissions in Indian cities.

1.1.1 Effects of air pollution on living organisms

Our respiratory system has a number of mechanisms that help in protecting us from air pollution. The hair in our nose filters out large particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants sneezing and coughing expel contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or break- down these natural defenses causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other respiratory diseases are especially vulnerable to air pollution.

Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001 percent of carbon monoxide for several hours can cause collapse, coma and even death. As carbon monoxide re- mains attached to hemoglobin in blood for a long time, it accumulates and reduces the oxy- gen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headaches, drowsiness, dizziness andnausea. Carbon monoxide in heavy traffic causes head- aches, drowsiness and blurred vision **Sulfur dioxide** irritates respiratory tissues. Chronic exposure causes a condition similar tobronchitis. It also reacts with water, oxygen and other material in the air to form sulfur-containing acids. The acids can become attached to particles which when inhaled are verycorrosive to the lung.

Nitrogen oxides especially NO can irritate the lungs, aggravate asthma or chronic bronchitis and also increase susceptibility to respiratory infections such as influenza or common colds Many **volatile organic compounds** such as (benzene and formaldehyde) and toxic particulates(such as lead, cadmium) can cause mutations, reproductive problems or cancer. Inhaling ozone,a component of photochemical smog causes coughing, chest pain, breathlessness and irritationof the eye, nose and the throat.

Suspended particles aggravate bronchitis and asthma. Exposure to these particles over a long period of time damages lung tissue and con- tributes to the development of chronic respira- tory disease and cancer.

1.1.2 Effects on plants

When some gaseous pollutants enter leaf pores they damage the leaves of crop plants. Chronic exposure of the leaves to air pollutants can break down the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosynthesis and plant growth, reduces nutrient uptake and causesleaves to turn yellow, brown or drop off altogether. At a higher concentration of sulphur dioxide majority of the flower buds become stiff and hard. They eventually fall from the plants, as they are unable to flower. Prolonged exposure to high levels of several air pollutants from smelters, coal burning power plants and industrial units as well as from cars and trucks can damage trees and other plants

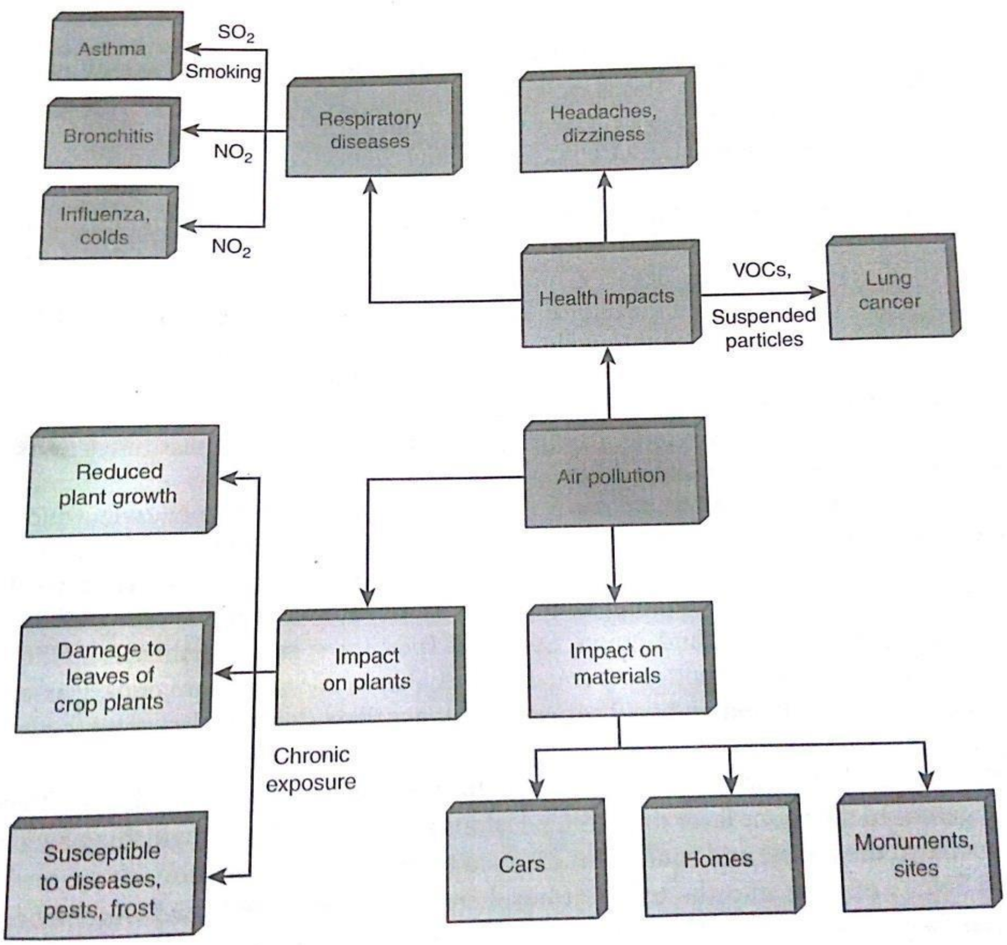


Fig. 5.2 Impact of air pollution

1.1.3 Effects of air pollution on materials

Every year air pollutants cause damage worth billions of rupees. Air pollutants break down exterior paint on cars and houses. All around the world air pollutants have discoloured irreplaceable monuments, historic buildings, marble statues, etc.

1.1.4 Ozone depletion-What does it do?

Changes in the ozone layer have serious implications for mankind.

Effects on human health: Sunburn, cataract, aging of the skin and skin cancer are caused by increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

Food production: Ultra violet radiation affects the ability of plants to capture light energy during the process of photosynthesis. This reduces the nutrient content and the growth of plants. This is seen especially in legumes and cabbage.

Increased ultra-violet radiation, It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

Effect on materials: Increased UV radiation damages paints and fabrics, causing them to fade faster.

Effect on climate: Atmospheric changes induced by pollution contribute to global warming, a phenomenon which is caused due to the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents such as water vapour, carbon dioxide, methane, nitrogen oxides and Chloro Fluro Carbons trap heat in the form of infra-red radiation near the earth's surface. This is known as the 'Green- house Effect'.

1.1.5 Control measures for air pollution

Air pollution can be controlled by two fundamental approaches: preventive techniques and effluent control.

One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases though scrubbers, closed collection recovery systems through which it is possible to collect the pollutants before they escape, use of dry and wet collectors, filters, electrostatic precipitators, etc. Providing a greater height to the stacks can help in facilitating the discharge of pollutants as far away from the ground as possible. Indus- tries should be located in places so as to minimize the effects of pollution after considering the topography and the wind directions. Substitution of raw material that causes more pollution with those that cause less pollution can be done.

1.2 Water Pollution

Introduction: Water is the essential element that makes life on earth possible. Without water there would be no life. We usually take water for granted. It flows from our taps when they are turned on. Most of us are able to bathe when we want to, swim when we choose and water our gardens.

Although 71% of the earth's surface is covered by water only a tiny fraction of this water is avail- able to us as fresh water. About 97% of the total water available on earth is found in oceans and is too salty for drinking or irrigation. The remaining 3% is fresh water. Of this 2.997% is locked in ice caps or glaciers. Thus only 0.003% of the earth' total volume of water is easily avail-able to us as soil moisture, groundwater, water vapour and water in lakes, streams, rivers and wetlands

Water availability on the planet: Water that is found in streams, rivers, lakes, wetlands and artificial reservoirs is called surface water. Water that percolates into the ground and fills the pores in soil and rock is called groundwater. Porous water-saturated layers of sand, gravel or bedrock through which ground water flows are called aquifers. Most aquifers are replenished naturally by rainfall that percolates down- ward through the soil and rock. This process is called natural recharge. If the withdrawal rate of an aquifer exceeds its natural recharge rate, the water table is lowered. Any pollutant that is discharged onto the land above is also pulled into the aquifer and pollutes the groundwater resulting in polluted water in the nearby wells.

India receives most of her rainfall during the months of June to September due to the seasonal winds and the temperature differences between the land and the sea.

The monsoon in India is usually reasonably stable but varies geographically. In some years the commencement of the rains may be delayed considerably over the entire country or a part of it. The rains may also terminate earlier than usual. They may be heavier than usual over one part than over another. All these may cause local floods or drought. However in India even areas that receive adequate rainfall during the monsoon suffer from water shortages in the post monsoon period due to lack of storage facilities.

When a source of pollution cannot be readily identified, such as agricultural runoff, acid rain, etc, they are said to be **non-point sources of pollution**.

Point sources of pollution: When a source of pollution can be readily identified because it has a definite source and place where it enters the water it is said to come from a point source. Eg. Municipal and Industrial Discharge Pipes.

1.2.1 Causes of water pollution

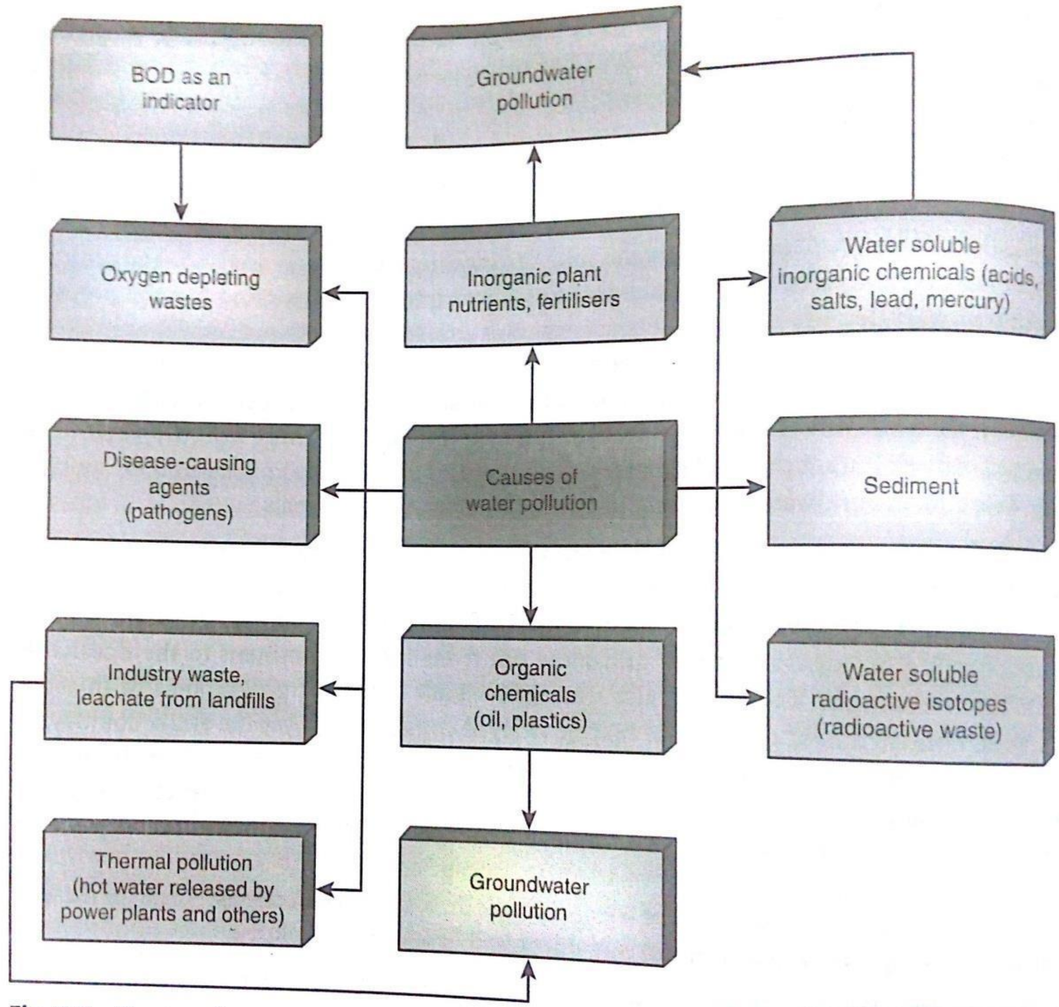


Fig. 5.5 Causes of water pollution

a). Disease causing agents (pathogens) which include bacteria, viruses, protozoa and parasitic worms that enter water from domestic sewage and untreated human and animal wastes. Human wastes contain concentrated populations of coliform bacteria such as Escherichia coli and Streptococcus faecalis. These bacteria normally grow in the large intestine of humans where they are responsible for some food digestion and for the production of vita- min K. These bacteria are not harmful in low numbers. Large amounts of human waste in water, increases the number of these bacteria which cause gastrointestinal diseases. Other potentially harmful bacteria from human wastes may also be present in smaller numbers.

b). oxygen depleting wastes: These are organic wastes that can be decomposed by aerobic (oxy- gen requiring) bacteria. Large populations of bacteria use up the oxygen present in water to degrade these wastes. In the process this de- grades water quality. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in the water is an indicator of the level of pollution. If too much organic matter is added to the water all the available oxygen is used up. This causes fish and other forms of oxygen dependent aquatic life to die. Thus anaerobic bacteria (those that do not require oxygen) begin to break down the wastes. Their anaerobic respiration produces chemicals that have a foul odour and an un-pleasant taste that is harmful to human health.

c). inorganic plant nutrients: These are water soluble nitrates and phosphates that cause excessive growth of algae and other aquatic plants. The excessive growth of algae and aquatic plants due to added nutrients is called eutrophication. They may interfere with the use of the water by clogging water intake pipes, changing the taste and odour of water and cause a buildup of organic matter. As the organic matter decays, oxygen levels decrease and fish and other aquatic species die.

d). water soluble inorganic chemicals which are acids, salts and compounds of toxic metals such as mercury and lead. High levels of these chemicals can make the water unfit to drink, harm fish and other aquatic life, reduce crop yields and accelerate corrosion of equipment that use this water

e). organic chemicals, which include oil, gasoline, plastics, pesticides, cleaning solvents, detergent and many other chemicals. These are harmful to aquatic life and human health. They get into the water directly from industrial activity either from improper handling of the chemicals in industries and more often from improper and illegal disposal of chemical wastes.

f). Sediment of suspended matter is another class of water pollutants. These are insoluble particles of soil and other solids that become suspended in water. This occurs when soil is eroded from the land. High levels of soil particles suspended in water, interferes with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases the suspended particles settle down at the bottom as sediments. Excessive sediments that settle down destroys feeding and spawning grounds of fish, clogs and fills lakes, artificial reservoirs etc.

g). Water soluble radioactive isotopes are yet another source of water pollution. These can be concentrated in various tissues and organs as they pass through food chains and food webs. Ionizing radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

h). Hot water let out by power plants and industries that use large volumes of water to cool the plant result in rise in temperature of the local water bodies. Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity.

i). Groundwater pollution: While oil spills are highly visible and often get a lot of media attention, a much greater threat to human life comes from our groundwater being polluted which is used for drinking and irrigation. While groundwater is easy to deplete and pollute it gets renewed very slowly and hence must be used judiciously. Groundwater flows are slow and not turbulent hence the contaminants are not effectively diluted and dispersed as com- pared to surface water. Moreover pumping groundwater and treating it is very slow and costly. Hence it is extremely essential to prevent the pollution of groundwater in the first place. Ground water is polluted due to:

- Urban run-off of untreated or poorly treated waste water and garbage
- Agricultural practices such as the application of large amounts of fertilizers and pesticides, animal feeding operations, etc. in the rural sector
- Industrial waste storage located above or near aquifers
- Mining wastes
- Poorly designed and inadequately maintained septic tanks
- Leakage from underground storage tanks containing gasoline and other hazardous substances

1.2.2 Control measures for preventing water pollution

While the foremost necessity is prevention, set- ting up effluent treatment plants and treating waste through these can reduce the pollution load in the recipient water. The treated effluent can be reused for either gardening or cooling purposes wherever possible. A few years ago a new technology called the Root Zone Process has been developed by Thermax. This system involves running contaminated water through the root zones of specially designed reed beds. The reeds, which are essentially wetland plants, have the capacity to absorb oxygen from the surrounding air through their stomatal openings. The oxygen is pushed through the porous stem of the reeds into the hollow roots where it enters the root zone and creates conditions suit- able for the growth of numerous bacteria and fungi. These micro-organisms oxidize impurities in the wastewaters, so that the water which finally comes out is clean.

1.3 Soil Pollution

Soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water that together support the growth of plant life. Several factors contribute to the formation of soil from the parent material. This includes mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important in the development of soils. Extremely dry or cold climates develop soils very slowly while humid and warm climates develop them more rapidly. Under ideal climatic conditions soft parent material may develop into a centimeter of soil within 15 years. Under poor climatic conditions a hard parent material may require hundreds of years to develop into soil.

Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium size particles) and gravel (coarse to very coarse particles). The relative amounts of the different sizes and types of mineral particles determine soil texture. Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

1.3.1 Causes of soil degradation

Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to an- other. While erosion is a natural process often caused by wind and flowing water it is greatly accelerated by human activities such as farming, construction, overgrazing by livestock, burning of grass cover and deforestation.

Loss of the topsoil makes a soil less fertile and reduces its water holding capacity. The topsoil, which is washed away, also contributes to water pollution clogging lakes, increasing turbidity of the water and also leads to loss of aquatic life.

Continuous contour trenches can be used to enhance infiltration of water reduce the run- off and check soil erosion. These are actually shallow trenches dug across the slope of the land and along the contour lines basically for the purpose of soil and water conservation. They are most effective on gentle slopes and in areas of low to medium rainfall. These bunds are stabilized by fast growing tree species and grasses. In areas of steep slopes where the bunds are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.

Gradonies can also be used to convert waste- lands into agricultural lands. In this narrow trenches with bunds on the downstream side are built along contours in the upper reaches of the catchment to collect run-off and to conserve moisture from the trees or tree crops. The area between the two bunds is use for cultivation of crops after development of fertile soil cover.

Some of the ways in which this can be achieved are:

- A bund constructed out of stones across the stream can also be used for conserving soil and water.
- Live check dams which barriers created by planting grass, shrubs and trees across the gullies can be used for this purpose.
- An Earthen check bund is constructed out of local soil across the stream to check soil erosion and flow of water.
- A Gabion structure is a bund constructed of stone and wrapped in galvanized chainlink.
- A Gabion structure with ferrocement impervious barrier has a one inch thick impervious wall of ferrocement at the center of the structure which goes below the ground level upto the hard strata. This ferrocement partition sup- ported by the gabion portion is able to retain the water and withstand the force of the runoff water.

1.3.2 Excess use of fertilizers

Fertilizers are very valuable as they replace the soil nutrients used up by plants. The three primary soil nutrients often in short supply are potassium, phosphorus and nitrogen compounds. These are commonly referred to as macronutrients. Certain other elements like boron, zinc and manganese are necessary in extremely small amounts and are known as micronutrients. When crops are harvested a large amount of macronutrients and a small amount of micronutrients are re- moved with the crops. If the same crop is grown again depleted levels of these nutrients can result in decreased yields. These necessary nutrients can be returned to the soil through the application of fertilizers. In addition to fertilizers a large amount of pesticides (chemicals used to kill or control populations of unwanted fungi, animals or plants often called pests) are also used to ensure a good yield. Pesticides can be subdivided into several categories based on the kinds of organisms they are used to control. Insecticides are used to control insect populations while fungicides are used to control unwanted fungal growth. Mice and rats are killed by rodenticides while plant pests are controlled by herbicides.

1.3.3 Problems with pesticide use

Pesticides not only kill the pests but also a large variety of living things including humans. They may be persistent or non-persistent. Persistent pesticides once applied are effective for a long time. However as they do not break down easily they tend to accumulate in the soil and in the bodies of animals in the food chain.

The use of DDT has been banned in some countries. India still however permits the use of DDT though for purposes of mosquito control only. Persistent pesticides become attached to small soil particles which are easily moved by wind and water to different parts thus affecting soils elsewhere. Persistent pesticides may also accumulate in the bodies of animals, and over a period of time increase in concentration if the animal is unable to flush them out of its system thus leading to the phenomenon called bioaccumulation. When an affected animal is eaten by another carnivore these pesticides are further concentrated in the body of the carnivore. This phenomenon of acquiring increasing levels of a substance in the bodies of higher trophic level organisms is known as biomagnification.

Other problems associated with insecticides are the ability of insect populations to become resistant to them thus rendering them useless in a couple of generations. Most pesticides kill beneficial as well as pest species. They kill the predator as well as the parasitic insects that control the pests. Thus the pest species increase rapidly following the use of a pesticide as there are no natural checks to their population growth. The short term and the long-term health effects to the persons using the pesticide and the public that consumes the food grown by using the pesticides are also major concerns. Exposure to small quantities of pesticides over several years can cause mutations, produce cancers, etc.

1.3.4 Excess salts and water

Another problem with irrigation is water logging. This occurs when large amount of water is used to leach the salts deeper into the soil. However if the drainage is poor this water ac- cumulates underground gradually raising the water table. The roots of the plants then get enveloped in this saline water and eventually die.

Irrigated lands can produce crop yields much higher than those that only use rainwater. How- ever this has its own set of ill effects. Irrigation water contains dissolved salts and in dryclimates much of the water in the saline solution evaporates leaving its salts such as sodium chloride in the topsoil. The accumulation of these salts is called salinization, which can stunt plant growth, lower yields and eventually kill the crop and render the land useless for agriculture. These salts can be flushed out of the soil by using more water. This practice however increases the cost of crop production and also wastes enormous amounts of water. Flushing salts can also make the downstream irrigation water saltier.

1.4 Marine Pollution

Marine pollution can be defined as the introduction of substances to the marine environment directly or indirectly by man resulting in adverse effects such as hazards to human health, obstruction of marine activities and lowering the quality of sea water. While the causes of marine pollution may be similar to that of general water pollution there are some very specific causes that pollute marine waters

- Waste through pipes directly discharging wastes into the sea. Very often municipal waste and sew- age from residences and hotels in coastal towns are directly discharged into the sea

- Pesticides and fertilizers from agriculture which are washed off the land by rain, enter water courses and eventually reach the sea.
- Petroleum and oils washed off from the roads normally enter the sewage system but storm water overflows carry these materials into rivers and eventually into the seas
- Ships carry many toxic substances such as oil, liquefied natural gas, pesticides, industrial chemicals, etc. in huge quantities some- times to the capacity of 350,000 tonnes. Ship accidents and accidental spillages at sea therefore can be very damaging to the marine environment
- Offshore oil exploration and extraction also pollute the seawater to a large extent.

1.4.1 Pollution due to organic wastes

The amount of oxygen dissolved in the water is vital for the plants and animals living in it. Wastes, which directly or indirectly affect the oxygen concentration, play an important role in determining the quality of the water. Normally the greatest volume of waste discharged to watercourses, estuaries and the sea is sewage, which is primarily organic in nature and is de- graded by bacterial activity. Using the oxygen present in the water these wastes are broken down into stable inorganic compounds. How- ever as a result of this bacterial activity the oxy- gen concentration in the water is reduced. When the oxygen concentration falls below 1.5 mg/ lit, the rate of aerobic oxidation is reduced and their place is taken over by the anaerobic bacteria that can oxidize the organic molecules with- out the use of oxygen. This results in end products such as hydrogen sulphide, ammonia and methane, which are toxic to many organ- isms. This process results in the formation of an anoxic zone which is low in its oxygen content from which most life disappears except for anaerobic bacteria, fungi, yeasts and some protozoa. This makes the water foul smelling.

1.4.2 Control measures

Pollution load on marine waters is through the introduction of sewage treatment plants. This will reduce the biological oxygen demand (BOD) of the final product before it is discharged to the receiving waters.

Various stages of treatment such as primary, secondary or advanced can be used depending on the quality of the effluent that is required to be treated.

Primary treatment: These treatment plants use physical processes such as screening and sedimentation to remove pollutants that will settle, float or, that are too large to pass through simple screening devices. This includes stones, sticks, rags, and all such material that can clog pipes.

Secondary treatment: The main objective of secondary treatment is to remove most of the BOD. There are three commonly used approaches: trickling filters, activated sludge process and oxidation ponds. Secondary treatment can remove at least 85 percent of the BOD.

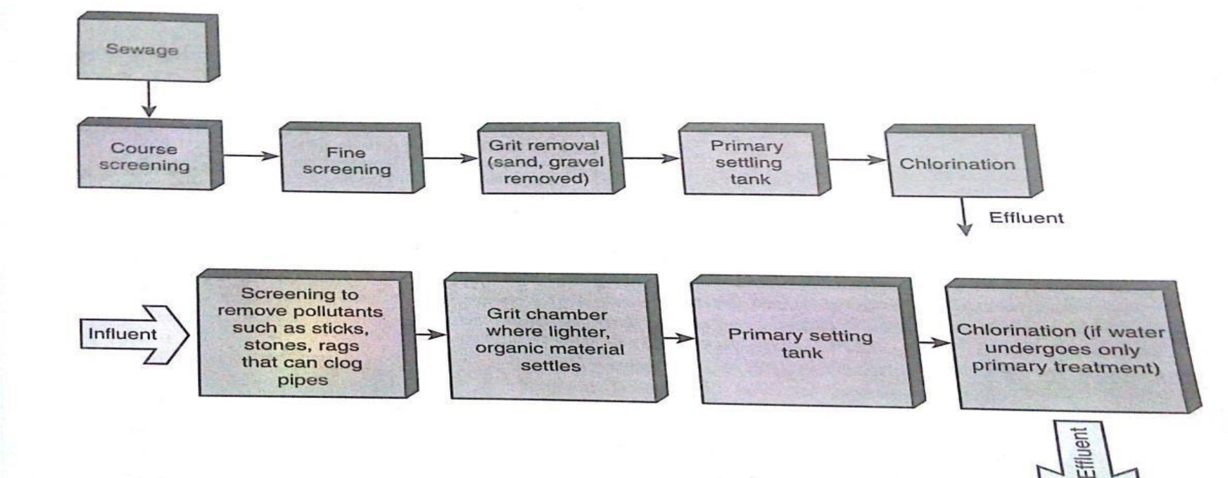


Fig. 5.7 Primary treatment

1.4.3 Pollution due to oil

Oil pollution of the sea normally attracts the greatest attention because of its visibility. Thereare several sources though which the oil can reach the sea,

- Tanker operations,
- All ships need periodic dry docking for servicing, repairs, cleaning the hull, etc. During this period when the cargo compartments are to completely emptied, residual oil finds its way into the sea.
- Bilge and fuel oils
- Offshore oil production
- Tanker accidents

1.4.4 Control measures for oil pollution

Cleaning oil from surface waters and contaminated beaches is a time consuming labour intensive process. The natural process of emulsification of oil in the water can be accelerated through the use of chemical dispersants which can be sprayed on the oil. A variety of slick- lickers in which a continuous belt of absorbent material dips through the oil slick and is passed through rollers to extract the oil have been designed. Rocks, harbour walls can be cleaned with high- pressure steam or dispersants after which the surface must be hosed down.

1.4.5 Effects of marine pollution

- Apart from causing eutrophication a large amount of organic wastes can also result in the development of red tides. These are phytoplankton blooms of such intensity that the area is discolored. Many important commercially important marine species are also killed due to clogging of gills or other structures.
- Oil slicks damage marine life to a large extent. Salt marshes, mangrove swamps are likely to trap oil and the plants, which form the basis for these ecosystems thus suffer. For salt marsh plants, oil slicks can affect the flowering, fruiting and germination
- When liquid oil is spilled on the sea it spreads over the surface of the water to form a thin film called an oil slick. The rate of spreading and the thickness of the film depend on the sea temperature and the nature of the oil.
- Fish and shellfish production facilities can also be affected by oil slicks. The most important commercial damage can however also come from tainting which imparts an unpleasant flavour to fish and seafood and is detectable at extremely low levels of contamination. This reduces the market value of seafood

1.5 Noise Pollution

Noise may not seem as harmful as the contamination of air or water but it is a pollution problem that affects human health and can contribute to a general deterioration of environmental quality. Noise is undesirable and unwanted sound. Not all sound is noise. . Sound is measured in a unit called the 'Decibel'.

There are several sources of noise pollution that contribute to both indoor and outdoor noise pollution. Noise emanating from factories, vehicles, playing of loudspeakers during various festivals can contribute to outdoor noise pollution while loudly played radio or music systems, and other electronic gadgets can contribute to indoor noise pollution. There are however some very harmful effects caused by exposure to high sound levels. These effects can range in severity from being extremely annoying to being extremely painful and hazardous.

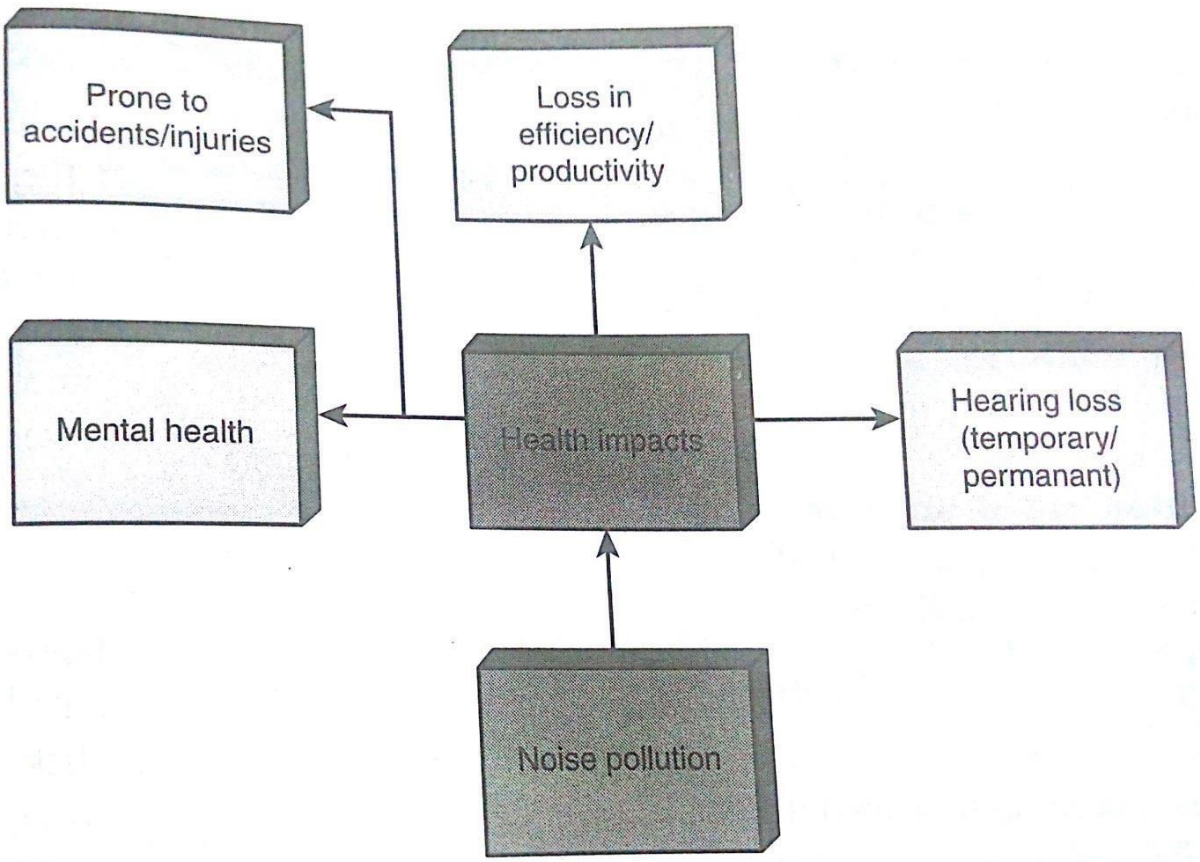


Fig. 5.12 Impact of noise pollution

1.5.1 Effects of noise pollution on physical health

The most direct harmful effect of excessive noise is physical damage to the ear and the temporary or permanent hearing loss often called a temporary threshold shift (TTS). People suffering from this condition are unable to detect weak sounds. However hearing ability is usually recovered within a month of exposure. In Maharashtra people living in close vicinity of Ganesh mandals that play blaring music for ten days of the Ganesh festival are usually known to suffer from this phenomenon. Permanent loss, usually called noise induced permanentthreshold shift (NIPTS) represents a loss of hearing ability from which there is no recovery.

Below a sound level of 80 dBA haring loss does not occur at all. However temporary effects are noticed at sound levels between 80 and 130 dBA. About 50 percent of the people exposed to 95 dBA sound levels at work will develop NIPTS and most people exposed to more than 105 dBA will experience permanent hearing loss to some degree. A sound level of 150 dBA or more can physically rupture the human eardrum.

1.5.2 Effects of noise pollution on mental health

Noise can also cause emotional or psychological effects such as irritability, anxiety and stress. Lack of concentration and mental fatigue are significant health effects of noise. It has been observed that the performance of school children is poor in comprehension tasks when schools are situated in busy areas of a city and suffer from noise pollution.

Thus noise is just more than a mere nuisance or annoyance. It definitely affects the quality of life. It is thus important to ensure mitigation or control of noise pollution. As noise interferes with normal auditory communication, it may mask auditory warning signals and hence increases the rate of accidents especially in industries. It can also lead to lowered worker efficiency and productivity and higher accident rates on the job.

1.5.3 Noise Control techniques

There are four fundamental ways in which noise can be controlled: Reduce noise at the source, block the path of noise, increase the path length and protect the recipient. In general, the best control method is to reduce noise levels at the source.

Source reduction can be done by effectively muffling vehicles and machinery to reduce the noise. In industries noise reduction can be done by using rigid sealed enclosures around machinery lined with acoustic absorbing material. Isolating machines and their enclosures from the floor using special spring mounts or absorbent mounts and pads and using flexible couplings for interior pipelines also contribute to reducing noise pollution at the source. However one of the best methods of noise source reduction is regular and thorough maintenance of operating machinery. Noise levels at construction sites can be controlled using proper construction planning and scheduling techniques. Locating noisy air compressors and other equipment away from the site boundary along with creation of temporary barriers to physically block the noise can help contribute to reducing noise pollution. Most of the vehicular noise comes from movement of the vehicle tires on the pavement and wind resistance. However poorly maintained vehicles can add to the noise levels. Traffic volume and speed also have significant effects on the overall sound. For example doubling the speed increases the sound levels by about 9 dBA and doubling the traffic volume (number of vehicles per hour) increases sound levels by about 3 dBA. A smooth flow of traffic also causes less noise than doesa stop-and-go traffic pattern. Proper highway planning and design are essential for controlling traffic noise. Establishing lower speed limits for highways that pass through residential areas, limiting traffic volume and providing alternative routes for truck traffic are effective noisecontrol measures. The path of traffic noise can also be blocked by construction of vertical barriers alongside the high-way. Planting of trees around houses can also act as effective noise barriers. In industries different types of absorptive material can be used to control interiornoise. Highly absorptive interior finish material for walls, ceilings and floors can decrease indoor noise levels significantly. Sound levels drop significantly with increasing distance from the noise source. Increasing the path length between the source and the recipient offers a passive means of control. Municipal land-use ordinances pertaining to the location of airports make use of the attenuating effect of distance on sound levels. Use of earplugs and earmuffs can protect individuals effectively from excessive noise levels. Specially designed earmuffs can reduce the sound level reaching the eardrum by as much as 40 dBA. However very often workers tend not to wear them on a regular basis despite company requirements for their use.

1.6 Thermal Pollution

The discharge of warm water into a river is usually called a thermal pollution. It occurs when an industry removes water from a source, uses the water for cooling purposes and then returns the heated water to its source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat. This heated water, which is at least 15oC higher than the normal is discharged back into the water body

1.6.1 Effects

The warmer temperature decreases the solubility of oxygen and increases the metabolism of fish. This changes the ecological balance of the river. Within certain limits thermal additions can promote the growth of certain fish and the fish catch may be high in the vicinity of a power plant. However sudden changes in temperature caused by periodic plant shutdowns both planned and unintentional can change result in death of these fish that are acclimatized to living in warmer waters.

Tropical marine animals are generally unable to withstand a temperature increase of 2 to 3^0C and most sponges, mollusks and crustaceans are eliminated at temperatures above 37^0C. This results in a change in the diversity of fauna as only those species that can live in warmer water survive.

1.6.2 Control measures:

Thermal pollution can be controlled by passing the heated water through,

- To construct a large shallow pond. Hot water is pumped into one end of the pond and cooler water is removed from the other end. The heat gets dissipated from the pond into the atmosphere
- To use a cooling tower. These structures take up less land area than the ponds. Here most of the heat transfer occurs through evaporation. Here warm waters coming from the condenser is sprayed down- ward over vertical sheets or baffles where the water flows in thin films. Cool air enters the tower through the water inlet that encircles the base of the tower and rises upwards causing evaporative cooling.

1.7 Nuclear Hazards

Nuclear energy can be both beneficial and harmful depending on the way in which it is used. We routinely use X-rays to examine bones for fractures, treat cancer with radiation and diagnose diseases with the help of radioactive isotopes. Approximately 17 % of the electrical energy generated in the world comes from nuclear power plants. However on the other hand it is impossible to forget the destruction that nuclear bombs caused the cities of Hiroshima and Nagasaki. The radioactive wastes from nuclear energy have caused serious environmental damage.

In order to appreciate the consequences of using nuclear fuels to generate energy it is important to understand how the fuel is processed. Low-grade uranium ore, which contains 0.2 percent uranium by weight, is obtained by surface or underground mining. After it is mined the ore goes through a milling process where it is crushed and treated with a solvent to concentrate the uranium and produces yellow cake a material containing 70 to 90 percent uranium oxide. Naturally occurring uranium contains only 0.7 percent of fissionable U-235, which is not high enough for most types of reactors. Hence it is necessary to increase the amount of U-235 by enrichment though it is a difficult and ex- pensive process. The enrichment process in- creases the U-235 content from 0.7 to 3 percent. Fuel fabrication then converts the enriched material into a powder, which is then compacted into pellets. These pellets are sealed in metal fuel rods about 4 meters in length which is then loaded into the reactor. As fission occurs the concentration of U-235 atoms decreases. After about three years, a fuel rod does not have enough radioactive material to sustain a chain reaction and hence the spent fuel rods must be replaced by new ones. The spent rods are how- ever still very radioactive containing about one percent U-235 and one percent plutonium. These rods are a major source of radioactive waste material produced by a nuclear reactor. Initially it was thought that spent fuel rods could be reprocessed to not only provide new fuel but also to reduce the amount of nuclear waste. However the cost of producing fuel rods by re- processing was found to be greater than the cost of producing fuel rods from ore. Presently India does operate reprocessing plants to reprocess spent fuel as an alternative to storing them as nuclear waste. At each step in the cycle there is a danger of exposure and poses several health and environmental concerns.

1.8 Solid Waste Management: Causes, Effects and Control Measures of Urban and Industrial Waste

Around most towns and cities in India the approach roads are littered with multi-coloured plastic bags and other garbage. Waste is also burnt to reduce its volume. Modern methods of disposal such as incineration and the development of sanitary landfills, etc. are now attempting to solve these problems. Lack of space for dumping solid waste has become a serious problemin several cities and towns all over the world. Dumping and burning wastes is not an acceptable practice today from either an environmental or a health perspective. Today disposal of solid waste should be part of an integrated waste management plan. The method of collection, processing, resource recovery and the final disposal should mesh with one another to achieve a common objective.

1.8.1 Characteristics of municipal solid waste

Municipal solid waste contains a wide variety of materials. It can contain food waste such as vegetable and meat material, left over food, egg shells, etc. which is classified as wet garbage as well as paper, plastic, tetrapacks, plastic cans, newspaper, glass bottles, cardboard boxes, aluminum foil, metal items, wood pieces, etc. which is classified as dry garbage.

1.8.2 Control measures of urban and industrial wastes

An integrated waste management strategy includes three main components:

1. Source reduction
2. Recycling
3. Disposal

Source reduction is one of the fundamental ways to reduce waste. This can be done by using less material when making a product, reuse of products on site, designing products or pack- aging to reduce their quantity. On an individual level we can reduce the use of unnecessary items while shopping, buy items with minimal pack- aging, avoid buying disposable items and also avoid asking for plastic carry bags.

Recycling is reusing some components of the waste that may have some economic value. Recycling has readily visible benefits such as conservation of resources reduction in energy used during manufacture and reducing pollution levels. Some materials such as aluminum and steel can be recycled many times. Metal, paper, glass and plastics are recyclable. Mining of new aluminum is expensive and hence recycled aluminum has a strong market and plays a significant role in the aluminum industry. Paper recycling can also help preserve forests as it takes about 17 trees to make one ton of paper. Crushed glass (cullet) reduces the energy required to manufacture new glass by 50 percent. Cullet lowers the temperature requirement of the glassmaking process thus conserving energy and reducing air pollution. However even if recycling is a viable alternative, it presents several problems.

Disposal of solid waste is done most commonly through a sanitary landfill or through incineration. A modern sanitary landfill is a depression in an impermeable soil layer that is lined with an impermeable membrane. The three key characteristics of a municipal sanitary landfill that distinguish it from an open dump are:

- The waste is covered each day with a layer of compacted soil.
- The waste material is spread out and compacted with appropriate heavy machinery
- Solid waste is placed in a suitably selected and prepared landfill site in a carefully pre-scribed manner

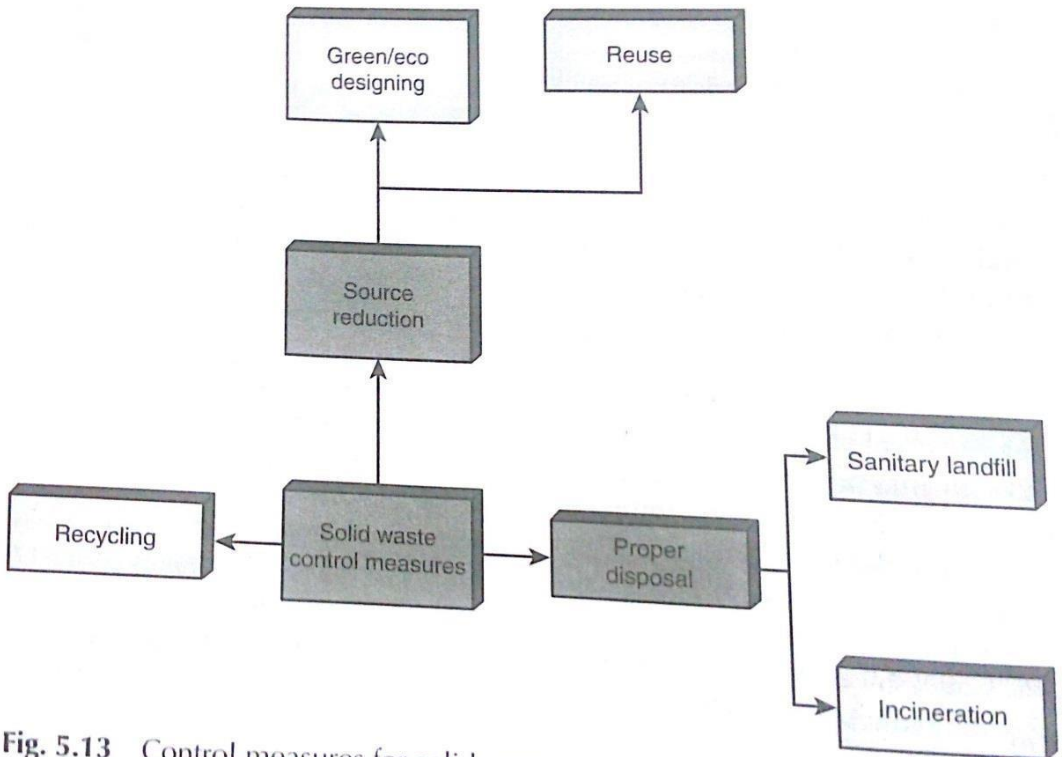


Fig. 5.13 Control measures for solid waste

1.8.3 Incineration

It is the process of burning municipal solid waste in a properly designed furnace under suitable temperature and operating conditions. Incineration is a chemical process in which the combustible portion of the waste is combined with oxygen forming carbon dioxide and water, which are released into the atmosphere. This chemical reaction called oxidation results in the release of heat. For complete oxidation the waste must be mixed with appropriate volumes of air at a temperature of about 815° C for about one hour. Incineration can reduce the municipal solid waste by about 90 percent in volume and 75 percent in weight. The risks of incineration however involve air- quality problems and toxicity and disposal of the fly and bottom ash produced during the incineration process. Fly ash consists of finely divided particulate matter, including cinders, mineral dust and soot. Most of the incinerator ash is bottom ash while the remainder is fly ash. The possible presence of heavy metals in incinerator ash can be harmful. Thus toxic products and materials containing heavy metals (for example batteries and plastics) should be segregated. Thus extensive air pollution control equipment and high-level technical supervision and skilled employees for proper operation and maintenance is required.

1.8.4 Vermicomposting

Nature has perfect solutions for managing the waste it creates, if left undisturbed. The bio-geochemical cycles are designed to clear the waste material produced by animals and plants. We can mimic the same methods that are present in nature. All dead and dry leaves and twigs decompose and are broken down by organisms such as worms and insects, and is finally broken down by bacteria and fungi, to form a dark rich soil-like material called compost.

These organisms in the soil use the organic material as food, which provides them with nutrients for their growth and activities. These nutrients are returned to the soil to be used again by trees and other plants. This process recycles nutrients in nature.

1.9 Hazardous wastes

Hazardous wastes are those that can cause harm to humans or the environment. Wastes are normally classified as hazardous waste when they cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of.

1.9.1 Characteristics of hazardous wastes

A waste is classified as a hazardous waste if it exhibits any of the four primary characteristics based on the physical or chemical properties of toxicity, reactivity, ignitability and corrosivity. In addition to this waste products that are either infectious or radioactive are also classified as hazardous

Toxic wastes are those substances that are poisonous even in very small or trace amounts. Some may have an acute or immediate effect on humans or animals causing death or violent illness. Others may have a chronic or long term effect slowly causing irreparable harm to ex- posed persons. Acute toxicity is readily apparent because organisms respond to the toxin shortly after being exposed. Chronic toxicity is much more difficult to determine because the effects may not be seen for years. Certain toxic wastes are known to be carcinogenic, causing cancer and others may be mutagenic causing biological changes in the children of exposed people and animals.

Corrosive wastes are those that destroy materials and living tissue by chemical reaction. For example, acids and bases.

Ignitable wastes are those that burn at relatively low temperatures (less than 6^0 C) and are capable of spontaneous combustion during storage, transport or disposal. For example, gasoline, paint thinners, and alcohol.

Reactive wastes are those that have a tendency to react vigorously with air or water, are un- stable to shock or heat, generate toxic gases or explode during routine management. For ex- ample, gunpowder, nitroglycerine, etc.

Radioactive waste is basically an output from the nuclear power plants and can persist in the environment for thousands of years before it decays appreciably

Infectious wastes include human tissue from surgery, used bandages and hypodermic needles, microbiological materials, etc.

1.9.2 Environmental problems and health risks caused by hazardous wastes

As most of the hazardous wastes are disposed of on or in land the most serious environmental effect is contaminated groundwater. Once groundwater is polluted with hazardous wastes it is very often not possible to reverse the damage.

Pesticides are used increasingly to protect and increase food production. They form residues in the soil which are washed into streams which then carry them forwards. The residues may persist in the soil or in the bottom of lakes and rivers. Exposure can occur through ingestion, inhalation and skin contact resulting in acute or chronic poisoning. Today we have an alternative to the excess use of pesticides through the use of Integrated Pest Management

(IPM). The IPM system uses a wide variety of plants and insects to create a more natural process. The natural balance between climate, soil and in- sect populations can help to prevent an insect from overpopulating an area and destroying a particular crop

Lead, mercury and arsenic are hazardous sub- stances which are often referred to as heavy metals. Lead is an abundant heavy metal and is relatively easy to obtain. It is used in batteries, fuel, pesticides, paints, pipes and other places where resistance to corrosion is required. Most of the lead taken up by people and wildlife is stored in bones. Lead can affect red blood cells by reducing their ability to carry oxygen and shortening their life span. Lead may also dam- age nerve tissue which can result in brain dis- ease.

Mercury occurs in several different forms. Mercury is used in the production of chlorine. It is also used as a catalyst in the production of some plastics. Industrial processes such as the production of chlorine and plastics are responsible for most of the environmental damage resulting from mercury. Our body has a limited ability to eliminate mercury. In the food web mercury becomes more concentrated as it is taken up by various organisms. In an aquatic environment, mercury can be absorbed by the plankton which are then consumed by fish. In addition, fish take up mercury through their gills and by eating other fish contaminated with mercury. Generally older the fish greater is the mercury con- centration in its body. Birds that eat the fish concentrate even more mercury in their bodies. It is a cumulative poison (it buildsup in the body over long periods of time) and is known to cause brain damage.

Thousands of chemicals are used in industry every day. When used incorrectly or inappropriately they can become health hazards. PCBs (Polychlorinated biphenyls) are resistant to fire and do not conduct electricity very well which makes them excellent materials for several industrial purposes. Rainwater can wash PCBs out of disposal areas in dumps and landfills thus contaminating water. PCBs do not break down very rapidly in the environmentand thus retain their toxic characteristics. They cause long term exposure problems to both humans and wild- life. PCBs are concentrated in the kidneys and liver and thus cause damage. They cause reproductive failure in birds and mammals.

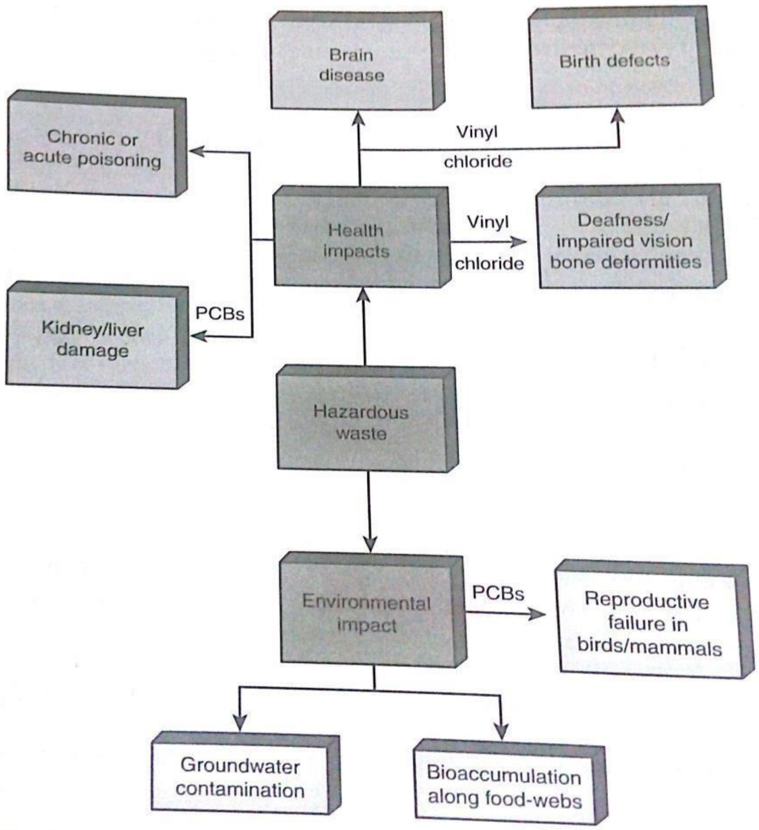


Fig. 5.15 Impact of hazardous waste

Vinyl chloride is a chemical that is widely used in the manufacture of plastic. Usually people are only exposed to high levels of vinyl chloride if they work with it or near it but exposure can also occur from vinyl chloride gas leaks. After a long continuous exposure (one to three years) in humans, vinyl chloride can cause deafness, vision problems, circulation disorders and bone deformities. Vinyl chloride can also cause birth defects.

It is essential to substitute the use of PCBs and vinyl chloride with chemicals that are less toxic. Polyvinyl chloride use can be lowered by reducing our use of plastics. Thus by reducing waste, encouraging recycling and using products that are well made and durable we can greatly re- duce our consumption of these chemicals thus curtailing our exposure to these substances.

2.0 Role Of An Individual In Prevention Of Pollution

- Develop respect or reverence for all forms of life.
- Each individual must try to answer four basic questions:

  Where do the things that I consume come from?

What do I know about the place where I live?

How am I connected to the earth and other living things?What is my purpose

and responsibility as a human being

Try to plant trees wherever you can and more importantly take care of them.They reduce air pollution

- Reduce the use of wood and paper products wherever possible. Manufacturing paper leads to pollution and loss of forests which releases oxygen and takes up carbon dioxide. Try to recycle paper products and use recycled paper wherever possible.

From the mail you receive reuse as many envelopes that you can

Do not buy furniture, doors, window frames made from tropical hardwoods such as teak and mahogany. These are forest based

- Help in restoring a degraded area near your home or join in an afforestation program.

Use pesticides in your home only when absolutely necessary and use them in as small amounts as necessary. Some insect species help to keep a check on the populations of pest species

- Advocate organic farming by asking your grocery store to stock vegetables and fruits grown by an organic method. This will automatically help to reduce the use of pesticides.

Reduce the use of fossil fuels by either walking up a short distance using a car pool, sharing a bike or using public transport. This reduces air pollution

- Shut off the lights and fans when not needed.
  - Don’t use aerosols spray products and commercial room air fresheners. They damage the ozone layer.
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- Shut off the lights and fans when not needed.
- Don’t use aerosols spray products and commercial room air fresheners. They damage the ozone layer.
- Do not pour pesticides, paints, solvents, oil or other products containing harmful chemicals down the drain or on the ground.
- Buy consumer goods that last, keep them as long as possible and have them repaired as far as possible instead of disposing them off. Such products end up in landfills that could pollute ground water.
- Buy consumer goods ages in refillable glass containers instead of cans or throwaway bottles
- Use rechargeable batteries
- Try to avoid asking for plastic carry bags when you buy groceries or vegetables or any other items. Use your own cloth bag instead
- Use sponges and washable cloth napkins, dish towels and handkerchiefs instead of paper ones.
- Choose items that have the least packaging or no packaging
- Recycle all newspaper, glass, aluminum and other items accepted for recycling in your area. You might have to take a little trouble to locate such dealers
- Set up a compost bin in your garden or terrace and use it to produce manure for your plants to reduce use of fertilizers
- Try to lobby and push for setting up garbage separation and recycling programs in your localities.
- Don’t use throwaway paper and plastic plates and cups when reusable versions are available.

- Start individual or community composting or vemicomposting plants in your neighbor- hood and motivate people to join in.
- Do not litter the roads and surroundings just because the sweeper from the Municipal Corporation will clean it up. Take care to put trash into dustbins or bring it back home with you where it can be appropriately dis- posed.
- Learn about the biodiversity of your own area. Understand the natural and cultural assets. This would help you to develop a sense of pride in your city/town/village and will also help you understand the problems facing their survival..
- Take care to put into practice what you preach. Remember environment protection begins with YOU.

Module 5: Social Issues and The Environment

Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust, case studies, waste land 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.

1. Climate Change

The average temperature in many regions has been increasing in recent decades. The global average surface temperature has increased by 0.6° + 0.2° C over the last century. Many countries have experienced increases in rainfall, particularly in the countries situated in the mid to high latitudes. Globally, 1998 was the warmest year. Projections of future climate change are derived from a series of experiments made by computer based global climate models. These are worked out on estimates of aspects such as future population growth and energy use. According, warming will be greatest over land areas, and at high altitudes. The frequency of weather extremes is likely to increase leading to floods or drought. Global mean sea level is projected to rise by 9 to 88 cm by the year 2100. More than half of the world's population now lives within 60 km of the sea.

1.1 Effects of climate change

- Human societies are seriously affected by extremes of climate such as droughts and floods.
- This is often a major concern for human health. To a large extent, public health depends on safe drinking water, sufficient food, secure shelter, and good social conditions. All these factors are affected by climate change.
- Fresh water supplies may be seriously affected, reducing the availability of clean water for drinking and washing during drought as well as floods.
- Water can be contaminated and sewage systems may be damaged.
- The risk of spread of infectious diseases such as diarrhea diseases increased.
- Food production will be seriously reduced in vulnerable regions directly and also indirectly through an increase in pests and plant or animal diseases.
- The local reduction in food production would lead to starvation and malnutrition with long-term health consequences, especially for children.

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- Food production will be seriously reduced in vulnerable regions directly and also indirectly through an increase in pests and plant or animal diseases.
- The local reduction in food production would lead to starvation and malnutrition with long-term health consequences, especially for children.
- Food and water shortages may lead to conflicts in vulnerable regions, with serious implications for public health.
- Climate change related impacts on human health could lead to displacement of a large number of people, creating environmental refugees and lead to further health issues.

2. Global warming

- About 75% of the solar energy reaching the Earth is absorbed on the earth's surface which increases its temperature.
- The rest of the heat radiates back to the atmosphere.
- Some of the heat is trapped by greenhouse gases, mostly carbon dioxide.
- As carbon dioxide is released by various human activities, it is rapidly increasing. This is causing global warming.
- The average surface temperature is about 15 $°C$. This is about 33 $°C$ higher than it would be in the absence of the greenhouse effect.
- Human activities during the last few decades of industrialisation and population growth have polluted the atmosphere to the extent that it has begun to seriously affect the climate.
- Carbon dioxide in the atmosphere has increased by 31% since pre-industrial times, causing more heat to be trapped in the lower atmosphere.

3. Acid rain

- When fossil fuels such as coal, oil and natural gas are burnt, chemicals like sulfur dioxide and nitrogen oxides are produced. These chemicals react with water and other chemicals in the air to form sulfuric acid, nitric acid and other harmful pollutants like sulfates and nitrates.
- These acid pollutants spread upwards into the atmosphere, and are carried by air currents, to finally return to the ground in the form of acid rain, fog or snow. The corrosive nature of acid rain causes many forms of environmental damage.

3.1 Effects:

- Acid rain dissolves and washes away nutrients in the soil which are needed by plants.
- Acid rain indirectly affects plants by removing nutrients from the soil in which they grow.
- Acid rain that falls or flows as ground water to reach rivers, lakes and wetlands, causes the water in them to become acidic. This affects plant and animal life in aquatic ecosystems.
- Acid rain also has far reached effects on wildlife. By adversely affecting one species, the entire food chain is disrupted, ultimately endangering the entire ecosystem.
- Acid rain and dry acid deposition damages buildings, automobiles, and other structures made of stone or metal.

3.2 Solutions:

- The best way to stop the formation of acid rain is to reduce the emissions of sulfur dioxide and nitrogen oxides into the atmosphere.
- This can be achieved by using less energy from fossil fuels in power plants, vehicles and industry. Switching to cleaner burning fuels is also a way out.

4. Ozone layer depletion

Ozone is formed by the action of sunlight on oxygen. It forms a layer 20 to 50 kms above the surface of the earth. This action takes place naturally in the atmosphere, but is very slow. Ozone is a highly poisonous gas with a strong odour. It is a form of oxygen that has three atoms in each molecule. It is considered a pollutant at ground level and constitutes a health hazard by causing respiratory ailments like asthma and bronchitis. It also causes harm to vegetation and leads to a deterioration of certain materials like plastic and rubber. Ozone in the upper atmosphere however, is vital to all life as it protects the earth from the sun's harmful ultraviolet radiation. The ozone layer in the upper atmosphere absorbs the sun's ultraviolet radiation, preventing it from reaching the earth's surface. This layer in the atmosphere protects life on earth from the dangerous UV radiation from the sun. Chlorofluorocarbons or CFCs, which were used as refrigerants and aerosol spray propellants, posed a threat to the ozone layer.

The CFC molecules are virtually indestructible until they reach the stratosphere, where UV radiation breaks them down to release chlorine atoms. The chlorine atoms react with ozone molecules which break down into oxygen molecules, which do not absorb UV radiations. Although the use of CFCs has been reduced and now banned in most countries, other chemicals and industrial compounds such as bromine, halocarbons and nitrous oxides from fertilizers may also attack the ozone layer.

4.1 Effects of ozone layer depletion

- The destruction of the ozone layer is seen to cause increased cases of skin cancer and cataracts.
- It also causes damage to certain crops and to plankton, thus affecting natures food chains and food webs. This in turn causes an increase in carbon dioxide due to the decrease in vegetation

5. Nuclear Accidents

- Nuclear energy was researched and discovered by man as a source of alternate energy which would be clean and cheap compared to fossil fuels
- A single nuclear accident can cause loss of life, long-term illness and destruction of property on a large scale for a long period of time.
- Radioactivity and radioactive fallout leads to cancer, genetic disorders and death in the affected area for decades after, thus affecting all forms of life for generations to come.

5.1 Nuclear holocaust:

- The use of nuclear energy in war has had devastating effects on man and earth.
- The Hiroshima and Nagasaki incident during World War II, the only use of nuclear power in war in history, is one of the worst disasters in history.
- In 1945, the United States dropped atomic bombs in Japan over the towns of Hiroshima and Nagasaki.
- These two atomic bombs killed thousands of people, left many thousands injured and devastated everything for miles around.
- The effects of the radiation from these nuclear bombs can still be seen today in the form of cancer and genetic mutations in the affected children and survivors of the incident.

6 CASE STUDY

i) Nuclear disasters and leakages

In 1986 the Nuclear Power Station at Chernobyl in USSR developed a problem that led to a fire and a number of explosions in its Nuclear Reactor. The radioactive dust spread over many kilometers and covered not only Europe but North America as well. Three people died in the explosion and 28 shortly after due to radiation exposure. Some 259 sick were hospitalized. As the area had to be evacuated 1,35,000 people had to be moved immediately and another 1.5 lac by 1991. As radioactive fall out continued even more people had to be moved. An estimated 6.5 lakh people may have been seriously affected. They may get cancer, thyroid tumours, and cataracts, and suffer from a lowered immune mechanism. As radioactivity passes from grass to herbivores, sheep in Scotland and Reindeer in Lapland were affected and were unfit for human consumption. Vegetable, fruit and milk were contaminated in Europe. A French Nuclear Waste Processing Center in Normandy may have affected the lives of children playing nearby. They may develop leukemia (blood cancer) in later life.

ii) The Narmada Issue

The controversy over the plan to build several dams on the Narmada River and its tributaries symbolizes the struggle for a just and equitable society in India. The construction of these dams displaces many poor and underprivileged communities, destroying their relatively self- sufficient environmentally sound economy and culture and reducing a proud people to the status of refugees or slum dwellers. The Narmada Bachao Andolan (Save the Narmada Movement) is one of the most dynamic people's movements fighting for the rights of these underprivileged people who are being robbed of their homes, livelihoods and way of living in the name of 'national interest'. One such dam, the SardarSarovar Dam, when completed will drown 37,000 hectares of fertile land and displace 200,000 adivasis and cause incomprehensible loss to the ecology.

iii) Silent Valley

The proposed Hydel project at Silent valley, a unique pocket of tropical biodiversity in South India, in the 1970s was stopped and the area declared a National Park in 1984. This was achieved by several dedicated individuals, groups and organisations lobbying to save the area from being submerged and protect its rich biodiversity. Among the many environmental battles that have been fought in this country some have been won while many others have been lost. These projects have led to serious environmental degradation in spite of the laws intended to control such damage.

7. Wasteland reclamation

- Loss of vegetation cover leads to loss of soil through erosion, which ultimately creates wastelands.
- Loss of soil has already ruined a large amount of cultivable land in our country.
- Unless we adequately safeguard our 'good' lands, we may eventually face a serious shortage of food grains, vegetables, fruit, fodder and fuel wood.
- Hence, conservation of soil, protecting the existing cultivable land and reclaiming the already depleted wastelands figures prominently among the priority tasks of planning for the future.
- Wasteland can be classified into three forms: (1) Easily reclaimable, (2) Reclaimable with some difficulty, (3) Reclaimable with extreme difficulty.
- Easily reclaimable wastelands can be used for agricultural purposes.
- Those which can be reclaimed with some difficulty can be utilized for agro forestry.
- Wastelands that are reclaimed with extreme difficulty can be used for forestry or to recreate natural ecosystems.

Agriculture:

Wasteland can be reclaimed for agriculture by reducing the salt content which can be done by reducing salt content and adding a Gypsum, urea, potash and compost are added before planting crops in such areas.

Agro forestry:

- This involves putting land to multiple uses. Its main purpose is to have trees and crops inter- and /or under planted to form an integrated system of biological production within a certain area. Thus, agro forestry implies integration of trees with agricultural crops or livestock management simultaneously.

Need for wasteland development:

- Wasteland development provides a source of income for the rural poor.

- It ensures a constant supply of fuel, fodder and timber for local use. It makes the soil fertile by preventing soil erosion and conserving moisture.
- The trees help in holding back moisture and reduce surface run off rates thus helping in the control of soil erosion.

Consumerism and waste products

Modern societies that are based on using large amounts of goods, especially those that are manufactured for one time use, are extremely wasteful. The increasing consumption of natural resources has lead to serious environmental problems around the world. Current consumption patterns are depleting non-renewable resources, poisoning and degrading ecosystems, and altering the natural processes on which life depends. The present pattern of consumption, especially in affluent societies, is mainly responsible for the high level of utilization of resources. People in the industrialized countries make up 20% of the world population but consume 80% of the world's resources and produce 80% of wastes. This is due to a pattern of economic development that ensures that people go on consuming even more than they actually need. India is rapidly moving into this unsustainable pattern of economic growth and development. The rich in such a society get richer often at the cost of the poor whose lives are not improved by the process of development. It is seen that today's consumption patterns are depleting natural resources at a rapid rate and widening the inequalities in consumption in different societies. Consumerism causes wasteful use of energy and material far beyond that needed for everyday living at a comfortable level. Money is not the only way to measure the cost of an item that we use. When one adds up all the raw material and energy that goes into the manufacture of goods or the services provided by nature that one uses during a day's activities, the toll on the environment is large. When this cost is multiplied over a lifespan, the amount is staggering. If one considered the over utilisation in each family, city or a country, the impacts are incredibly high. For example: two hundred billion cans, bottles, plastic cartons and paper cups, are thrown away each year in the "developed" world. "Disposable" items greatly increase this waste. Rather than compete on quality or reliability, many industrial consumer products are made for one-time use. Buying quality products that are warranteed against failure or wearing out, learning about the raw materials that things are made of, and an appreciation of their origin from nature's storehouse, as well as knowing the conditions of the workers that make them, are some ways of resisting consumerism and decreasing waste.

8. The environment protection act

- Passed in March 1986, it came into force on 19 November, 1986.
- It has 26 sections. The purpose of the Act is improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property.
- The spirit of the proclamation adopted by the United Nations Conference on Human Environment was implemented by the Government of India by creating this act.
- The act was amended in 1991

The main features of the act are

1. The central government shall have the power to take all such measure as it deems necessary or useful for the purpose of protecting and improving the quality of the environment and preventing, controlling and decreasing environmental pollution
2. No person carrying on any industry, operation or processes shall discharge or emit any environmental pollutants or permit to do so in excess of such standards as may be prescribed
3. No person shall handle or cause to be handled any hazardous substances except in accordance with such procedure and after complying with such safeguards as may be prescribed
4. The central government or any officer empowered by it, shall have power to take, for the purpose of analysis, sample of air, water, soil or other substances from any premises, factory etc may be prescribed
5. Whoever fails to comply with or violate any of the provisions of this act or the rules made or orders or directions issued there under shall in respect of each failure or violation be punishable with imprisonment or with fine or both

Air (prevention and control of pollution) act

- The Government passed this Act in 1981 to clean up our air by controlling pollution.
- The main objectives of the Act are as follows:

(a) To provide for the Prevention, Control and abatement of air pollution.

(b) To provide for the establishment of Central and State Boards with a view to implement the Act.

(c) To confer on the Boards the powers to implement the provisions of the Act and assign to the Boards functions relating to pollution.

- The presence of pollution beyond certain limits due to various pollutants discharged through industrial emission are monitored by the Pollution Control Boards set up in every State.

Central Board:

- The main function of the Central Board is to implement legislation created to improve the quality of air and to prevent and control air pollution in the country.
- The Board advises the Central Government on matters concerning the improvement of air quality and also coordinates activities, provides technical assistance and guidance to State Boards and lays down standards for the quality of air.

State Boards:

- The State Boards have the power to advice the State Government on any matter concerning the prevention and control of air pollution.
- They inspect air pollution control areas at intervals or whenever necessary. They are empowered to provide standards for emissions to be laid down for different industrial plants with regard to quantity and composition of emission of air pollutants into the atmosphere.
- A State Board may establish or recognize a laboratory to perform this function.
- The State Governments have been given powers to declare air pollution control areas after consulting with the State Board and also give instructions for ensuring standards of emission from automobiles and restriction on use of certain industrial plants.
- Penalties: Persons managing industry are to be penalized if they produce emissions of air pollutants in excess of the standards laid down by the State Board.
- The Board also makes applications to the court for restraining persons causing air pollution.

9. The water (prevention and control of pollution) act

- The Government has formulated this Act in 1974 to be able to prevent pollution of water by industrial, agricultural and household wastewater that can contaminate our water sources.
- The main objectives of the Water Act are to provide for prevention, control and abatement of water pollution and the maintenance or restoration of water.
- It is designed to assess pollution levels and punish polluters.
- The Central Government and State Governments have set up Pollution Control Boards that monitor water pollution.

Salient features

- The also aims at restoration of wholesomeness of water
- The water act is designed to assess pollution levels and punish polluters
- The central government and state governments have setup pollution control boards to monitor water pollution
- The water act of 1974 along with amendments in 1978 is an extensive legislation with more than sixty sections for prevention and control of water pollutions
- Central and state boards have been created under this act for preventing water pollution
- The act empowers the board to take

- Water samples for analysis
- Govern discharge of sewage
- Trade effluents
- Study or inspect appeals
- Revision of policies

- Set minimum and maximum penalties
- Publication of names of offenders
- Offences by companies or government departments

- Establish or recognize water testing laboratories and standard procedures
- Prevention and control of water pollution is achieved through a permit or a consent administration procedure
- Discharging effluents is permitted by obtaining the consent of state water boards

Penalties

- Penalties are charged for acts that have caused pollution.

- This includes failing to furnish information required by the Board, or failing to inform the occurrence of any accident or other unforeseen act.
- An individual or organization that fails to comply with the directions given in the subsections of the law can be convicted or punished with imprisonment for a term of three months or with a fine of Rs10,000 or both and in case failure continues an additional fine of Rs.5,000 everyday.
- If a person who has already been convicted for any offence is found guilty of the same offence again, he/she after the second and every subsequent conviction, would be punishable with imprisonment for a term not less than two years but which may extend to seven years with fine.

10. The wildlife protection act

The wild life act is aimed at preserving and protecting wildlife and came into effect in 1972

Salient features

- This act envisages national parks and wildlife sanctuaries as protected areas to conserve wildlife
- Under this act, wildlife populations are regularly monitored and management strategies are formulated to protect them
- The act covers the rights of forest dwellers. The act permits restricted grazing in sanctuaries but prohibits the same in national parks. The act also prohibits collection of non-forest timber which might not harm the system
- The act provides a comprehensive list of endangered species and prohibits hunting of the same
- The act provides for setting up national parks, wildlife sanctuaries etc
- The act provides for constitution of central zoo authority
- The act imposes a ban on trade or commerce of commercial animals
- The act provides a legal power to officers to punish offenders
- Under the act, captive breeding programs for endangered species have been initiated

Penalties:

- The offence is punishable with imprisonment for a term which may extend to three years or with a fine of Rs 25,000 or with both.
- An offence committed in relation to any use of meat of any such animal or animal articles like a trophy, shall be punishable with imprisonment for a term not less than one year and may extend to six years and a fine of Rs 25,000.

- In the case of a second or subsequent offence of the same nature mentioned in this sub-section, the term of imprisonment may extend to six years and not less than two years with a penalty of Rs.10,000.

11. Forest conservation act

- To appreciate the importance of the Forest Conservation Act of 1980, which was amended in 1988.
- The Indian Forest Act of 1927 consolidated all the previous laws regarding forests that were passed before the 1920's.
- The Act gave the Government and Forest Department the power to create Reserved Forests, and the right to use Reserved Forests for Government use alone.
- It also created Protected Forests, in which the use of resources by local people was controlled. Some forests were also to be controlled by a village community, and these were called Village Forests.

The salient features of the act are as follows

- The state government has been empowered under this act to use the forests only for forestry purposes
- It makes provision for conservation of all types of forests and for this purpose there is an advisory committee which recommends funding for it to the central government
- Any illegal non forest activity within a forest area can be immediately stopped under this act
- Forest officers and their categories of the forests, namely reserved forests, village forests, protected forests and private forests

Reserved forests:

- These forests are under the direct supervision of the government and no public entry is allowed for collection of timber or grazing of cattle

Protected forests:

- These forests are looked after by the government, but the local people are allowed to collect fuel wood/ timber and graze their cattle without causing serious damage to the forests

Village forests:

- Reserved forests assigned to a village community are called village forests

Private protected forests:

- These forest lands refer to protected areas inside India whose land rights are owned by an individual or a corporation/ organization

Penalties

A person who commits any of the offences like felling of trees or strips off the bark or leaves from any tree or sets fire to such forests, or kindles a fire without taking precautions to prevent its spreading to any tree mentioned in the act, whether standing or felled, or fells any tree, drags timber, or permits cattle to damage any tree, shall be punishable with imprisonment for a term which may extend to six month or with a fine which may extend to Rs 500, or both

12 Issues involved in enforcement of environmental legislation

- Environmental legislation is evolved to protect our environment as a whole, our health, and the earth's resources.
- The presence of a legislation to protect air, water, soil, etc. does not necessarily mean that the problem is addressed.
- Once a legislation is made at the global, National or State level, it has to be implemented.
- For a successful environmental legislation to be implemented, there has to be an effective agency to collect relevant data, process it and pass it on to a law enforcement agency.
- If the law or rule is broken by an individual or institution, this has to be punished through the legal process.
- The interested concerned individual must file a Public Interest Litigation (PIL) for the protection of the environment. People need to keep an eye and inform the concerned and see to it that actions are taken against offenders

13 Environment Impact Assessment (EIA):

For all development projects, whether Government or Private, the MoEF requires an impact assessment done by a competent organisation. EIAs are expected to indicate what the likely impacts could be if the project is passed. The EIA must look into physical, biological and social parameters. The EIA must define what impact it would have on water, soil and air. It also requires that a list of flora and fauna identified in the region is documented and to specify if there are any endangered species whose habitat or life could be adversely affected. The Ministry of Environment and Forests (MoEF) has identified a large numberof projects that need clearance on environmental grounds. After the Environmental Protection Act of 1986 was passed, an EIA to get an environmental clearance for a projectbecame mandatory. To get an environmental clearance the proposer of the project is expected to apply to the State Pollution Control Board. The PCB checks and confirms that the EIA can be initiated. The Agency that does the assessment submits a Report to the proposer. This may take several months. A Report of the Environmental Statement is forwarded to the MoEF, which is the impact assessment authority and grants the project clearance

Citizens actions and action groups:

- Individuals can take one or several possible actions when they observe offenders whofor their own self-interest damage the environment for others living in the area.
- The person has the right to bring an environmental offence or nuisance to the attentionof authorities.
- Educated individuals have rights as well as have an obligation to perform their duties.
- They can accompany activity groups to strengthen the ecology movements.