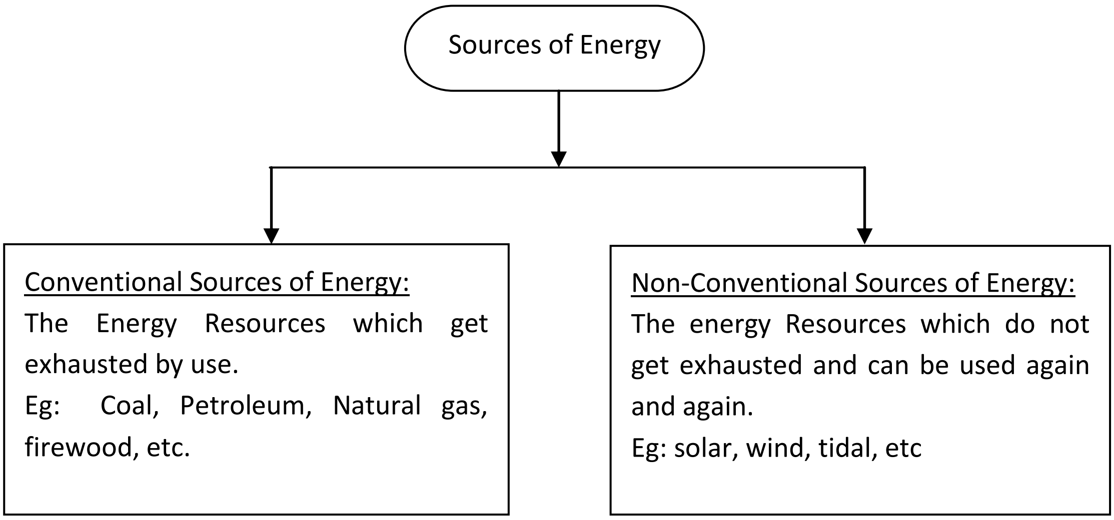
Unit I

Energy Sources

Conventional Energy Sources – Coal – Oil – Gas – Agriculture and Organic wastes – Water Power – Nuclear Power – Thermal Power.

Energy is an indispensable requirement in modern life. It may be manual or animal and mechanical or electrical. Electricity is used to operate various kinds of machines. Availability of energy is a pre-requisite of modern economic activities. There are several sources of energy; some of them are coal, petroleum, natural gas, solar energy, wind energy and hydel energy. Some of them are exhaustible and some are non-exhaustible. Sources of energy are categorized as conventional and non-conventional.



1.1 Conventional Energy Sources:

The energy sources which cannot be compensated, once these are used (after their exploitation) are termed as conventional energy sources.Petroleum, natural gas, coal, nitrogen, uranium and water power are examples of conventional sources of energy. They're also called non-renewable sources of energy and are mainly fossil fuels, except water power.

Conventional energy sources have a number of advantages, including being affordable, easy to harness, producing a lot of power and easy distribution. However, these sources of energy also have a disadvantage since they may cause environmental harm as they are being used. Conventional sources of energy are exhaustible, except water. Their use causes pollution as they emit ash and smoke. They're also very expensive to maintain, store and transmit since they're carried over long distances through transmission lines and grids.

Fossil fuels were created millions of years ago from plant and animal remains. They are used in transportation and manufacturing, and support the power and electrical systems of homes and industries.

Other conventional energy sources like water, nitrogen and uranium are used to generate electricity that's used in homes, schools, factories and businesses. Some important conventional energy sources are discussed below.

1.2 Coal:

1.2.1 Coal Formation:

Coal is a major conventional energy sources. Coal is a substance that is normally formed from organic materials that died ages ago and were subjected to high quantities of pressure and heat. It was formed from the remains of the trees and ferns grew in swamps around 500 millions year ago. That is Coal was made out of the ancient plants, 500 million years ago, even before dinosaurs, when huge plants started sedimentation in swamps. In millions of years that followed, mud was frothed over remains, transforming in that process huge heat in to a pressure, and all these factors combined gave ideal conditions for coal's "birthing place". Today coal is located mostly below the layers of rocks and mud, and to get to it, mines are excavating.

The bacterial and chemical decomposition of such plant debris (which remained buried under water or clay) produced an intermediate product known as peat which is mainly cellulose $(C_6H_{10}O_5)_n$. Due to progressive decomposition by heat and pressure, the cellulose lost moisture $H_2$and O_z and got converted in to coal as per the given equation

$$\text{Plants} \xrightarrow[\text{and Chemical action}]{\text{Bacterial}} \text{Peat} \xrightarrow[\text{Pressure}]{\triangle} \text{Lignite} \xrightarrow[\text{Pressure}]{\triangle\triangle} \text{Bituminous coal}$$

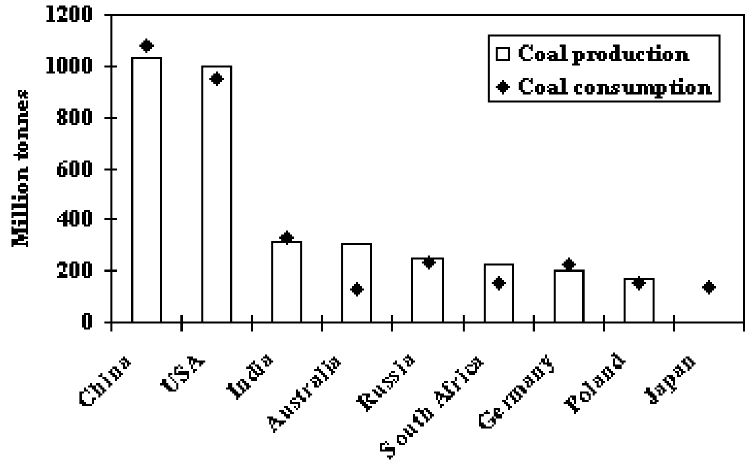
$$\xrightarrow[\text{Pressure}]{\triangle\triangle\triangle} \text{Anthracite coal}$$

The average formula of coal is $(C_{3/}H_{4/})_n$. Out of the 6000 billion tons coal stocks under earth crust, 200 tons have been exploited the present society. The quality of the coal is determined by the carbon content in it. The coal reserves are found in the states like Jharkhand, Orissa, West Bengal, M.P. and A.P. Some important coal fields are: Talcher, Raniganj, Jharia, Bokaro, PanchKonkam, Signoulli, Chanda etc.

Coal is important particularly because of the two reasons: steel production and electrical energy. Coal is giving about 23% of the world's total primary energy. 38% of the world's generated electrical energy is gained from coal. For 70% of the world's steel production, coal is needed as the key ingredient.

1.2.2Coal Production, Consumption And Its Reserves

Country wise production and consumption of coal is indicated in the chat



China is traditionally dependent on coal, and USA is high because of large consumption of all fossil fuels, including coal.

According to the rough predictions, there's still enough coal for the next 200 years if we continue today's tempo of its exploitation. That means that in our close future won't be problems with coal's supply, but could be problems because of cost-effective and ecological aspects of this energy's use.

1.2.3Role of Coal in electricity generation (Thermal Power)

Modern life is unimaginable without electricity. It lights houses, buildings, streets, provides domestic and industrial heat, and powers most equipment used in homes, offices and machinery in factories. Improving access to electricity worldwide is critical to relieving deficiency.

Coal plays a vital role in electricity generation worldwide. Coal-fired power plants currently fuel 41% of global electricity and, in some countries; coal fuels a higher percentage of electricity. The 5,400 MW Bełchatów Power Station in Poland is one of the world's largest coal-fired power stations.

Steam coal, also known as thermal coal, is used in power stations to generate electricity. Coal is first milled to a fine powder, which increases the surface area and allows it to burn more quickly. In these pulverised coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature (Figure1.1). The hot gases and heat energy produced converts water – in tubes lining the boiler – into steam.

The high pressure steam is passed into a turbine containing thousands of propeller-like blades. The steam pushes these blades causing the turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of carefully wound wire coils. Electricity is generated when these are rapidly rotated in a strong magnetic field. After passing through the turbine, the steam is condensed and returned to the boiler to be heated once again.

The electricity generated is transformed into the higher voltages (up to 400,000 volts) used for economic, efficient transmission via power line grids. When it nears the point of consumption, such as our homes, the electricity is transformed down to the safer 100-250 voltage systems used in the domestic market.

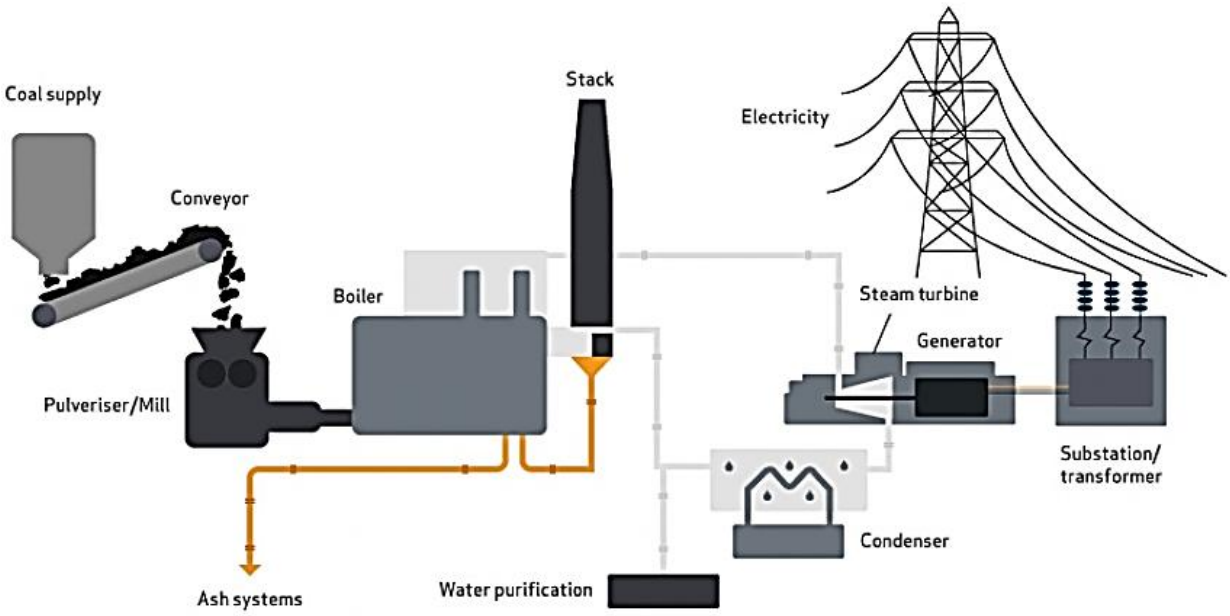


Figure 1.2Coal Converted into Electricity

The exploitation of oil on a large scale started after 1960, the year when the first commercial well is reported to have come into existence. In India, efforts made by the Oil and Natural Gas Corporation since the late 1950s have led to the identification of a number of oil and gas deposits both offshore and onshore.

The onshore fields were mainly discovered in the Mumbai, Gujarat, Assam and Arunachal Pradesh and the offshore fields in the sea are the notably Mumbai High fields such as North and South Basin and South Tapti. Oil and natural gas has also been discovered in the Godavari Basin on the East Coast and the Barmer district of Rajasthan. The new exploration strategy has been developed which places emphasis on intensive exploration, survey and drilling in order to add to petroleum reserves and to argument production.

Mumbai High is an off shore oil field located 160kms away from the coast of Mumbai in the Arabian Sea. It accounts for about 63% of thetotal petroleum production of our country. Gujarat contributes to 18% of the total production. Ankleshwar is the major oil field in this state.Assam, which is the oldest oil producing state contributes to 16% of the total oil production of our country. The major oil fields here are Digboi,NaharkatiyaanMorah-Hugrijan

Natural gas is also emerging as an important source of energy in India's commercial energy scene in view of large reserves of gas that have been established in the country, particularly, in South Bassein off west coast of India. Natural gas in also making significant contribution to the household sector.

About 30% of the country's output of LPG comes from this source. About three-fourths as the total gas comes from Mumbai high and rest is obtained from Gujarat, Andhra Pradesh, Assam Tamil Nadu and Rajasthan. The Oil and Natural Gas Corporation has made a significant hydro carbon finding and Reliance Industries struck gas off the Orissa coast in Bay of Bengal.

Natural gas - when various plant and animal remains are exposed to frequent heat and pressure over thousands of years, they become natural gas. It can be used to produce electricity and for cooking.

As with coal and natural gas, oil is formed when organic materials are subjected to heat and pressure over a long period of time. Oil is often used in powering vehicles, producing electricity and domestic heating.

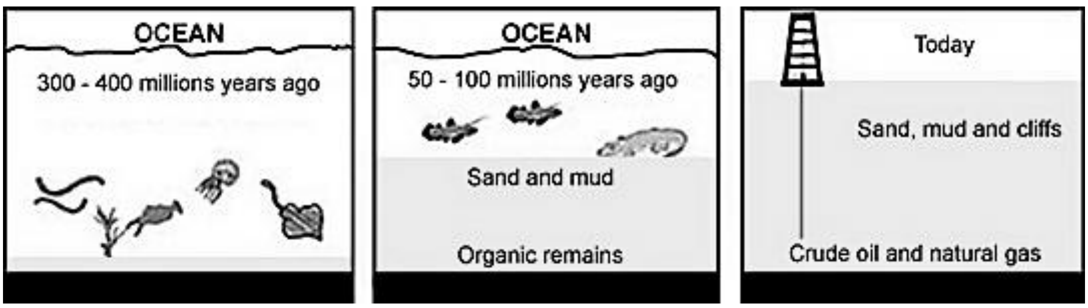
The composition of natural gas is a mixture of mainly methane, (95.0%), small amounts of ethane, propane and butane (3.6%) and traces of CO_2 (0.48%) and N_2 (1.92%).

A liquid mixture of propane and butane can be obtained from natural gas or refinery gases at room temperature under a pressure of 3-5 atmosphere. This is stored and distributed in 40-100 litre capacity steel cylinders.

The crude petroleum after being refined and purified, are available as petrol, diesel, kerosene, lubricating oil, plastic etc. for commercial and domestic use. In India, the oil deposits, are found at Ganga-Brahmaputra Valley, Bombay high, plains of Gujarat, Thar desert of Rajasthan and area around Andaman Nicobar islands.

On the world basis, petroleum deposits are found at Saudi Arab, Iraq, Iran, Kuwait, USA, Mexico, Russia etc. As per the current survey, it is found that world petroleum deposits are diminishing at a very faster rate. If preventive steps are not taken, the existing petroleum will be available maximum up to 40 years.

1.3.1 Development of the oil and natural gas shown in three steps.



Oil was made out of animal and plant remains, of animals that had lived in water many millions years ago. On the picture you can see the development of the oil and the natural gas shown in three steps. The first step was 300-400 millions of years ago. Then remains started to sediment on ocean's bottom and with time all was covered with sand and mud. Before 50-100 millions years those remains were already covered with big layer of sand and mud which created huge pressures and high temperatures. As a result of these conditions raw oil as well as natural gas turned up. Today we drill through the huge layers of mud, sand and cliffs in order to get to oil wells. Before drilling through of all those layers starts, scientists and engineers are studying cliff's structure. If a cliff's structure points to a possible oil well, drilling starts. The big problem during the drilling and transportation is possibility of oil leakage in to an environment. New technologies are making possible to increase the precision when searching oil, resulting in smaller number of necessary wells. In 1990 law that every newly built tanker must have double shell in order to prevent oil leakage in a case of shipwreck was laid down. Despite all technology improvements in drilling and transportation, oil leakage in the sea still happens very often, having as a result almost complete extermination of animals and plants in that part of the sea. Although there's the big sea pollution as the consequence of oil leakage, when relating with air pollution is in fact negligible. Oil derivatives, when combusting are releasing large quantities of the carbon dioxide in to an atmosphere. Carbon dioxide is a greenhouse gas and with its release in to an atmosphere we are influencing to an increase of global temperature on Earth. In order to solve this problem, Kyoto protocol was promoted, but largest pollutants still didn't ratify it.

1.3.2 Production, Consumption and Oil Reserves

Pointing out USA as the biggest consumer is expected because of their traditional relying on fossil fuels. The biggest producer is Saudi Arabia, followed by Russia and USA. USA with its entire production is covering just 39% of its own needs, so they're forced to import large quantities of oil. Major oil exporters to USA are Mexico and some countries of the Middle East. Largest reserves of oil are estimated to be in countries of Middle East. Saudi Arabia very much leads the way with 264 x 109 barrels of oil reserves. These are very understandable reasons why USA is always involved in Middle East country's policy and why USA military forces are always near these areas.

Exporting oil countries have formed its Association shortly called OPEC (Organization of the Petroleum Exporting Countries) which controls price and quantity of the oil that is yet to be produced. These countries are: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arabian Emirates and Venezuela.

For many years common believe was that natural gas is useless. Even today in some countries, people are trying to get rid of this gas by burning it in large torches. This gas is mainly made out of the methane, a simple union that consists of one carbon atom and four hydrogen atoms. Methane is highly flammable with almost full combustion. After combustion, there are no ashes, and air pollution is almost negligible. Natural gas has no color, taste, smell or shape in its natural form, so it's indiscernible to people. Because of this reason companies are adding chemical to it which has smell of rotten egg. That smell enables people easy detection of potential gas leaking in house.

In 19th century natural gas was almost solely used for street lamps. In those times there was still none of gas pipelines so the mass distribution to the households wasn't possible. About year 1890, majority cities started using electrical energy for the illumination, Robert Brunson invented in 1885 burner which mixed air with the natural gas. This invention has enabled exploit of natural gas for cooking and heating chambers. First more significant gas pipeline was built in 1891. It was 120 miles long, and was transporting gas from middle Indiana all the way to the Chicago.

1.3.3 Extracting Natural Gas from Earth and Sea

When pressure lowers it is necessary to pump the gas out of the earth. For this use pump called "hors head" is designed.When pressure is being still big enough, gas comes to surface through a pipe system called "Christmas tree".

In many cases, natural gas is an ideal fossil fuel because it's pretty clean, simple for transport and convenient for use. It's cleaner than oil and coal, so it's more and more spoken to be solution for actual climate changes and problems connected with poor air quality. Opposed to oil and coal, natural gas has bigger proportion hydrogen/carbon and has the smaller emission of the carbon dioxide to an atmosphere for the same amount of energy.

When extracting natural gas, often, both oil and natural gas are pulled off from the same well. Like in a process of an oil production, part of natural gas comes independently on surface because of the big pressure in deepness. Natural gas is found in different underground formations. Some formations are heavier and more expensive for exploit, but are also leaving the place for the improvement in future gas supply. After the natural gas is pulled to the surface, it gets brought across the gas pipeline system to containers, and after that to the final consumers as well.

1.3.4 Natural Gas Increased Demand

Decreased bad environment's influence and technology progress made natural gas to be considered as the preferred fuel. In the last ten years natural gas production had constant growth.

In China coal consumption decreased in 1999, and natural gas consumption increased for 10.9% till 1998. In Asian-Pacific region natural gas consumption has grown for 6.5%. With approximately 50% of world's population and growing economics in need of energy, this region has very big potential in natural gas' consumption. Regionally, Africa's continent has the highest consumption growth, with the growth of 9.1% in 1999. Africa has growing potential not just as the natural gas market, but as the producer as well.

1.3.5 Liquefied natural gas (LNG)

Liquefied natural gas (LNG) is natural gas under the big pressure that is refrigerated to a very low temperatures so it acquires liquid aggregate state. When natural gas is cooled all the way to 161 degrees of Celsius below zero, it becomes clear liquid without color, taste and smell. Since LNG takes only 1/600 of natural gas volume when in gaseous state, that state is suitable for tanker transportation across the world. Terminal for LNG is installation for filling and emptying tankers which are transporting that energent. Tankers that transport LNG can be longer than 300 meters, and minimal water depth must be more than 12 meters, when they're being completely full. These tankers must also have double lining and are specially designed to withstand low LNG temperatures.

After its reception in terminal, LNG is normally transported to isolated containers constructed specially for LNG saving. These containers must maintain low liquid temperature and must minimize quantity of the exhaled gas. Temperature inside container will remain unchanged if the pressure is regulated with the gas steam emission. Emissioned gas can be collected and used as the fuel in installation for trans-shipment and collection of LNG. Tankers that are transporting LNG can use this emissioned gas as a fuel. Although gas containers can be on surface as well, most often are used as the underground containers which must satisfy two basic characteristics: they must maintain LNG for future use and must have good gas transmission system (ventils, compressors, …). Natural gas is often stored in LNG shape and in distant installations, not just on terminals.

Before LNG’s energy can be exploited, it’s necessary to heat it in order to become useable for cooking, heating and electrical energy production. Largest exporters of liquefied natural gas are naturally countries which have largest reserves of this gas. These are Algeria, Australia, Indonesia, Lybia, Malaysia, Nigeria, Oman and Katar.

1.4 Fuel woods:

The rural peoples require fuel wood or fire Wood for their day to day cooking which are obtained from natural forests and plantations. Due to rapid deforestation, the availability of fire wood or fuel wood becomes difficult. This problem can be avoided by massive afforestation (plantation) on degraded forest land, cultivable waste land, barren land grazing land etc.

1.5 Hydropower:

Energy obtainable from water flow or water falling from a higher potential to lower potential, is known is hydro- power. It is a conventional and renewable form of energy which can be transmitted to long distance through cables and wires.

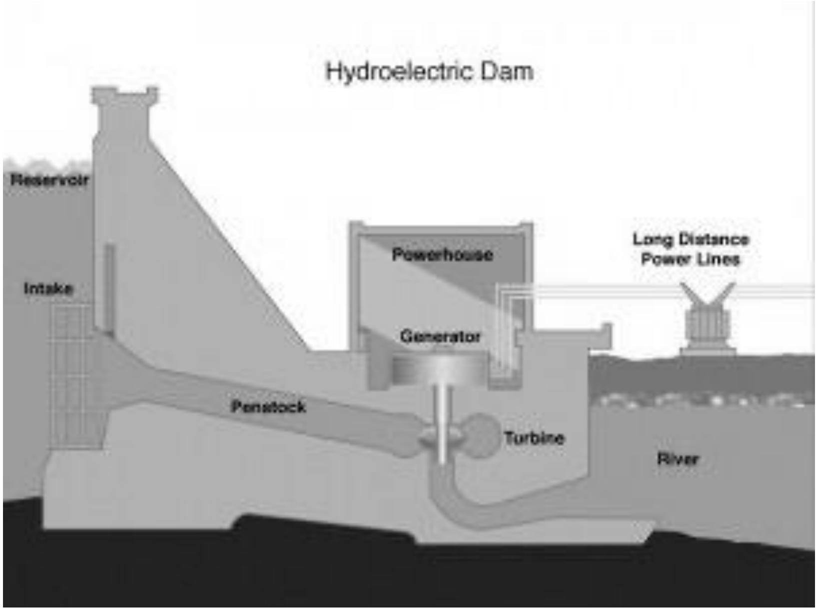
In India, hydroelectric power is generated by a number of multipurpose river valley projects e.g. Hydro-power project Hirakud, BhakraMangal project, Narmada valley project, NagarjunSagar project, SardarSarovar project etc.

Water energy (hydro energy) is most significant renewable energy source, the only one enough competitive to fossil fuels and nuclear energy. In the last thirty years or so, production of energy in water power plants has tripled, but hydro energy’s share was only increased for 50 % (from 2.2% to 3.3%). Nuclear power plants had in same period almost hundred times more production growth and its share 80 times more. That is because of the restrictions that hydro energy has. It can’t be used in all areas because it needs abundance of fast flowing water, and also is very desirable to have it enough throughout all year, because electricity can’t be cheaply stored.

1.5.1 Types of Hydro Electrics (Hydro Electric Power Plants)

There are three main types of hydroelectrics: fluid, accumulative (Hydroelectric Dam), and reversible (Pumped-storage Plants) hydroelectric

1.5.1.1 Hydroelectric dam working principle



By definition fluid hydroelectrics are the ones that don't have upstream accumulation or its accumulation can be emptied for less than two hours with its nominal power. This means that almost direct use of kinetic energy of the water is used for turbine's moving. These hydro electrics are easiest to build, but are very dependable on water's fluidity. Advantage of this type is small environment's influence and no underground waters level increasing.

On the picture you can see working principle of Hydroelectric Dam. Main parts of that hydroelectric are accumulation, dam, clench, gravity intake, water chamber, rail chamber, pressure pipelines, engine room and water vent. There are two types of Hydroelectric Dams: near the dam and derivational. Near the dam type is located under the dam itself, and derivational is located much more below the dam with pipelines as connectors to accumulation. Hydroelectric Dams are mostly used for gaining the electricity from water's energy. Problems are occurring during the summer months when natural flow gets too small for hydroelectric's functioning. In that case dam must be sealed and it's necessary as well to at least maintain water level which is biological minimum. Big problem is also the growth level of underground water.

Electrical energy consumption depends on certain daytime, day of the week, season, etc. Monday means highest consumption, but consumption is also huge in all other days of the working week. Weekend usually means lower energy consumption. For filling the working week's needs Pumped-storage Plants are being build. Those hydroelectrics are very similar to hydroelectric dams, but water's fluidity goes through both directions in to a derivational canal. When there's small energy consumption water pumps itself from lower lake to an upper accumulation. During the day it's turned to an electrical energy consumption, and this is the time when upper accumulation empties. Energetically this is not the best solution, but is still better than to build couple of thermal power plants for covering working week's energy consumption.

1.5.2 Small hydro (small hydroelectric)

Small hydro is facility which converts potential energy of the water into the kinetic energy in form of water current, then into mechanical energy spinning of the turbines, and finally in the end, electrical energy in the generator. In the last few years world trends in energy have shifted towards renewable energy sources, and because of this small hydroelectrics are becoming increasingly popular. Small hydroelectrics are believed to have zero impact on environment unlike big hydroelectric plants that cause big damage to nearby ecosystems, have negative influence on soil, cause flooding, increase methane emissions, and overall emissions connected with the building and transport process. The huge amounts of water in pipelines of drinking water are logical choice as the potential source of energy. Given the fact that the flow through pipelines exists by the water pump site, especially at the part of the pipeline near the well, water store and pump site, where the flow of the water through the pipes is mostly achieved by the gravitational force, setting up the turbine and the supportive electric generators does not disrupt the drinking water supply, and in the same time produces electrical energy. Hydropower technology, which is considered as the renewable energy source is today technically not only most known but also most developed on global level, with the very high level of efficiency. 22 percent of world's electricity generation comes from the small and big hydro power plants.

Term “small hydro” can be viewed from many different points of view, and differs from country to country, depending on its standards, hydrological, meteorological, topographic and morphologic characteristics of the location as well as about the level of technological development and economic standard.

Small hydro station

The difference between hydropower plants and small hydroelectrics is mainly in installed power. The boundary power that separates small from big hydroelectrics differs from country to country.

WATER TURBINES

Water turbine is the propulsion device in which the potential energy of the water is converted into the kinetic energy, and then with the change in amount of motion in the working wheel, in the mechanical energy of spinning. The arbor of the turbine working wheel is connected with the generator in which the mechanical energy of the spinning gets converted into the electricity. The conversion of energy towards the change of the pressure water during the motion through the working wheel is the main factor when separating different types of water turbines. Two main types of water turbines are reaction water turbines and action (impulsive) water turbines.

Reaction water turbines: – Reaction water turbines are those water turbines that have higher pressure at the entrance to the rotor compared to the pressure at its exit. In these turbines one part of the potential energy is transferred into the kinetic energy in stator, and part in rotor. Rotation of the working wheel is caused by the changes in amount of the motion and the reaction force (pressure difference, force, etc).

Action water turbines :– In Action water turbines pressure at the entrance of the rotor is the same as the pressure at its exit because all the potential energy gets transferred into kinetic energy in one place, namely the stator (nozzle) of the turbine. The rotation force is here the result of only changes in amount of the motion because of the rotation of the stream in the working wheel.

Advantages:

- Small hydroelectrics are ecologically very acceptable because they do not emit CO_2 while generating energy like fossil fuels do
- Decreased consumption of fossil fuels
- They help in protection from flooding, and do not require large areas
- They ensure safe and reliable supply with electricity, with efficiency up to 90%, and small running costs
- Positive social effect in region (new jobs, etc.)

One GWh of electricity produced in small hydro means:

- Avoiding the emission of 480 tons of carbon dioxide (CO_2)
- Enough electricity to supply 250 homes in developed, and 450 homes in developing countries
- Savings up to 220 tons of fuel or savings of 335 tons of coal

Disadvantages:

Though they do not influence the water streams like large hydroelectrics do, they still influence the local flora and fauna (migration of fish, downstream quality of water). In order to reduce this negative impact some measures can be done such as:

- Extra flow
- Passage ways for fish
- Collecting and storing the garbage
- Multifunctional drives
- Techniques that reduce noise and vibration
- Fish-friendly turbines
- Bio-design

1.6 Nuclear energy:

A small amount of radioactive substance (U^{235}) can produce a lot of energy through the process of nuclear fission. For example, one ton of uranium can provide energy which is much higher than three million tons of coal or 12 million barrels of oil. In order to obtain nuclear energy, nuclear reactors are required. There are around 300 nuclear reactors all over the world. India has only four nuclear power stations (reactors).

The nuclear energy can be used in production of electrical energy, as a fuel for marine vessel and space crafts and for the generation of heat in chemical processing plants. In India, Uranium deposits are found at different parts of Rajasthan and Singhbum of Jharkhand.

Thorium is recovered from monazite sand found in the state of Kerala. Due to the higher energy releasing tendency of these radioactive substances, these can be used in nuclear reactors to release energy crisis. But the radioactive substances are exhaustible and can be used to develop nuclear weapons of mass destruction. In addition, dumping or radioactive wastes cause serious environmental hazards.

1.6.1 Working principle

Procedure of releasing the nuclear energy. Uncontrolled process is called atomic bomb, and controlled process is a nuclear reactor.

Nuclear power plants are using as a fuel isotope of uranium U-235 which is very suitable for fission. In nature can be found uranium with more than 99% U-238 and only about 0.7% U-235. While U-238 is absorbing fast neutrons, U-235 on the other hand, when bombarded with slow neutrons degrades itself to very radioactive products of fission, releasing in this process more fast neutrons (process). Deceleration of these fast neutrons when crashing with molecules of heavy water, which is heating itself in process, makes the nuclear chain reaction possible. Released heat is in fact this desirable energy. In nuclear reactors this process happens all the time in strictly controlled conditions (couple of moments in Chernobyl excluded).

Atomic bomb is the result of deliberately caused enormous concentration of free neutrons which are then crashing with fission's sensible atoms achieving uncontrolled energy explosion in the process.

Although there's a significant number of Uranium in nature (hundred times more than silver) U-235 isotopes is very rare. Because of that uranium enrichment procedure becomes necessary. In final, useable faze, nuclear fuel will have a form of two and the half centimeter's long tablets. One this tablet will be enough to give approximately same amount of energy as one ton of coal. Energy released when bombarding uranium with neutrons is used for the water heating. That water (steam) is then starting generator, and after that it's necessary to cool the water off and put it back to a reactor. To succeed in this, it's necessary to maintain constant and big fluidity of the water around the core of the reactor.

1.6.2 Environment influence and radioactive waste:

Like every other process of energy production from non renewable sources, nuclear power plants are producing waste as well, in this case radioactive waste and hot water. Since nuclear power plants are not producing the carbon dioxide, its use isn't increasing greenhouse effect. Radioactive waste is generally divided in to a two main categories: low-radioactive and high-radioactive waste. Majority of nuclear waste is low-radioactive waste. Those are usually: junk, equipments, protective suits and others. That waste is contaminated with small level of radioactive dust or particles, and must be safely kept in order not to get in contact with outside materials.

Nuclear power plants, despite being harmless for environment if everything is played by the rules, still present great threat to environment in possibility of nuclear disaster during irregular use. Two major nuclear disasters happened during the peacetime: Chernobyl and Island Three Miles. The biggest disaster that ever happened in nuclear power plants was in Chernobyl, former SSSR, now Ukraine, on 26th April of 1986.

1.6.3 Countries' use of nuclear energy

Country that has the largest share of its electrical energy manufactured in nuclear power plants is France with 75%. Lithuania follows with 73%, and then Belgium with 58%, Bulgaria, Slovakia and Sweden with 47%, Ukraine with 44%, and Republic of Korea with 43%. Ten countries more have more than 25% of its total electrical energy produced in nuclear power plants. US is producing 19.8% of its electrical energy in nuclear power plants, but because of the high production range they are having the biggest share in the total electrical energy produced in nuclear power plants with 28%. France is second with 18%, and Japan third with 12%.

With the rising number of countries having nuclear power plants, risk that fuel from nuclear power plants will get in the hands of individuals that won't use it for peaceful intentions increased as well. Lately terrorism is being very alluring and terrorists with nuclear technology in their dispose could cause huge nuclear disaster. Politicians and scientists must take certain measures to protect us from this malicious use of nuclear energy. International organizations, specifically because of this problem imposed the safety rules for 140 countries across the globe. Problems with storage of the nuclear fuel (and radioactive waste as well) is momentarily mostly expressed in poor countries

Unit II

Non conventional energy sources: Solar energy- wind energy-energy from Bio mass and bio gas – ocean energy – tidal energy – geo thermal energy – Advantage of renewable energy.

Non-conventional energy is considered the energy of the future. The conventional energy sources discussed above are exhaustible and in some cases, installation of plants to get energy is highly expensive.Energy generated by using wind, tides, solar, geothermal heat, and biomass including farm and animal waste as well as human excreta is known as non-conventional energy. All these sources are renewable or inexhaustible and do not cause environmental pollution. Moreover they do not require heavy expenditure.

Considering the benefits of non-conventional energy generation, many countries have started producing this energy in large scale. In order to meet the energy demand of increased population, there is continuous research for development of technology in this field to reduce the cost of production and to make it more cost-effective.The scientists developed alternate nonconventional natural Resources sources of energy which should be renewable and provide a pollution free environment.

Some nonconventional, renewable and inexpensive energy sources are described below:

1. Solar energy:

Solar energy, a primary energy source, is non-polluting and inexhaustible.There are several ways to harness solar energy: photovoltaics (also called solar electric), solar heating & cooling, concentrating solar power (typically built at utility-scale), and passive solar

Three methods to harness solar energy:

(i) Converting solar energy directly into electrical energy in solar power stations using photo cells or photovoltaic cells or silicon solar cell.

Photovoltaic:

Photovoltaic (PV) devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by solar energy and can be induced to travel through an electrical circuit, powering electrical devices or sending electricity to the grid.

PV devices can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses.

Solar heating & cooling:

Solar heating & cooling (SHC) technologies collect the thermal energy from the sun and use this heat to provide hot water, space heating, cooling, and pool heating for residential, commercial, and industrial applications. These technologies displace the need to use electricity or natural gas.Solar water heating systems are comprised of three main elements: the solar collector, insulated piping, and a hot water storage tank. Electronic controls can also be included, as well as a freeze protection system for colder climates. The solar collector gathers the heat from solar radiation and transfers the heat to potable water. This heated water flows out of the collector to a hot water tank, and is used as necessary. Auxiliary heating can remain connected to the hot water tank for back-up if necessary.

Concentrating solar power:

Concentrating solar power (CSP) plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity. The thermal energy concentrated in a CSP plant can be stored and used to produce electricity when it is needed, day or night. Today, over 1,800 megawatts (MW) of CSP plants operate in the United States.

Parabolic trough systems use curved mirrors to focus the sun's energy onto a receiver tube that runs down the center of a trough. In the receiver tube, a high-temperature heat transfer fluid (such as a synthetic oil) absorbs the sun's energy, reaching temperatures of 750°F or even higher, and passes through a heat exchanger to heat water and produce steam. The steam drives a conventional steam turbine power system to generate electricity. A typical solar collector field contains hundreds of parallel rows of troughs connected as a series of loops, which are placed on a north-south axis so the troughs can track the sun from east to west. Individual collector modules are typically 15-20 feet tall and 300-450 feet long.

(ii) Using photosynthetic and biological process for energy trapping. In the process of photosynthesis, green plants absorb solar energy and convert it into chemical energy, stored in the form of carbohydrate.

(iii) Converting solar energy in to thermal energy by suitable devices which may be subsequently converted into mechanical, chemical or electrical energy.

Since solar energy is non-ending and its conversion to some other energy form is nonpolluting, attention should be paid for the maximum utilization of solar energy.

2. Wind energy:

Wind is air in motion. The movement of air takes place due to the convection current set out in the atmosphere which is again due to heating of earth's surface by solar radiation, rotation of earth etc. The movement of air occurs both horizontally and vertically.

Wind energy is a form of renewable energy produced through machines that use wind as their power source.It is a form of electricity that is created by wind turbines. Wind energy is used as a mechanical power that is transformed into electricity, with the use of a generator.Energy that is created by bulk-powered wind turbines is either directly used or placed onto the nation's power grid and stored for future use. Smaller single turbines can be used to provide energy to homes that are located in areas that do not have access to the electrical grid.

The average annual wind density is 3 $kW/m^2/day$ along costal lines of Gujarat, western ghat central parts of India which may show a seasonal variation (i.e., in winter it may go up to $10kW/m^2/day$).]. Since wind has a tremendous amount of energy, its energy can be converted into mechanical or electrical energy using suitable devices, now days, wind energy s converted in to electrical energy which is subsequently used for pumping water, grinding of corns etc. As per available data dearly 20,000 mW of electricity can be generated from wind. In Puri, wind farms are set up which can generate 550 kW of electricity.

3. Bio-mass based energy:

The organic matters originated from living organisms (plants and animals) like wood, cattle dung, sewage, agricultural wastes etc. are called as biomass. These substances can be burnt to produce heat energy which can be used in the generation of electricity. Thus, the energy produced from the biomass is known as biomass energy.

There are three forms of biomass:

(i) Biomass in traditional form:

Energy is released by direct burning of biomass (e.g. wood, agricultural residue etc.)

(ii) Biomass in nontraditional form:

The biomass may be converted in to some other form of fuel which can release energy. For example carbohydrate can be converted into methanol or ethanol which may be used as a liquid fuel.

(iii) Biomass for domestic use:

When organic matters like cow dung, agricultural wastes, human excreta etc. subjected to bacterial decomposition in presence of water in absence of air, a mixture of CH_4, $C0_2$, H_2, H_2S etc. is produced. These gases together is known as biogas. The residue left after the removal of biogas is a good source of manure and biogas is used as a good source of non-polluting fuel.

Petro plants:

In order to release the pressure on mineral oils (a nonrenewable resource), the scientists have discovered some potential plant species from which liquid hydrocarbons can be extracted. The liquid hydrocarbons present in such plants can be converted in to petroleum.

Such plants are known as petro plants which belong to families Apocynaceae, Ascalepiadaceae, Euphrobiaceae; Convolvulaceae and Spontaceae. Still research is on to increase the biomass of the petro plants and effective method of converting their hydrocarbons in petroleum.

Dendro thermal energy (Energy plantation):

Due to rapid deforestation and overgrazing, a number of denuded wastelands are formed. On these wastelands, fast growing trees and shrubs may be planted which will provide fuel wood, charcoal, fodder, etc. Through gasification, these plants can produce a lot of energy-

Bagasse-based plants:

Bagasse is generated as a waste product in sugar mills. This can be utilised to produce electrical energy. As per available data, the sugar mills in India can generate about 2000 mW surplus electricity during crushing season.

Energy from urban waste:

Sewage and solid municipal wastes can also generate energy on their suitable treatments.

4. Biogas:

Biogas is an important source of energy to meet energy, requirements of rural area. As per given data, around 22,420-million m^3 of gas can be produced from the large amount of cow dungs obtained in rural areas in a year. The gas is generated by the action of bacteria on cow dung in absence of air (oxygen). There are two types of biogas plants namely. Fixed done type and floating gas holder type (Fig.4.3 & 4.4).

These plants are commonly known as Gobar gas plants because the usual raw material is cow dung (Gobar). The methodology involves in the process is to prepare a slurry of cow dung with water. Sometimes form waters can also be added to the slurry.

The slurry is subjected to bacterial decomposition at 35 .C. There are about 330, 00 biogas plants in India. All India dung production is about 11.30 kg per cattle and 11.60 kg per buffalo with about 67.10 m^3 of gas per ton of wet dung.

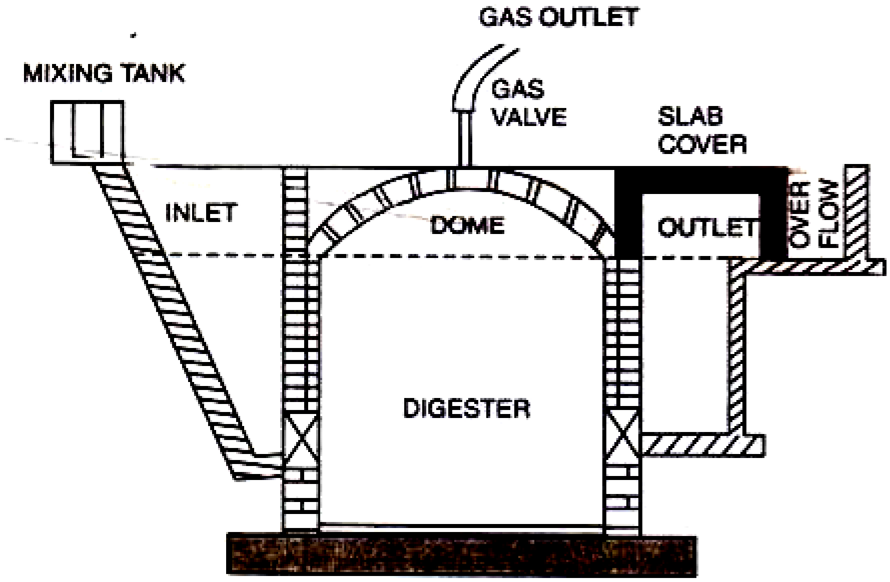


FIG. 4.3 : FIXED DOME TYPE BIOGAS PLANT

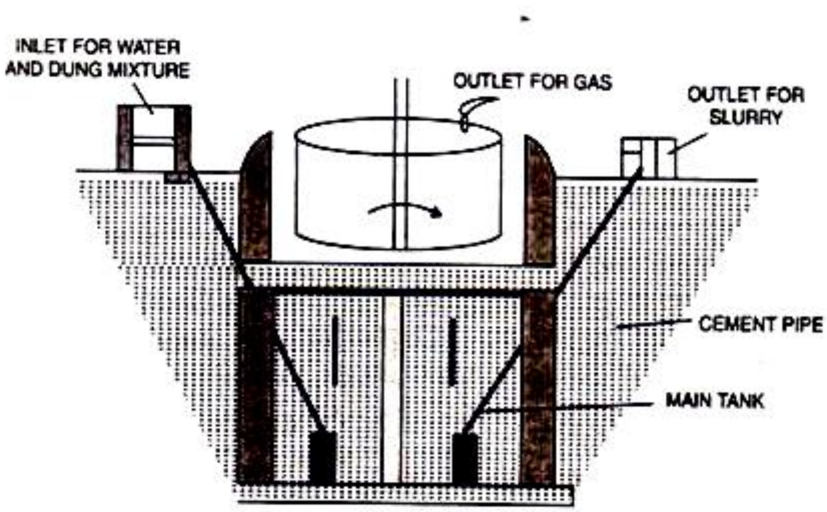


FIG. 4.4 : FLOATING GAS HOLDER TYPE BIOGAS PLANT

5. Ocean Energy:

The ocean is an enormous source of energy. It is estimated that 0.1% of the energy in ocean waves could be capable of supplying the entire world's energy requirements five times over. Currently, a number of technologies aimed at harnessing this potential have been investigated and are at different stages of development including tidal and marine energy, wave energy, difference of temperature and salinity energy.

Generating electrical power from the ocean include tidal power, wave power, ocean thermal energy conversion, ocean currents, ocean winds and salinity gradients is known as Ocean energy. The three most well-developed technologies are tidal power, wave power and ocean thermal energy conversion.Ocean can produce the thermal energy from the sun's heat, and the mechanical energy from the tides and waves.

6. Wave energy:

Wave energy conversion takes advantage of the ocean waves caused primarily by interaction of winds with the ocean surface. Wave energy is an irregular and oscillating low-frequency energy source that must be converted to a 60-Hertz frequency before it can be added to the electric utility grid.

Although many wave energy devices have been invented, only a small proportion have been tested and evaluated. Furthermore, only a few have been tested at sea, in ocean waves, rather than in artificial wave tanks.

A wave energy converter may be placed in the ocean in various possible situations and locations. It may be floating or submerged completely in the sea offshore or it may be located on the shore or on the sea bed in relatively shallow water. A converter on the sea bed may be completely submerged, it may extend above the sea surface, or it may be a converter system placed on an offshore platform. Apart from wave-powered navigation buoys, however, most of the prototypes have been placed at or near the shore

The incidence of wave power at deep ocean sites is three to eight times the wave power at adjacent coastal sites. The cost, however, of electricity transmission from deep ocean sites is prohibitively high. Wave power densities in California's coastal waters are sufficient to produce between seven and 17 megawatts (MW) per mile of coastline

According to the European Union, "Among the different converters capable of exploiting wave power, the most advanced is unquestionably the Pelamis Wave Energy Converter, a kind of "undulating sea serpent" developed by Ocean Power Delivery. This technology is the object of a commercial contract for installation of a farm in Portugal. In 2007, three machines, with a total capacity of 2.25 megawatts. Another 5 MW project is being studied for England this time."

Many research and development goals remain to be accomplished, including cost reduction, efficiency and reliability improvements, identification of suitable sites in California, interconnection with the utility grid, better understanding of the impacts of the technology on marine life and the shoreline. Also essential is a demonstration of the ability of the equipment to survive the salinity and pressure environments of the ocean as well as weather effects over the life of the facility

Ocean Thermal Energy Conversion:

There is a temperature differencebetween the surface and in deep of the ocean. Ocean is warmer on the surface because sunlight warms the water. But below the surface, the ocean gets very cold. The French Engineer Jacques D'Arsonval first thought of the idea of using the temperature of water to make energy.

Power plants can be built that use this difference in temperature to make energy. A difference of at least 38 degrees Fahrenheit is needed between the warmer surface water and the colder deep ocean water. The cold ocean water can also be used to cooling buildings, and desalinated water is often a by-product.

Using this type of energy source is called Ocean Thermal Energy Conversion or OTEC. It was demonstrated in Hawaii at the Open Cycle Ocean Thermal Energy Conversion (OC-OTEC) system located at the Natural Energy Laboratory of Hawaii Authority (NELHA) at Keahole Point on the Big Island of Hawaii.

7. Tidal Energy:

Another form of ocean energy is called tidal energy.Tides are generated through a combination of forces exerted by the gravitational pull of the sun and the moon and the rotation of the earth. The relative motion of the three bodies produces different tidal cycles which affect the range of the tides. In addition, the tidal range is increased substantially by local effects such as shelving, funneling, reflection and resonance.

Energy can be extracted from tides by creating a reservoir or basin behind a barrage and then passing tidal waters through turbines in the barrage to generate electricity. Tidal energy is extremely site specific requires mean tidal differences greater than 4 meters and also favorable topographical conditions, such as estuaries or certain types of bays in order to bring down costs of dams etc. Since India is surrounded by sea on three sides, its potential to harness tidal energy has been recognized by the Government of India.

A way of converting the energy of tides into electric power: A tidal barrage works in a similar way to that of a hydroelectric scheme, except that the dam is much bigger and spans a river estuary. When the tide goes in and out, the water flows through tunnels in the barrage. The ebb and flow of the tides can be used to turn a turbine, or it can be used to push air through a pipe, which then turns a turbine.

The most attractive locations are the Gulf of Cambay and the Gulf of Kachchh on the west coast where the maximum tidal range is 11 m and 8 m with average tidal range of 6.77 m and 5.23 m respectively. The Ganges Delta in the Sunderbans in West Bengal also has good locations for small scale tidal power development. The maximum tidal range in Sunderbans is approximately 5 m with an average tidal range of 2.97 m.

The identified economic tidal power potential in India is of the order of 8000-9000 MW with about 7000 MW in the Gulf of Cambay about 1200 MW in the Gulf of Kachchh and less than 100 MW in Sundarbans.

8. Geothermal energy:

The geothermal energy may be defined as the heat energy obtainable from hot rocks present inside the earth crust. At the deeper region of earth crust, the solid rock gets melted in to magma, due to very high temperature. The magma layer is pushed up due to some geological changes and get concentrated below the earth crust. The places of hot magma concentration at fairly less depth are known as hot spots. These hot spots are known as sources of geothermal energy.Its potential is limitless in human terms and its energy is comparable to the sun. Geothermal heat and water have been used for thousands of years. The Romans, Chinese and Native Americans used hot mineral springs for bathing, cooking and for therapeutic purposes.

Now a days, efforts are being made to use this energy for generating power and creating refrigeration etc. There are a quite few number of methods of harnessing geothermal energy. Different sites of geothermal energy generation are Puga (Ladakh), Tattapani (Suraguja, M.P.), Cambay Basin (Alkananda Valley, Uttaranchal).

Geothermal water is used in many applications such as district heating, systems which provide steam or hot water to multiple units, as well as for heating and cooling of individual buildings, including offices, shops and residential houses, by using geothermal heat pumps. Moreover, it has industrial potential for raising plants in greenhouses, drying crops, heating water at fish farms and other industrial processes.

For close to 100 years geothermal energy has also been used for electricity generation. Today, so called Enhanced Geothermal Systems (EGS, also known as Hot Dry Rock), enable the exploitation of the Earth's heat for producing electricity without having natural water resources. To extract energy from hot impermeable rock, water is injected from the surface into boreholes in order to widen them and create some fractures in the hot rock. Flowing through these holes, the water heats up and, when it returns to the surface, it is used for generating electricity.

Clean, renewable, constant and available worldwide, geothermal energy is already being used in a large number of thermal and electric power plants.

Geothermal - generated electricity was first produced in Larderello, Italy, in 1904. Currently just over 1 GW geothermal electric power (of which 0.95 GW operational) is in use in the EU, producing roughly 7 000 GWh of electricity per year. The geothermal market is currently concentrated in a number of countries across Europe, with Italy, France, Portugal, Iceland and Turkey leading the electricity sector, and Sweden, Italy, Greece, France, Germany, Hungary, Turkey, Iceland and Switzerland leading the heating sector.According to the IEA, geothermal power plants grew worldwide at a broadly constant rate of about 200 MW/year from 1980 to 2005. In 2007 the total capacity reached around 10 GW, generating 56TWh/year of electricity.

Enhanced geothermal system technologies (EGS) have the potential to cost-effectively produce large amounts of electricity almost anywhere in the world. Several pilot projects are at the moment being conducted in United States, Australia and Europe.

RENEWABLE ENERGY AND ITS ADVANTAGES

1. It Cannot Possibly be Depleted

The sources for renewable energy may consist of wind, hydro, ocean, biomass, geothermal and solar. Each of them offers a big advantage as they are not depleted and are renewable. They provide clean energy because they are non-pollutant and non-contributor to greenhouse effects and global warming.

2. Reduced Cost of Operations

As the sources are known to be natural, the operations and costs are reduced. This only means that even the government and private sector can save more from using renewable sources. They also need less maintenance.

3. Only Uses the Energy from the Sun

This is proven to be advantageous because even the systems may fit on already existing buildings. The systems are not mainly affecting the use of lands; however, it may still require materials.

4. With Renewable Energy Comes the Creation of Jobs

Among regions that already have turned to renewable energy, there is a change and economic growth is even seen. As for people, they can be employed and enjoy the most from their incomes.

5. Facilities Need Less Maintenance and Renewable Energy Has Little Waste Products

The facilities to be used on renewable energy need less maintenance. The fuel that is derived from available and natural resources limits the overall costs, prior to operations.

More importantly, renewable energy only has no or little waste products. These waste products may include of chemical pollutants or carbon dioxide. They are only less and may have minimum impact in the environment.

6. The Projects Provide Economic Benefits

The projects related on renewable energy provide economic benefits to people, in the regional areas. Many of the projects are not situated near suburbs and urban centers. These benefits may be associated in the tourism and local services.

Unit III

Solar Energy

Solar Radiation – Solar constant – Solar radiation measurements – Pyrheliometers – Pyranometers – Estimation of average solar radiation – Applications of solar energy

3.1 Solar Radiation:

Sunlight, we experience is actually solar radiation. Sunlight is the light and energy that comes from the Sun. When this energy reaches the earth's surface, it is called insolation. It is the radiation and heat from the Sun in the form of electromagnetic waves.

The atmosphere affects the amount of solar radiation received. When solar radiation travels through the atmosphere, some of it is absorbed by the atmosphere (16%). Some of it is scattered to space (6%). Some of it is reflected by clouds (28%). About 47% of it reaches the Earth's surface.

Without sunlight, there could be no life on Earth. Plants need sunlight for the process of photosynthesis. During photosynthesis the plants use the energy of the sunlight, water, and carbon dioxide, to create glucose (sugar). The glucose can later be used by the plant for energy or animals eat the plant and the glucose in it. Plants need sunlight to grow green. Without enough sunlight but with enough water, the plant grows very tall very quickly, but looks yellow and dehydrated, although when touched, the leaves are very moist.

Solar radiation can be both good and bad for a person's health. When in the light, the human body uses the ultraviolet part of sunlight to make its own Vitamin D. Without sunscreen too much ultraviolet light can cause sunburn and skin cancer. Angle of incidence of the sunlight makes difference in seasons on Earth as well as in the length of day and night. A high angle of incidence makes the tropics hot, and a low angle makes the arctic cold.

Solar Energy is measured in kilowatt-hour. 1 kilowatt = 1000 watts.India receives solar energy equivalent to over 5000 Trillion kWh/year, which is far more than the total energy consumption of the country.India is one of the few countries with long days and plenty of sunshine, especially in the Thar Desert region. This zone, having abundant solar energy available, is suitable for harnessing solar energy for a number of applications. In areas with similar intensity of solar radiation, solar energy could be easily harnessed. Solar thermal energy is being used in India for heating water for both industrial and domestic purposes. A 140 MW integrated solar power plant is to be set up in Jodhpur but the initial expense incurred is still very high.

Solar energy is used in many different ways by people all over the world both in its traditional way for heating, cooking or drying and to make electricity where other power supplies are absent, such as in remote places on Earth or in the space. Sometimes, it is cheaper to make electricity from sunlight than from coal or oil.

3.2 Solar constant:

Solar constant, the total radiation energy received from the Sun per unit of time per unit of area on a theoretical surface perpendicular to the Sun's rays and at Earth's mean distance from the Sun. It is most accurately measured from satellites where atmospheric effects are absent. The value of the constant is approximately 1.366 kilowatts per square metre.

ie., The solar constant, a measure of flux density, is the mean solar electromagnetic radiation (the solar irradiance) per unit area that would be incident on a plane perpendicular to the rays, at a distance of one astronomical unit (AU) from the Sun (roughly the mean distance from the Sun to the Earth). The solar constant includes all types of solar radiation, not just the visible light. It is measured by satellite as being 1.361 kilowatts per square meter (kW/m^2) at solar minimum and approximately 0.1% greater (roughly 1.362 kW/m^2) at solar maximum. The solar constant is merely an average of the actually varying value.

The solar constant is calculated by multiplying the sun's surface irradiance by the square of the radius of the sun over the average distance between the Earth and the sun. Irradiance is sometimes referred to as flux and is a measurement of electromagnetic energy from the sun

The formula for calculating the solar constant is written as $S_o = \frac{E \times R^2}{r^2}$

where S_o is the solar constant, E is the irradiance of the sun, R is the radius of the sun and r is the distance between the Earth and the sun, which is the radius of the Earth's orbit. The solar constant is used to calculate solar radiation.

3.3 Solar Radiation Measurements:

Solar radiation is a term used to describe visible and near-visible (ultraviolet and near-infrared) radiation emitted from the sun. The different regions are described by their wavelength range within the broad band range of 0.20 to 4.0 µm (microns). Terrestrial radiation is a term used to describe infrared radiation emitted from the atmosphere. The following is a list of the components of solar and terrestrial radiation and their approximate wavelength ranges:

- Ultraviolet: 0.20 – 0.39 µm
- Visible: 0.39 – 0.78 µm
- Near-Infrared: 0.78 – 4.00 µm
- Infrared: 4.00 – 100.00 µm

Approximately 99% of solar, or shortwave, radiation at the earth's surface is contained in the region from 0.3 to 3.0 µm while most of terrestrial, or longwave, radiation is contained in the region from 3.5 to 50 µm.

The solar radiation spectrum that reaches earth's surface extends its wavelength approximately from 300 nm to 2800 nm.

To make a measurement of irradiance, it is required by definition that the response to "beam" radiation varies with the cosine of the angle of incidence. This ensures a full response when the solar radiation hits the sensor perpendicularly (normal to the surface, sun at zenith, 0° angle of incidence), zero response when the sun is at the horizon (90° angle of incidence, 90° zenith angle), and 0.5 at a 60° angle of incidence. It follows that a pyranometer should have a so-called "directional response" or "cosine response" that is as close as possible to the ideal cosine characteristic.

The relationship of the components of solar radiation is:

GHI = DHI + DNI*cos(θ) where θ is the solar zenith angle(vertically above the location is 0°, horizontal is 90°).

GHI is measured by a horizontally installed pyranometer.The pyranometer for GHI may be conveniently mounted on top of the tracker

DHI can be measured by fitting a second pyranometer on top ofthe sun tracker and a shading assembly that moves with the tracker to always block the direct beam radiation from reaching thepyranometer

DNI is measured using a pyrheliometer

3.3.1 Pyranometer:

A pyranometer is used for measuring solar irradiance on a planar surface and it is designed to measure the solar radiation flux density (W/m^2) from the hemisphere above within a wavelength range 0.3 µm to 3 µm. The name pyranometer stems from the Greek words πῦρ (pyr), meaning "fire", and ἄνω (ano), meaning "above, sky".

A typical pyranometer does not require any power to operate. However, recent technical development includes use of electronics in pyranometers, which do require (low) external power.

There are three types of pyranometers can be recognized and grouped in two different technologies: thermopile technology and silicon semiconductor technology.The light sensitivity, known as 'spectral response', depends on the type of pyranometer.

3.3.1.1 Thermopilepyranometer:

A thermopile pyranometer is a sensor based on thermopiles designed to measure the broadband of the solar radiation flux density from a 180° field of view angle. A thermopile pyranometer thus usually measures 300 to 2800 nm with a largely flat spectral sensitivity. The first generation of thermopile pyranometers had the active part of the sensor equally divided in black and white sectors. Irradiation was calculated from the differential measure between the temperature of the black sectors, exposed to the sun, and the temperature of the white sectors, sectors not exposed to the sun or better said in the shades.

In all thermopile technology, irradiation is proportional to the difference between the temperature of the sun exposed area and the temperature of the shadow area.

A thermopile pyranometer is constructed with the following main components:

A thermopile sensor with a black coating. It absorbs all solar radiation, has a flat spectrum covering the 300 to 50,000 nanometer range, and has a near-perfect cosine response.

A glass dome. It limits the spectral response from 300 to 2,800 nanometers (cutting off the part above 2,800 nm), while preserving the 180° field of view. It also shields the thermopile sensor from convection. For first class and secondary standard pyranometers a second glass dome is used. This construction provides an additional "radiation shield", resulting in a better thermal equilibrium between the sensor and inner dome, compared to using a single dome. The effect of having a second dome is a strong reduction of instrument offsets.

In the modern thermopile pyranometers the active (hot) junctions of the thermopile are located beneath the black coating surface and are heated by the radiation absorbed from the black coating. The passive (cold) junctions of the thermopile are fully protected from solar radiation and in thermal contact with the pyranometer housing, which serves as a heat-sink. This prevents any alteration from yellowing or decay when measuring the temperature in the shade, thus impairing the measure of the solar irradiance.

The thermopile generates a small voltage in proportion to the temperature difference between the black coating surface and the instrument housing. This is of the order of 10 µ • VW/m^2. Typically, on a sunny day the output is around 10 mV. Each pyranometer has a unique sensitivity, unless otherwise equipped with electronics for signal calibration.

Thermopile pyranometers are frequently used in meteorology, climatology, climate change research, building engineering physics and in photovoltaic systems.

3.3.1.2 Photodiode-based pyranometer

A photodiode-based pyranometeralso known as a silicon pyranometercan detect the portion of the solar spectrum between 400 nm and 900 nm, with the most performant detecting between 350 nm and 1100 nm. The photodiode converts the aforementioned solar spectrum frequencies into current at high speed, the photoelectric effect. The conversion is influenced by the temperature with a raise in current produced by the raise in temperature (about 0,1% • °C)

A photodiode-based pyranometer is composed by a housing dome, a photodiode, and a diffuser or optical filters. The photodiode has a small surface area and acts as a sensor. The current generated by the photodiode is proportional to irradiance; an output circuit, such as a trans-impedance amplifier, generates a voltage directly proportional to the photocurrent. The output is usually on the order of millivolts, the same order of magnitude of thermopile-type pyranometers.

Photodiode-based pyranometers are the core of luxmeter used in photography, cinema and lighting technique. Sometimes they are also installed close to modules of photovoltaic systems.

3.3.1.3 Photovoltaic pyranometer:

The photovoltaic pyranometer is a derivation of the photodiode pyranometer.The active part of the sensor is composed of a photovoltaic cell working in near short-circuit condition. As such, the generated current is directly proportionate to the solar radiation hitting the cell in a range between 350 nm and 1150 nm. When invested by a luminous radiation in the mentioned range, it produces current as a consequence of the photovoltaic effect. Its sensitivity is not flat, but it is same as that of Silicon photovoltaic cell.

A photovoltaic pyranometer is essentially assembled with the following parts:

1. A metallic container with a fixing staff
2. A small photovoltaic cell
3. Signal conditioning electronics

Silicon sensors such as the photodiode and the photovoltaic cell vary the output in function of temperature. Photovoltaic pyranometers are used in solar simulators.

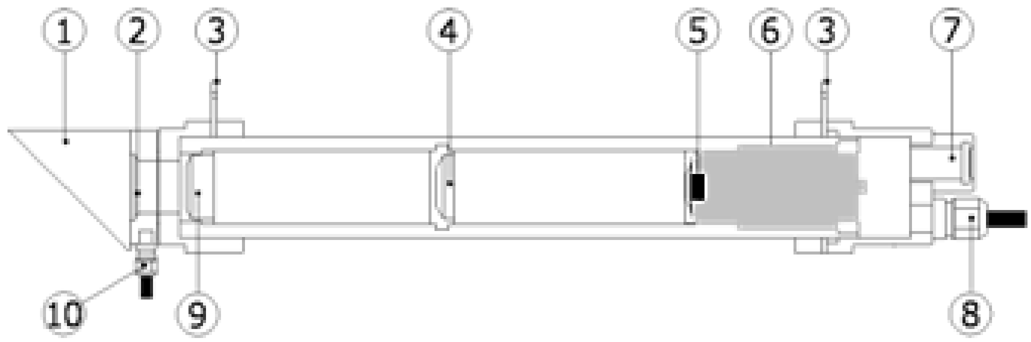
In the more recent models, the electronics compensate the signal with the temperature, therefore removing the influence of temperature out of the values of solar irradiance.

3.3.2 Pyrheliometer :

A pyrheliometer is an instrument for measurement of direct beam solar irradiance. Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded. The signal voltage is converted via a formula to measure watts per square metre. It is used with a solar tracking system to keep the instrument aimed at the sun. A pyrheliometer is often used in the same setup with a pyranometer.

Typical pyrheliometer measurement applications include scientific meteorological and climate observations, material testing research, and assessment of the efficiency of solar collectors and photovoltaic devices.

Pyrheliometers are typically mounted on a solar tracker. As the pyrheliometer only 'sees' the solar disk, it needs to be placed on a device that follows the path of the sun.



(1) protection cap, (2) window with heater, (3) sight, (4) aperture tube,(5) sensor, (6) thermopile, (7) humidity indicator, (8) cable gland, (9) window assembly with heater,(10) cable for heater.

3.4 Estimation of solar radiation:

Solar radiation data:Solar radiation data are available in several forms and should include the following information.

1. Whether they are instantaneous measurement or values integrated over some period of time (usually hour or day).
2. The time or time period of the measurements.
3. Whether the measurements are of beam, diffuse or total radiation, and the instrument used.
4. The receiving surface orientation (Usually horizontal, it may be inclined at a fixed slope, or normal)
5. If averaged, the period over which they are averaged(e.g., monthly average of daily radiation).

Most of the data on solar radiation received on the surface of the earth are measured by solarimeter which give readings for instantaneous measurements at rate throughout the day for total radiation on a horizontal surface. Integrating the plot of rate of energy received per unit time per unit area over a whole day gives the langleys of radiation received on a horizontal surface. For instance, the total daily solar radiation received in Calcutta (lat.$20^0 32'$ N) on the basis of yearly average is 680 langleys (I,e., 680 cals/cm^2 day).

Average solar radiation data are also available from maps. Maps can be used as a source of average radiation if data are not available. Charts are also available for clear day horizontal radiation for any period for any latitude. Tables are also available for hours of sunshine for various locations.

India lies between latitudes 7^0 and 37^0 N and receives an annual average intensity of solar radiation between 400 to 700 cal/cm^2/day. The daily solar insolation figures over the different places in India are accurately available. Peak values are generally measured in April or May, with parts of Rajasthan and Gujarat receiving over 600 cal/cm^2 /day. During the monsoon and winter months the daily solar radiation decreases to about 400 cal/cm^2 /day .

The annual daily diffuse radiation received over the whole country is observed to be about 175 cal/cm^2 /day. The minimum values of diffuse radiation, measured over many parts of the country during November and December, are between 75 and 100cal/cm^2 /day, while maximum values measured over the whole country are about 300 cal/cm^2 /day. Specially in July in Gujarat.

3.4.1 Estimation of Average Solar Radiation:

One of the earliest expressions, for monthly average horizontal solar radiation H_{av} was given by Angstrom (1924), which is

$H_{av}=H_{0'}\left(a' + b'\,\frac{\bar{n}}{N}\right)$...---(1)

Where a' and b' are arbitrary constants, (Freitz 1951, suggested that $a' = 0.35$ and b' = 0.61)

$H_{0'}$ = the monthly average horizontal solar radiation for a clear day.

$\bar{n}$= average daily hours of bright sunshine for same period .

N =maximum daily hours of bright sunshine for same period.

Values $H_{0'}$ for use in equation (1) can be obtained from charts of Fig. 1.

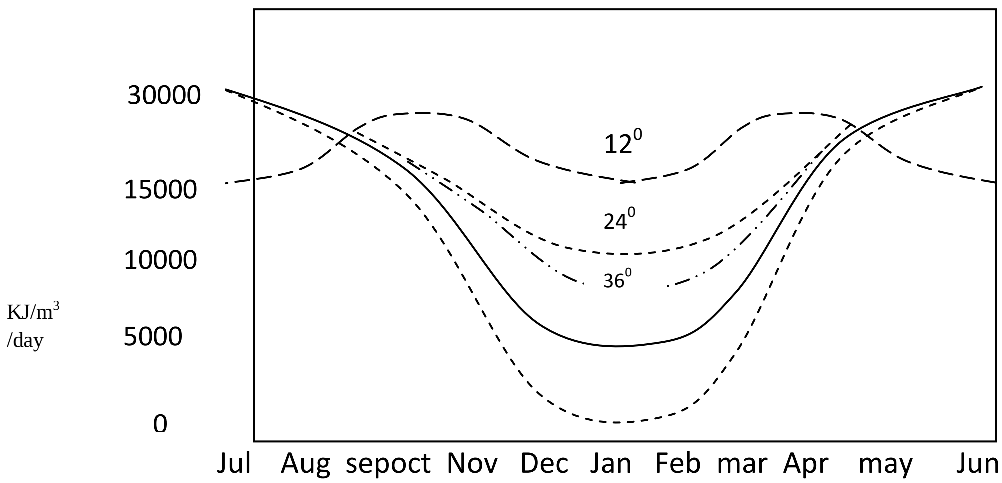


Fig. 1 Solar radiation on a horizontal plane for a clear day at various latitudes

The day length can be obtained from a nomogram developed by Whillier(Fig. 2) or can be calculated from the equation .

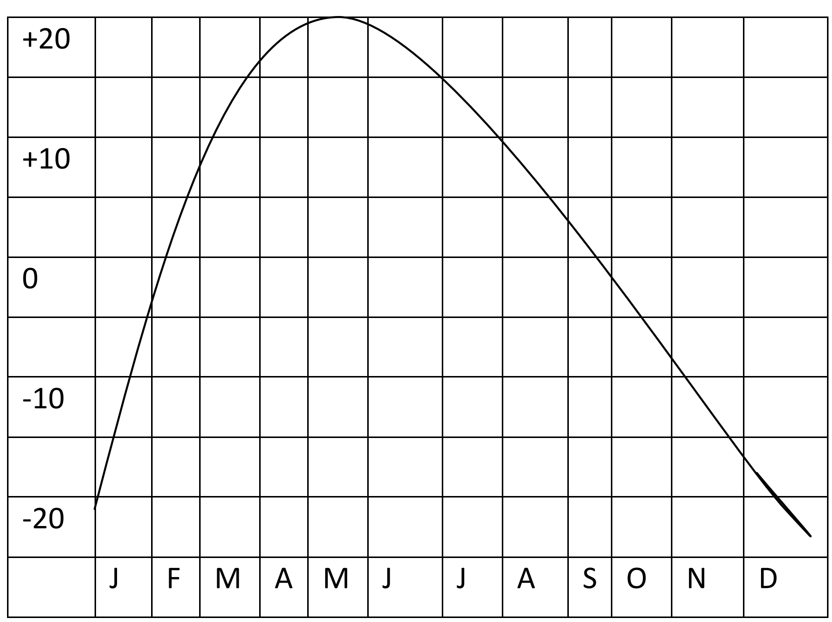


Fig. 2 . A nomogram for calculating the length of the day in hours

N = $T_d = \frac{2}{15} cos^{-1}(-tan\phi \; tan\delta)$

A better form of equation (1) is suggested as

$H_{av} = H_0 \left(a + b\frac{\bar{n}}{N}\right)$-------------------(2)

$where \; H_0$= the average monthly insolution at the top of the atmosphere.

a and b are the modified constants depending upon the location.

Constants a and b for various locations and climate conditions can be obtained from standard tables.

Table 1 gives the values of constants a and b for some Indian towns.

H_0can be obtained from charts or it can be calculated by

$H_0 = \frac{24}{\pi} I_{sc} \left[\left\{1 + 0.033 \cos\left(\frac{360n}{365}\right)\right\}\left(cos\varphi cos\delta sin\omega_s + \frac{2\pi\omega_s}{360} sin\varphi sin\delta\right)\right]$-------------------(3)

Where I_{sc}= solar constant per hour

n = day of the years and ω_s = sunrise hour angle.

Table 1. Constants a and b for some Indian Towns

location	a	b
Ahmedabad	0.28	0.48
Bangalore	0.18	0.64
Baroda	0.28	0.48
Bhavnagar	0.28	0.47
Bhopal	0.27	0.50
Calcutta	0.28	0.42
Goa	0.30	0.48
Jodhpur	0.33	0.46
Madras	0.30	0.44
Mangalore	0.27	0.43
Shilong	0.22	0.57
Srinagar	0.35	0.40
Trivandrum	0.37	0.39
Vishakhapatnam	0.28	0.47
Nagpur	0.27	0.50
New Delhi	0.25	0.57
Poona	0.31	0.43
Roorkee	0.25	0.56

The declination can be obtained from cooper equation and the sunrise hour angle from the relation, $\omega_s = tan\phi \ tan\delta$.

The surface temperature of sun:

We know that energy falling in one second on the unit area of the earth's surface held normal to sun's rays is called solar constant S. Experimentally, S has been found to be equal to 1388 Wm^{-2}.

Let R be the radius of the sun and r be the radius of earth's orbit around the sun. Let E be the energy emitted by the sun per second per unit area. Then, the total energy emitted by the sun in one second $= 4\pi R^2 \times E$. This energy is falling on a sphere of radius equal to the radius of the Earth's orbit around the sun i.e., on a sphere of surface area $4\pi r^2$.

$$The\ energy\ falling\ per\ unit\ area = \frac{4\pi R^2 \times E}{4\pi r^2} = \frac{E \times R^2}{r^2}$$

By definition, this is the solar constant S

$$ie., \quad S = \frac{E R^2}{r^2} \quad but \quad E = \sigma T^4$$

$$According\ to\ Stefan's\ law,\ S = \frac{\sigma T^4 R^2}{r^2} \quad or \quad T^4 = \frac{S r^2}{\sigma R^2} \quad ie., T = \left[\frac{S r^2}{\sigma R^2}\right]^{1/4}$$

$$where\ S = 1388 Wm^{-2}; R = 6.96 \times 10^8\ m; r = 1.496 \times 10^{11} m, and\ \sigma = 5.68 \times 10^{-8}\ SI\ units$$

On substituting these values, we get T, the surface temperature of the sun. It is found to be equal to 5791 K. In this way, the surface temperature of sun can be estimated.

3.5Application of Solar Energy:

When we hang out our clothes to dry in the sun, we use the energy of the sun. In the same way, solar panels absorb the energy of the sun to provide heat for cooking and for heating water. Such systems are available in the market and are being used in homes and factories.

Solar energy can also be used to meet our electricity requirements. Through Solar Photovoltaic (SPV) cells, solar radiation gets converted into DC electricity directly. This electricity can either be used as it is or can be stored in the battery. This stored electrical energy then can be used at night. SPV can be used for a number of applications such as:

a. domestic lighting

b. street lighting

c. village electrification

d. water pumping

e. desalination of salty water

f. powering of remote telecommunication repeater stations and

g. railway signals.

3.5.1 Residential Application:

Use of solar energy for homes has number of advantages. The solar energy is used in residential homes for heating the water with the help of solar heater. The photovoltaic cell installed on the roof of the house collects the solar energy and is used to warm the water. Solar energy can also be used to generate electricity. Batteries store energy captured in day time and supply power throughout the day. The use of solar appliances is one of the best ways to cut the expenditure on energy.

3.5.2 Industrial Application:

Sun’s thermal energy is used in office, warehouse and industry to supply power. Solar energy is used to power radio and TV stations. It is also used to supply power to lighthouse and warning light for aircraft.The largest solar power plant in the world is located in the Mojave Desert in California, covering 1000 acres.

3.5.3 Remote Application:

Solar energy can be used for power generation in remotely situated places like schools, homes, clinics and buildings. Water pumps run on solar energy in remote areas. Large scale desalination plant also use power generated from solar energy instead of electricity.

3.5.4 Transportation:

Solar energy is also used for public transportation such as trolleys, buses and light-rails.

3.5.5 Pool heating:

Solar heating system can be used to heat up water in pool during cold seasons

3.5.6 Some of the gadgets and other devices:

Solar cooker, Flat plate solar cookers, Concentrating collectors, Solar hot water systems (Domestic and Industrial), Solar pond, Solar hot air systems, Solar Dryers, Solar timber kilns, solar stills, Solar photovoltaic systems, Solar pond, Concentrating collectors, Power Tower, Air conditioning, Solar collectors, coupled to absorption, Refrigeration systems

Unit IV

Wind Energy

The Nature of wind – Power in the Wind – Wind Energy Conversion – Basic components of a wind energy conversion system (WECS) – Advantages and disadvantages of WECS.

Wind is the flow of gases on a large scale. On the surface of the Earth, wind consists of the bulk movement of air. In outer space, solar wind is the movement of gases or charged particles from the Sun through space, while planetary wind is the outgassing of light chemical elements from a planet's atmosphere into space.

Winds are commonly classified by their spatial scale, their speed, the types of forces that cause them, the regions in which they occur, and their effect. Winds have various aspects, an important one being its velocity (wind speed); another the density of the gas involved; another its energy content or wind energy

The strongest observed winds on a planet in the Solar System occur on Neptune and Saturn

In meteorology, winds are often referred to according to their strength, and the direction from which the wind is blowing. Short bursts of high speed wind are termed gusts. Strong winds of intermediate duration (around one minute) are termed squalls. Long-duration winds have various names associated with their average strength, such as breeze, gale, storm, and hurricane. Wind occurs on a range of scales, from thunderstorm flows lasting tens of minutes, to local breezes generated by heating of land surfaces and lasting a few hours, to global winds resulting from the difference in absorption of solar energy between the climate zones on Earth.

The two main causes of large-scale atmospheric circulation are the differential heating between the equator and the poles, and the rotation of the planet (Corioliseffect). Within the tropics, thermal low circulations over terrain and high plateaus can drive monsoon circulations.

In coastal areas the sea breeze/land breeze cycle can define local winds; in areas that have variable terrain, mountain and valley breezes can dominate local winds.

In human civilization, wind has inspired mythology, influenced the events of history, expanded the range of transport and warfare, and provided a power source for mechanical work, electricity and recreation. Wind powers the voyages of sailing ships across Earth's oceans. Hot air balloons use the wind to take short trips, and powered flight uses it to increase lift and reduce fuel consumption. Areas of wind shear caused by various weather phenomena can lead to dangerous situations for aircraft. When winds become strong, trees and man-made structures are damaged or destroyed.

Winds can shape landforms, via a variety of aeolian processes such as the formation of fertile soils, such as loess, and by erosion. Dust from large deserts can be moved great distances from its source region by the prevailing winds; winds that are accelerated by rough topography and associated with dust outbreaks have been assigned regional names in various parts of the world because of their significant effects on those regions. Wind also affects the spread of wildfires. Winds can disperse seeds from various plants, enabling the survival and dispersal of those plant species, as well as flying insect populations. When combined with cold temperatures, wind has a negative impact on livestock. Wind affects animals' food stores, as well as their hunting and defensive strategies.

Wind is caused by differences in the atmospheric pressure. When a difference in atmospheric pressure exists, air moves from the higher to the lower pressure area, resulting in winds of various speeds. On a rotating planet, air will also be deflected by the Corioliseffect, except exactly on the equator. Globally, the two major driving factors of large-scale wind patterns (the atmospheric circulation) are the differential heating between the equator and the poles (difference in absorption of solar energy leading to buoyancy forces) and the rotation of the planet. Outside the tropics and aloft from frictional effects of the surface, the large-scale winds tend to approach geostrophic balance. Near the Earth's surface, friction causes the wind to be slower than it would be otherwise. Surface friction also causes winds to blow more inward into low-pressure areas.

Power of the Wind:

Wind energy is the kinetic energy of the air in motion. The kinetic energy of a packet of air of mass m with velocity v is given by $\frac{1}{2}mv^2$. To find the mass of the packet passing through an area A perpendicular its velocity (which could be the rotor area of a turbine), we multiply its volume after time t has passed with the air density ρ, which gives us $m = Avt\rho$. So, we find that the total wind energy is:

$$E = \frac{1}{2}\rho A v^3 t$$

Differentiating with respect to time to find the rate of increase of energy, we find that the total wind power is:

$$P = dE/dt = \frac{1}{2}\rho A v^3$$

Wind power is thus proportional to the third power of the wind velocity.

Wind energy conversion system (WECS):

A wind energy conversion system (WECS), or wind energy harvester is a machine that, powered by the energy of the wind, generates mechanical energy that can be used to directly power machinery (mill, pump, ...) or to power an electrical generator for making electricity. The term can thus refer to windmills, windpumps as well as wind turbines.

The conversion of the energy of the wind into more useful forms can be done using a rotor fitted with blades or sails. Note that a suitable location needs to be chosen for the WECS, preferably an open area. Also, some general locations lend themselves far better than others for WECS

A windmill is a mill powered by the wind. It allows reducing a solid or coarse substance into pulp or minute grains by crushing, grinding, or pressing.

A windpump is a type of windmill used for pumping water from a well or draining land.

The most modern generations of windmills are more properly called wind turbines, or wind generators, and are primarily used to generate electricity and electrical energy. Modern windmills are designed to convert the energy of the wind into electricity. The largest wind turbines can generate up to 6MW of power.

With increasing environmental concern, and approaching limits to fossil fuel consumption, wind power has regained interest as a renewable energy source. It is increasingly becoming more useful and sufficient in providing energy for many areas of the world, especially in temperate climates.

Wind Turbine systems have a competitively high Energy Return on Investment (EROI) estimated to be around 36.5:1. (National Renewable Energy Laboratory)

To generate enough power for a family, the tower and the blades need to be sufficiently large.

WECS Technology

A WECS is a structure that transforms the kinetic energy of the incoming air stream into electrical energy.

The basic device in the wind energy conversion system is the wind turbine which transfers the kinetic energy into a mechanical energy. The wind turbine is connected to the electrical generator through a coupling device gear train. The output of the generator is given to the electrical grid by employing a proper controller to avoid the disturbances and to protect the system or network. Figure 1shows the overall block diagram of the wind energy conversion system (WECS). Here, Vω represents wind speed, Pω, Pm and Perepresent wind power, mechanical power and electrical power respectively.

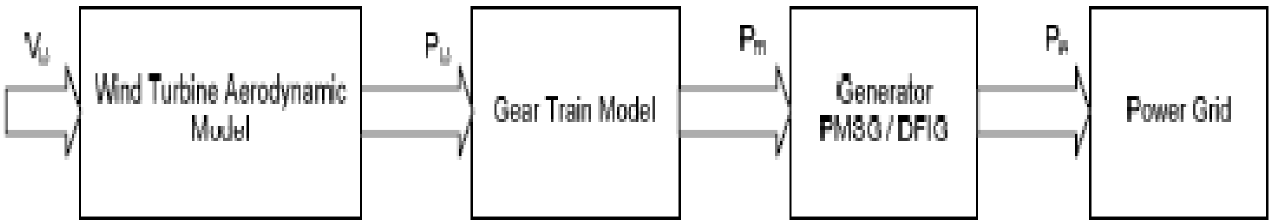


Fig. 1.WECS Block Diagram.

This conversion takes place in two steps, as follows.

The extraction device, named wind turbine rotor turns under the wind stream action, thus harvesting a mechanical power. The rotor drives a rotating electrical machine, the generator, which outputs electrical power. Several wind turbine concepts have been proposed over the years. A historical survey of wind turbine technology is beyond the scope here, but someone interested can find that in Ackermann (2005).

There are two basic configurations, namely vertical axis wind turbines (VAWT) and, horizontal axis wind turbines (HAWT). Today, the vast majority of manufactured wind turbines are horizontal axis, with either two or three blades. HAWT is comprised of the tower and the nacelle, mounted on the top of the tower (Figure2). Except for the energy conversion chain elements, the nacelle contains some control subsystems and some auxiliary elements (e.g., cooling and braking systems, etc.).

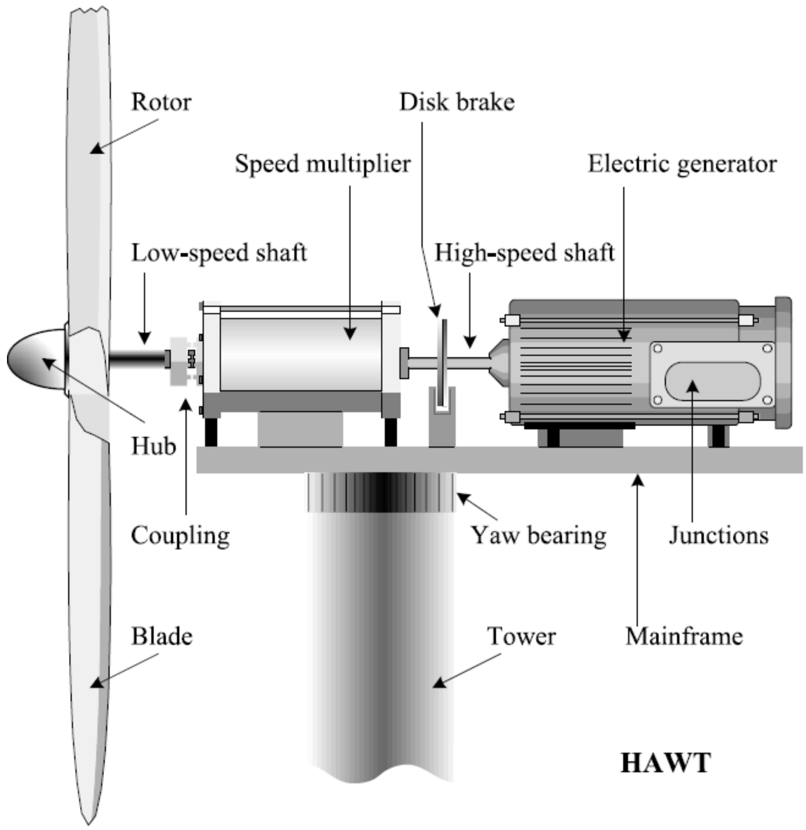


Figure 2

The energy conversion chain is organised into four subsystems:

- Aerodynamic subsystem, consisting mainly of the turbine rotor, which is composed of blades, and turbine hub, which is the support for blades;
- Drive train, generally composed of: low-speed shaft – coupled with the turbine hub, speed multiplier and high-speed shaft – driving the electrical generator;
- Electromagnetic subsystem, consisting mainly of the electric generator;
- Electric subsystem, including the elements for grid connection and local grid.

All wind turbines have a mechanism that moves the nacelle such that the blades are perpendicular to the wind direction. This mechanism could be a tail vane (small wind turbines) or an electric yaw device (medium and large wind turbines). Concerning the power conversion chain, it involves naturally some loss of power. Because of the nonzero wind velocity behind the wind turbine rotor one caneasily understand that its efficiency is less than unity. Also, depending on theoperating regime, both the motion transmission and the electrical power generation involve losses by friction and by Joule effect respectively. Being directly coupled one with the other, the energy conversion chain elements dynamically interact, mutually influencing their operation.

ADVANTAGES OF WIND POWER:

1. The wind is free and with modern technology it can be captured efficiently.

2. Once the wind turbine is built the energy it produces does not cause green house gases or other pollutants.

3. Although wind turbines can be very tall each takes up only a small plot of land. This means that the land below can still be used. This is especially the case in agricultural areas as farming can still continue.

4. Many people find wind farms an interesting feature of the landscape.

5. Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.

6. Wind turbines have a role to play in both the developed and third world.

7. Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them. Single households to small towns and villages can make good use of range of wind turbines available today.

Some disadvantages of wind power are:

1. Noise disturbances: Turbines may create noise that can make them unpopular for residential areas.

2. Threat to wildlife: Large-scale construction of wind turbines could be a threat to nearby wildlife.

3. Unpredictability: Wind cannot be predicted so areas that need large amounts of power could be under-served.

4. Regionality: Wind turbines are suited to coastal regions that receive wind throughout the year.

5. Visual impact: Some feel turbines are visually undesirable.

Unit V

Energy From BioMass

Biomass Energy conversion Technologies – Wet Process – Dry Process – Photosynthesis – Biogas Generation – Bio Gas from Plant Wastes – Methods for Maintaining Biogas Production – Fuel Properties of Biogas

Bioenergy consists of solid, liquid, or gaseous fuels. Liquid fuels can be used directly in the existing road, railroad, and aviation transportation network stock, as well as in engine and turbine electrical power generators. Solid and gaseous fuels can be used for the production of electrical power from purpose-designed direct or indirect turbine-equipped power plants. Chemical products can also be obtained from all organic matter produced. Additionally power and chemicals can come from the use of plant-derived industrial, commercial, or urban wastes, or agricultural or forestry residues

Biomass resources include primary, secondary, and tertiary sources of biomass. Primary biomass resources are produced directly by photosynthesis and are taken directly from the land. They include perennial short-rotation woody crops and herbaceous crops, the seeds of oil crops, and residues resulting from the harvesting of agricultural crops and forest trees (e.g., wheat straw, corn stover, and the tops, limbs, and bark from trees). Secondary biomass resources result from the processing of primary biomass resources either physically (e.g., the production of sawdust in mills), chemically (e.g., black liquor from pulping processes), or biologically (e.g., manure production by animals). Tertiary biomass resources are post-consumer residue streams including animal fats and greases, used vegetable oils, packaging wastes, and construction and demolition debris.

There are various conversion technologies that can convert biomass resources into power, heat, and fuels for potential use in various countries. Figure summarizes the various bioenergy conversion processes.

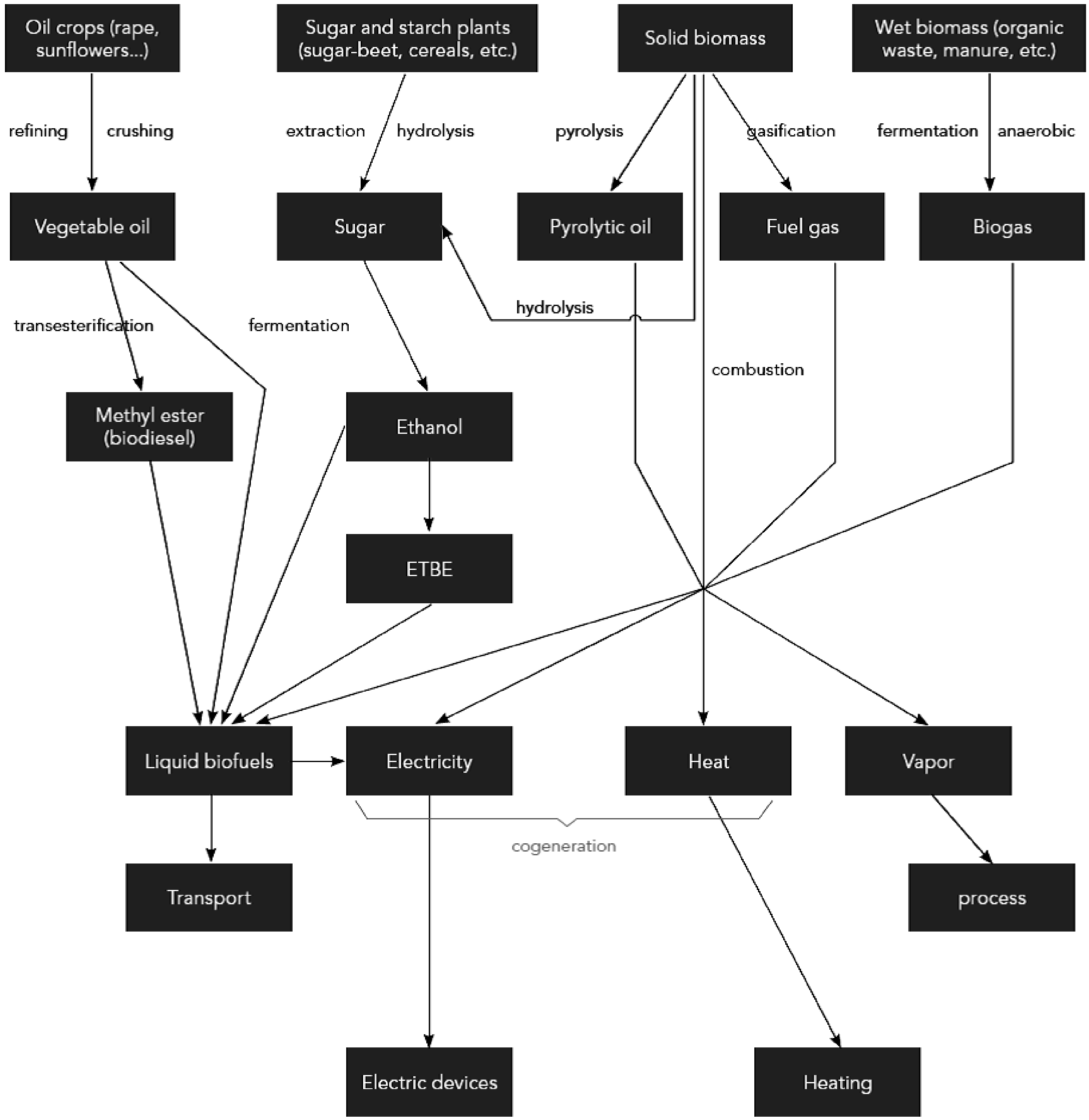


Figure :Bioenergy Conversion Processes

Wet processes:

Anaerobic digestion :Bio gas is produced by the bacterial decomposition of wet sewage sludge, animal dung or green plants in the absence of oxygen. Feed stocks like –wood shavings, straw and refuse may be used, but digestion takes much longer. The natural decay process, anaerobic decomposition can be speeded up by using a thermally insulated, air- tight tank with a stirrer unit and heating system. The gas collects in the digester tank above the slurry and can be piped off continuously. At optimum temperature complete decomposition of animal or human faces takes around 10 days. Gas yields depend critically on the nature of the waste-pig manure. Each kilogram of organic material can be expected to yield 450 – 500 litres of biogas at atmospheric pressure in a modern batch. The residue left after digestion is valuable fertilizer.

Fermentation :As stated , ethanol is produced by the fermentation of sugar solution by natural yeasts. After about 30 hours of fermentation the brew contains 6- 10% alcohol and this can readily be removed by distillation. Suitable feed stocks include crushed sugar cane and beet, fruit etc. Sugar cane also be manufactured from vegetable starches and cellulose, maize, wheat grain, or potatoes. Cellulose materials like wood, paper waste or straw, require harsher pre-treatment with hot acid. One tone of sugar will produce upto 520 litres of alcohol; a tone of grain, 350 litres and a tone of wood, an estimated 260 to 540 litres. After fermentation, the residue from grains and other feed stuffs contains high protein content and is a useful cattle-feed supplement.

The hydrolysis and distillation steps require a high energy input; for woody feedstocks direct combustion or pyrolysis is probably more productive. The energy requirement for distillation is also likely to be cut dramatically. Alcohol can be separated from the beer by many methods which are now under intensive development. These include solvent extraction, reverse osmosis; molecular sieves and use of new desiccants for alcohol drying. It may soon be possible to halve the energy required for alcohol production to produce a greater net energy gain.

Chemical reduction; chemical reduction is the least developed of the wet biomass conversion processes. It involves pressure-cooking animal waste or plant cellulosic slurry with an alkaline catalyst in the presence of carbon monoxide at temperatures between 250^0c and 400^0. Under these conditions the organic material is converted into a mixture of oils with a yield approaching 50%. If the pressure is reduced and the temperature increased, the product is a high calorific value gas.

Dry processes:

Pyrolysis: a wide range of energy –rich fuels can be produced by roasting dry woody matter like straw and wood-chips. The material is fed into a reactor vessel or retort in a pulverized or shredded form and heated in the absence of air. As the temperature rises, the cellulose and lign in break down to simpler substance which are driven off leaving a char residue behind. This process has been used for centuries to produce charcoal.

The end products of the reaction depend critically on the conditions employed; at lower temperatures –m around 500^0C – organic liquid predominate, whilst at temperatures nearer 1000^0C a combustible mixture of gases results.

Liquefaction; liquid yields are maximizes by rapid heating of the feedstock to comparatively low temperatures. The vapoursare condensed from the gas stream and these separate into two-phase liquor; the aqueous phase contains a soup of water-soluble organic materials like acetic acid, acetone and methanol; the non-aqueous phase consists of oils and tars. These crude products can be burnt, bulb it is usually more profitable to up-grade them to premium fuels by conventional refining techniques.

Other pyrolysis products include fuel gas – essentially carbon monoxide and hydrogen and carbon char. The gas is generally burnt to maintain the temperature of the reactor; the char can be manufactured into briquetts for use as solid fuel.

Pyrolysis can be carried out in the presence of small quantities of oxygen, water or hydrogen.

Gasification: pyrolysis of wet biomass produces fuel gas and very little liquid. An alternative technique for maximizing gas yields is to blow small quantities of air or oxygen into the reactor vessel and to increase the temperature to over 1000^0C . This causes Part of the feed to burn. Fuel gas from air blown gasifiers has a low calorific value and may contain upto 40% inert nitrogen gas overall yields of 80 – 85% can be expected. Fuel gas from oxygen– fed systems has a medium calorific value. This gas can either be burnt or converted into substitute natural gas or methanol by standard catalytic processes. Methanol yields of around 50% can be achieved from biomass.

Steam- gasification: methane is produced directly from woody matter by treatment at high temperatures and pressures with hydrogen gas. The hydrogen can be added.

Hydrogenation: under less severe conditions of temperature and pressure carbon monoxide and steam react with cellulose to produce heavy oils which can be separated and refined to premium fuels.

Photosynthesis:

The most important chemical reaction on the earth is the reaction of sunlight and green plants. Radiant energy of sun is absorbed by the green pigment chlorophyll in the plant and is stored within the plant in the form of chemical bond energy. Photosynthesis in the plants is an example of biological conversion of solar energy into sugars and starches which are energy rich compounds. So if plant fast growing trees having high photo-synthesis efficiency we can harvest and burn them to produce steam in a similar manner as in thermal power stations ultimates to produce the electric power. Such an energy plantation would be a renewable resource and an economical means of harnessing solar energy. However, photo-synthesis concepts are less attractive as the average efficiency of solar energy conversion in plants is about 1% and the overall efficiency of the conversion sunlight to electricity would be about be about 0.3% compared to 10% for photo-voltaic cells.

In this reaction, water and Co_2 molecules broken down and a carbohydrate is formed with the release of pure oxygen. The process can be expressed as

$Co_2 + H_2o$ = light + chlorophyll → $(\mathrm{H_2CO})_6\ (sugar) + O_2\ + Chlorophyll$

$$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

The absorbed light is in the ultraviolet and infrared range. Visible light having a wavelength below 700A^0 is absorbed by the green chlorophyll which becomes activated and passes its energy on to the water molecules. A hydrogen atom is then released and reacts with the carbon dioxide molecule, to produce $\mathrm{H_2CO}$ and oxygen. $\mathrm{H_2CO}$is the basic molecule forming carbohydrate, stable at low temperature, it breaks at high temperature, releasing an amount of heat equal to 112,000 cal/mole.

$$\mathrm{H_2CO + O_2} \rightarrow C\mathrm{O_2 + H_2O + 112kcal/mole}$$

The absorbed energy of photons should be atleast equal to this amount. It is possible to produce large amount of carbohydrate by growing algae under optimum conditions in plastic tubes or in ponds. The algae could be converted into electricity by conventional methods.

Thus photo-synthesis consists in building up of simple carbohydrates such as sugar etc. in the green leaf in presence of sunlight. The oxygen liberated is from $\mathrm{H_2O}$ molecule and not from $\mathrm{O_2}$. This process is called as carbon fixation or carbon assimilation. Photo- synthesis is essentially a reduction and oxidation process.

The process of photo-synthesis has two main steps:

1. Splitting of $\mathrm{H_2O}$ molecule in to $\mathrm{H_2}$ and $\mathrm{O_2}$ under the influence of chlorophyll and sunlight. This phase of reaction is called the light-reaction. In this phase of reaction, light absorbed by chlorophyll causes photolysis of water. $\mathrm{O_2}$escapes and $\mathrm{H_2}$ is transformed into some unknown compounds. Thus solar energy is converted into potential chemical energy.
2. In the second phase, hydrogen is transferred from this unknown compound to $\mathrm{CO_2}$ to form starch or sugar. Formation of starch and sugar are dark reaction not requiring sunlight.

The conditions necessary for photo-synthesis are:

1. Light: one of the important inputs for biomass production is the intensity of solar radiation only a part of this energy of wavelength (400-700A^0) to produce photo-synthesis. This range of light is called photo-synthetically active radiation. The upper limit of the photo-synthesis efficiency is about 5%.
2. CO_2Concentration: carbon dioxide is the primary raw material for photo-synthesis. CO_2 Constitutes about 0.03% of the atmosphere. However, if CO_2 availabilty is increased artificially, linear increase in the yield of several crops,upto a limit, have been observed. Hence one of the methods of increasing biomass is by supplying additional CO_2 to the plants.

   $The\ main\ sources\ of\ CO_2\ are:$

   I. Animal respiration,
   II. Combustion of fuel
   III. The major source is the decay of organic matter by bacteria
   IV. Ocean also is an important store of CO_2, much of which comes from which can be tolerated by proteins, ie.,0^0 C to 60^0C. Although photo chemical part is not affected by temperature, but biochemical part, controlled by enzymes, is highly sensitive to temperature.

3. Temperature. Photosynthesis is restricted to the temperature range which can be tolerated by proteins, ie., 0^oC to 60^oC. Although photo chemical part is not affected by temperature, but biochemical part, controlled by enzymes, is highly sensitive to temperature.

Biogas Generation:

Biogas, a mixture containing 55-65% methane, 30-40% CO_2 and the impurities H_2, H_2S and N_2, can be produced from the decomposition of animal, plant and human waste. It can be used directly in cooking. It is named as Gobar gas because cow dung has been the material for its production. Not only are the excreta of the cattle, but also the piggery waste as well as poultry droppings used for biogas generation. Apart from animal waste some other materials like algae, crop residues, garbage kitchen wastes, paper wastes, sea wood, human waste, waste from sugarcane refinery, water hyacinth etc are used for biogas generation.

Biogas is produced by digestion, pyrolysis, or hydrogasification. The container in which this digestion takes place is known as the digester. The calorific value between 5000 to 5500 kcal/kg or 38131 kJ/m^3.

Biogas from Plant wastes

Biogas production from fresh-plant wastes is not new.It was a common feature even 40 years ago on many European farms.The biogas was used in kitchen oven,chickenhatching,washingmachine,automobiles,roomheaters,refrigeratorsetc.,Thesse plants were essentially batch fermentation plants which had heating systems.The process of biodigestion is carried out genearallly in following two recognized systems:

1.Batch fermentation and

2.Continous fermentation.

In Batch fermentation,the feeding is between intervals.The plant is emptied once the process of digestion is complete.

In continuous fermentation,the feeding is done every day and digested slurry equivalent to the amount of feed overflows from the plant.

The continuous process may be completed in a single stage or separated into two stages.

a) Single stage process:The entire process of conversion of organic substances into biogas is completed in a single chamber.This chamber is regularly fed with the raw materials while the spent residue keeps moving out.

b) Double stage process:The acidogenic stage and methanogenic stage are physically separated into two chambers.The acid production is carried out in a sepatate chamber as the first stage.Only the diluted acids are fed into the second chamber where bio-methanationtakes place and biogas is collected from the second chamber.Fermenting fibrous plant waste materials is suitable in two stage process.

Wet and Dry Fermenation

1.Wet Fermentation.

The digester is largely filled with water so that dry matter remains less than 10%.Cow dung like material ferment very well in this process.Light fresh plant materials float on the water forming scum.The scum must be broken and submerged every few hours to maintain continuity of the process.This is the major problem for fermenting agricultural waste by this process.

2.Dry fermentation

The amount of water is kept minimum so that it is enough to keep the raw materials wet for its active fermentation.The total solids may be 25-30% with no free water.The scum will not form but acid accumulation and gas entrapment may occur.The movement of the plant material in the digester may not take place.

Thus the problems of pH regulation,proper uniform culture,and development of movement of materials pose serious problems in this process.These problems are less severe when dry fermentation is carried out in the batch fermentation process.

Problems in Straw fermentation

1 Scum formation

When cow dung is mixed with equal amount of water, it ferments well in any simple digester.The straw material floats on water. Water is essential for fermentation. It also helps scum formation.Straw material submerges after a while but gas bubble formation increases the buoyancy of the straw materials thereby it helps in floatation.This scum may be more compacted as time goes on and becomes sufficiently strong.When a family size plant is fully loaded with straw material,freshly submerged scum may reappear within a few hours during summer months.This phenomenon poses the greatest problem in successful straw fermentation in continuous fermentation system. Thus suitable manual stirring device which one man can operate is needed to be developed.

2. Movement in Digester

Automatic movement of the charged material inside the digester from its inlet to outlet due to the density gradient is essential. While cow dung slurry moves smoothly allowing the gas bubbles to escape, the straw materials remains floating and may trap the gas. It moves away from the feeding point as the slurry fed is daily pushed in. Stirring is essential.

Pilot Plants using Plant Wastes:

A domestic biogas plant of 0.4m3 capacity was developer and fabricated at Jyoti Solar Energy Institute VallabhaVidyanagar, which could be placed inside the kitchen and save 50% LPG requirements. This is fast growing aquatic weed. This waste can be fed into the biogas generator to generate biogas. This plant produces 53.5 liters of biogas with 78% of methane content.

Methods for Maintaining Biogas Production :

The following are the techniques of the biogas production:

1 Insulating the gas Plant:

To reduce the heat loss the external digester is insulated using materials like mineral wool, aluminum cladding, fiber glass, straw etc. So the Janta types of plants are constructed below the ground level. In the floating dome design, the insulation by readily available dry agriculture on the top of the glass holder reduces the heat loss from the top.

2 Composting:

The heat released in aerobic composting of agriculture residues around the annular ring in the upper part of the digester could be utilized to raise the digester operating temperatures. It is reported that a temperature rise of 8 -100C above ambient temperature even during the coldest season. Under optimum conditions of moisture, composting is complete in 3- 4 weeks and the released heat varies with remarkable time. Small quantity of water in the straw around the digester is added later when the drop in temperature occurs and therefore the temperature of the composting material and digester contents can be kept relatively at constant temperature.

In the plant as shown in fig. a composed pit 1 m×1 m all-round the digester is excavated. It is lined with 13 cm thick wall. Then it is filled with alternate layers of paddy straw and dung. The thickness of each layer is about 15 cm and 5 cm respectively. Each layer must be thoroughly moisturised by sprinkling water. The decomposition of the organic matter and paddy straw will start within 2- 3 days and sufficient heat would be produced which will raise the temperature of the digested slurry.

Hot water circulation;This system is efficient for maintain temperatures of the fermented slurry at the desired level.

Use of chemicals:

Chemicals such as urea and urine have been suggested to increase the digester temperature. Addition of urine of animals was observed to enhance the gas production.

Solar energy systems:

The solar heat to the biogas digester could be provided in two distinct ways 1) the active 2) the passive means. The active systems involve heating of the digester feed or direct of the digester contents. In the first method, the incoming feed is preheated using solar energy during the day and is fed to the digester when it attains the desired temperature. The production rate is increased by 10- 11 % in this method. In another method, the hot water from the solar pond is circulated through the coils in the digester by a biogas powered pump.

The passive method involves the construction of a “green house” around the digester to capture the radiant heat energy. A passive green house built over an under ground digester raised the temperature by 10 0 C .

In another method, a solar canopy is used to enhance the biogas production for the low temperature in winter, polythene or plastic sheet is used for canopy. Because of snow and low temperature, this method is not effective at higher hills. The way to effectively insulate the biogas plant in the hilly areas to enhance the biogas production is to construct a house or cattle shed on the biogas plant.

Fuel Properties of Bio-gas:

Biogas generated by anaerobic fermentation of organic wastes, essentially contains Methane and carbon dioxide in large proportion and has traces of other gases. The important properties are as follows:

Composition	% volume
Methane	50-60
Carbon dioxide	30-45
Hydrogen	5-10
Nitrogen	0.5-0.7
Hydrogen Sulphide and Oxygen	Traces

Calorific value

60% Methane :	22.350 to 24.22 MJ/m^3
Without CO_2:	33.525 to 35.390 MJ/m^3
Octane rating without CO_2:	130
Octane rating with CO_2:	110
Ignition Temperature	650^oC
Air to methane ratio for complete combustion(by volume)	10 to 1
Explosion limits to air(by volume)	5 to 15