MCN201 SUSTAINABLE ENGINEERING

MODULE 4

"Resources and its utilisation: Basic concepts of Conventional and non-conventional energy, General idea about solar energy, Fuel cells, Wind energy, Small hydro plants, bio-fuels, Energy derived from oceans and Geothermal energy."

4.1 SUN AS A PRIMARY SOURCE OF ENERGY

Sun is the primary source of Energy. The ultimate source of almost all forms of energy that we use today is the energy that comes from the Sun. The Sun, is about 93 million miles away from the Earth. The sun provides us enormous amounts of energy in the form of sola rradiation reaching the surface of the earth from a distance of 93 million miles in only **8 minutes.**

The interior of the sun is supposed to be a temperature of 45 million degrees Fahrenheit and is in a gaseous state. At such a high temperature, **hydrogen atoms fuse with helium to produce the energy** that powers the planet earth.

The energy is electromagnetic in nature. Green plants use this solar energy to produce food. These plants are in turn, consumed by animals to get energy. The fossil fuels we use today are a form of solar energy stored millions of years ago in plant and other living things.

The scientific definition of energy is that **"Energy is an indirectly observed physical quantity which is the ability of body or a system to do work."** On a logical point of view, we can understand energy as something which enables us to do work. Law of conservation of energy states that "**Energy can neither be created nor be destroyed but it can transform from one form to other"**.

Some of the many forms of energy are:

1. Kinetic energy.
2. Potential energy.
3. Gravitational energy.
4. Nuclear energy.
5. Chemical energy.
6. Heat energy.
7. Electrical energy.

8. Electromagnetic energy.

9. Sound energy.

10. Solar energy.

In nature, all biological systems harvest their energy from the sun, directly or indirectly. Plants utilize the solar energy from the sun and produce carbohydrates through the process of photosynthesis. Herbivorous animals get their energy by eating these plants and carnivorous animals get their energy by eating these animals and the food chain continues.

4.2 TYPES OF ENERGY SOURCES

There are two ***types of energy sources***, Renewable and Non-Renewable sources. Renewable *energy sources* are sources that can be replenished or which are available naturally in excess. Non-Renewable energy sources are limited in their availability.

4.2.1 RENEWABLE ENERGY SOURCES:

sources are more **'Environment-Friendly'** as they do not cause any natural imbalances. When the energy source used is freely regenerated in a short period and there are practically limitless reserves; An example is the **solar energy** that is the source of energy from the sun, or the wind energy.

4.2.2 NON-RENEWABLE ENERGY SOURCES:

They are coming from energy limited sources on Earth in quantity and, therefore, are exhaustible. Acquisition and usage of Non-Renewable energy sources causes disruption and disturbs the balance of environment

NON-RENEWABLE ENERGY SOURCES ARE:

- Coal
- Nuclear Energy
- Oil
- Natural Gas

RENEWABLE ENERGY SOURCES ARE:

- Air (Wind Energy)
- Water (Hydro-Electric Energy)
- Sun (Solar Energy)

- Biomass (Alternative fuels)
- Hydrogen
- Inner Earth Layers (Geothermal Energy

4.3 CONVENTIONAL AND NON-CONVENTIONAL SOURCES OF ENERGY

- The conventional sources of Energy include:

- Coal, petroleum, natural gas is the conventional sources for Thermal power in India.
- Water is the conventional source for Tidal Power, etc.

- The Non-conventional sources of energy include:

- Solar Energy, tidal energy, geo-thermal energy, wind energy, etc.

4.3.1The comparison between the Conventional and Non-conventional sources of Energy is mentioned below :

1. **Conventional energy**, such as thermal powers (from coal, petroleum, and natural gas), hydel power (from high velocity of running water) are tapped and used abundantly at present. Their uses are practiced for a long time. *But*, in contrast to conventional sources of energy, **non-conventional sources of energy** (solar energy, tidal energy, geo-thermal energy, wind energy, etc.) are not used frequently and in large scale (commercially). Their uses are comparatively more recent.

2. Except hydel power, the sources of thermal power i.e. other **conventional energies** are non-renewable in nature. The enormous reserve of fossil fuels (coal, crude-oil, natural gas, etc.) is fast depleting. But the sources of **non-conventional energy** are flow-resources. There is no anxiety for their exhaustion.

3. Except hydel power, the generation of other **conventional energy** produces air pollution and causes environmental threats. But the generation of **non-conventional energy** does not produce air pollution.

4. Except hydel power, the other **conventional energy** is costly. But comparatively, the **non-conventional energy** is much cheaper.

4.3.2 Advantages of Non-Conventional Sources of Energy

The non-conventional sources of energy have many advantages. They are discussed below:

1. Cheaper and Renewable: Most of the Non-conventional Power resources are cheaper and renewable as compared to the conventional sources.
2. Scarcity of Fossil Fuels: The overall limitation and scarcity of fossil fuels has given rise to the urgent need for exploiting alternative energy sources.
3. Rural Energy Needs: Locally available non-conventional and renewable power resources can meet localized rural energy needs with minimum transportional cost.
4. Inexhaustible and Environment friendly: Power from Non-conventional and Renewable is a must in order to reduce carbon dioxide (CO_2) emissions of the coal-based power plants. It is inexhaustible in nature and environment friendly.

4.3.3 NON-CONVENTIONAL SOURCES OF ENERGY IN INDIA

There are four major areas of renewableenergybeing tapped for power generation. These are solar energy, wind energy, small hydro and Biomass.

1. **Solar Energy:** Solar energy in India is utilized thorough Photo-voltaic route and Thermal route. Solar Photo-voltaic (SPV) technology enables the conversion of solar radiation into electricity without involving any moving part like turbine, etc. *A BHEL made SPV battery charging system was successfully used in the Indian Antarctic stations at DakshinGangotri and Maitri. The Biswanath Rail station in the Bangalore Chennai section is being served by solar energy based electricity.*
2. **Biomass:** Power generating systems based on biomass combustion as well as biomass gasification were launched in different centers in India.
3. **Wind Energy:** Wind Energy is being used for power generationby using roating blades coupled with generators. *A wind generator has been installed to operate a lighthouse at Kanai Creek, Gujarat. The electric generator which gives a power output of 300 watts has been installed on an eighteen meter high tower. Wind farms of a total capacity of 7-5 mw were installed in the coastal areas of Gujarat, Maharashtra, Tamil Nadu and Orissa. At Lamba in Gujarat a wind farm of 10 mw capacity, the largest in Asia has been commissioned. Kappata hills in Karnataka are the windiest site in India. Wind velocity here is between 28 km and 30 km per hour. The site is ideal for wind farms.*
4. **Geothermal Energy:** Geothermal Energy occurs in the form of hot springs. *Parbati valley in Himachal Pradesh and Puga valley in Jammu and Kashmir are the two prospective geothermal energies potential. A cold storage plant based on geothermal energy at Manikaran, Kullu district, Himachal Pradesh is functioning.*
5. **Energy from Urban and Industrial Waste:***Energy from Urban waste plant under construction at Timarpur in Delhi will generate 3,745 mw of power from 300 tons per day of municipal solid waste. The project for generation of 6 mw power from bagasse at a co-operative sugar mill Tamil Nadu has been undertaken.*

4.4 SOLAR ENERGY:

- Solar water heater
- Solar space heating of buildings
- Solar air conditioning
- Solar refrigeration
- Solar drying
- Solar cooking
- Solar electricity – thermal
- Solar green houses
- Solar furnaces
- Solar desalination
- Salt production
- Solar electricity – photovoltaic

Q. What is Solar Energy?

Solar energy Originates with the thermonuclear fusion reactions occurring in the sun.

The Earth receives **174,000 terawatts** (TW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle.

The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C.

By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as

-geography,

-time variation,

-cloud cover, and

Geography affects solar energy potential because areas that are closer to the equator have a greater amount of solar radiation. However, the use of solar panels that can follow the position of the sun can significantly increase the solar energy potential in areas that are farther from the equator.

Time variation affects the potential of solar energy because during the nighttime there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day.

Cloud cover can affect the potential of solar panels because clouds block incoming light from the sun and reduce the light available for solar cells.

Land availability has a large effect on the available solar energy because solar panels can only be set up on land that is unowned and suitable for solar panels. Roofs have been found to be a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way.

4.5 SOLAR THERMAL SYSTEM

A system that converts sunlight (solar energy) into heat is known as solar thermal system. Some examples of solar thermal systems are:

-Solar collector,

-Solar dish,

-Solar furnace - a concave mirror that concentrates the rays of the sun; can produce high temperatures

Solar thermal energy (STE) is a form of energy and a technology for harnessing solar energy to generate thermal energy or electrical energy for use in industry, and in the residential and commercial sectors. **The first installation of solar thermal energy equipment occurred in the Sahara Desert approximately in 1910 when a steam engine was run on steam produced by sunlight**. Because liquid fuel engines were developed and found more convenient, the Sahara project was abandoned, only to be revisited several decades later.

4.5.1 SOLAR COLLECTORS

Solar thermal collectors are classified as

-Low-temperature collectors

-Medium- temperature collectors and

-High-temperature collectors.

Low-temperature collectors are flat plates generally used to heat swimming pools.

Medium-temperature collectors are also usually flat plates but are used for heating water or air for residential and commercial use.

High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for fulfilling heat requirements up to 300^0C/20 bar pressure in industries, and for electric power production.

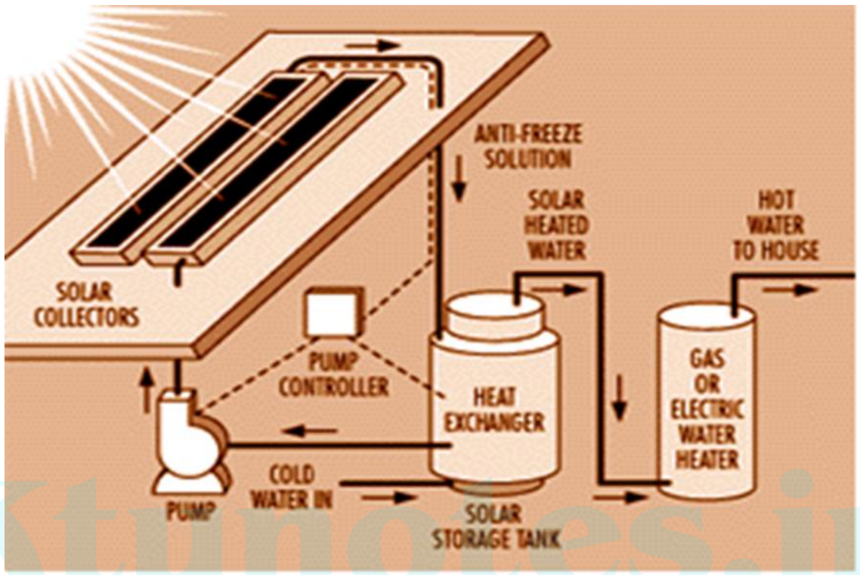


Fig: Solar Thermal System

There are two types of solar thermal systems: **passive** and **active**. A passive system requires no equipment, like when heat builds up inside your car when it's left parked in the sun. An active system requires some way to absorb and collect solar radiation and then store it.Solar thermal power plants are active systems.

WORKING: Mirrors reflect and concentrate sunlight, and receivers collect that solar energy and convert it into heat energy. A generator can then be used to produce electricity from this heat energy.

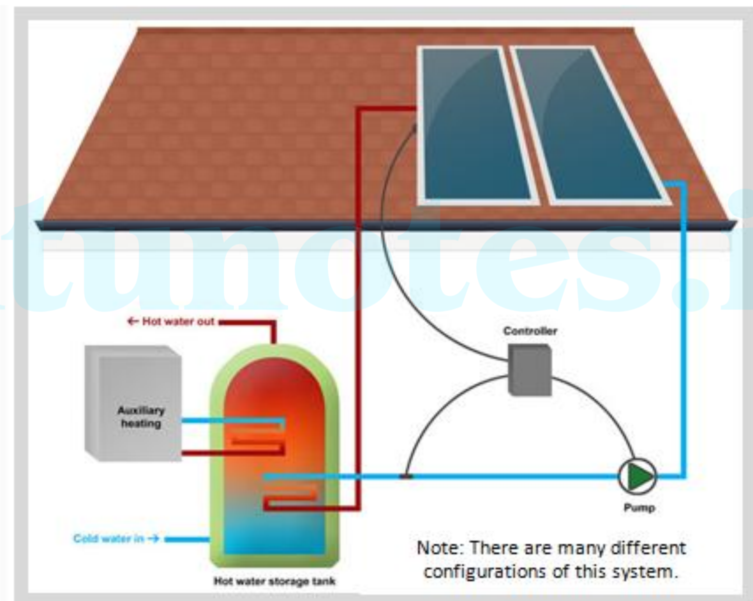
4.5.2SOLAR POWER TOWER SYSTEMS are another type of solar thermal system. Power towers rely on thousands of heliostats, which are large, flat sun-tracking mirrors, to focus and concentrate the sun's radiation onto a single tower-mounted receiver. Like parabolic troughs, heat-transfer fluid or water/steam is heated in the receiver (power towers, though, are able to concentrate the sun's energy as much as 1,500 times), eventually converted to steam and used to produce electricity with a turbine and generator.

4.5.3 SOLAR WATER HEATING

- The Sun rays fall on the Solar Collector. A black absorbing surface (absorber) inside the collector, which absorbs solar radiation and transfers the heat energy to water flowing through it. Heated water is collected in a tank which is insulated to prevent heat loss. Then Circulation of water from the tank through the collector and back to the tank continues automatically. A Solar Water Heater consists of a Collector panel to collect solar energy and an Insulated Storage Tank to store hot water.

Major Components:

- Solar Collector, Its purpose is to collect solar energy
- Insulated Tank, Its purpose is to store hot water
- Supporting Stand
- Connecting Pipes and Instrumentation, etc.



4.5.4 SOLAR SPACE HEATING OF BUILDINGS

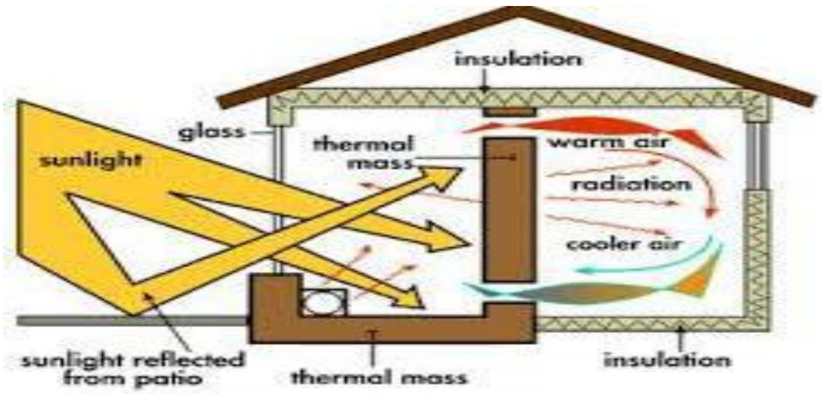
Solar space heating uses solar thermal energy to heat the space inside a building. Heating with solar energy can help you lower your home's heating bills and reduce your dependence on fossil fuels such as oil, propane, and natural gas.

Passive Space Heating

Passive solar space heating involves the design of buildings to absorb, store, and redistribute thermal energy without the use of mechanical equipment. This effect can be achieved through the use of specific materials, architectural features, and an understanding of thermal fluids.

Active Space Heating

Collectors are required in active heating to absorb the thermal energy and redistribute the heated fluid. These collectors differ from passive systems in their ability to include energy storage and their more standardized design. Placing large flat-plate or evacuated tube collectors on a roof is functionally similar to implementing photovoltaic electricity cells.



4.5.4 SOLAR DISH

A third system is the solar dish/engine. Compared to the parabolic trough and power towers, dish systems are small producers (about 3 to 25 kilowatts). There are two main components: the solar concentrator (the dish) and the power conversion unit (the engine/generator). The dish is pointed at and tracks the sun and collects solar energy; it's able to concentrate that energy by about 2,000 times. A thermal receiver, a series of tubes filled with a cooling fluid (such as hydrogen or helium), sits between the dish and the engine. It absorbs the concentrated solar energy from the dish, converts it to heat and sends that heat to the engine where it becomes electricity.

4.6 SOLAR PHOTOVOLTAIC SYSTEM,

It is also known as solar PV power system, or PV system. It consists of an arrangement of several components, including

-Solar panels to absorb and convert sunlight into electricity,

-A solar inverter to change the electric current from DC to AC, as well as mounting,

-Cabling and other electrical accessories to set up a working system.

It may also use a solar tracking system to improve the system's overall performance.

PV systems operating silently and without any moving parts or environmental emissions, for mainstream electricity generation. A roof-top system recoups the invested energy for its manufacturing and installation within 0.7 to 2 years and produces about 95 percent of net clean renewable energy over a 30-year service lifetime.

4.6.1 HOW A PV SYSTEM WORKS.

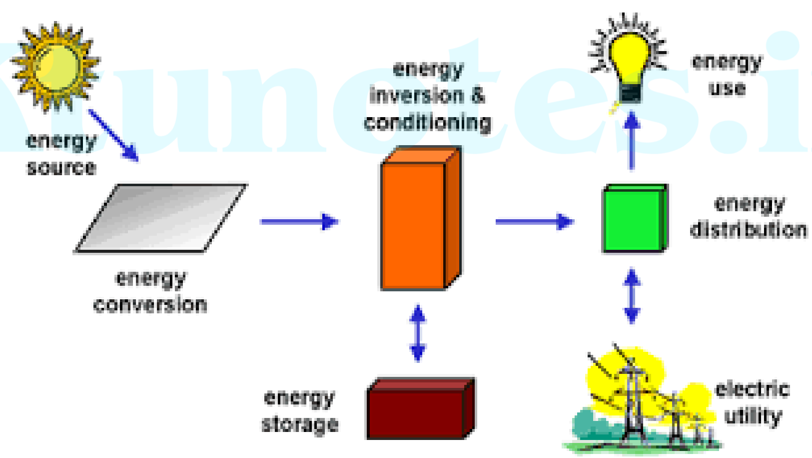
Working of PV systems is different from conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same. Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute, and store the energy produced by the array.

Depending on the functional and operational requirements of the system, the specific components required may include major components such as

-A DC-AC power inverter,

-Battery bank, system and battery controller,

-Auxiliary energy sources and sometimes the specified electrical load (appliances).



4.6.2 WHY BATTERIES ARE USED IN SOME PV SYSTEMS?

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons batteries are used in PV systems are to operate the PV array near its maximum power point, to power electrical loads at stable voltages, and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge.

4.7 FUEL CELL

Q .What is a fuel cell?

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution–much of the hydrogen and oxygen used in generating electricity ultimately combines to form a harmless byproduct, namely water. The output of the fuel cell will be direct current (DC Current)

4.7.1 HOW DO FUEL CELLS WORK?

The purpose of a fuel cell is to produce an electrical current that can be directed outside the cell to do work, such as powering an electric motor or illuminating a light bulb or a city. Because of the way electricity behaves, this current returns to the fuel cell, completing an electrical circuit.

There are several kinds of fuel cells. But in general terms, hydrogen atoms enter a fuel cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. If alternating current (AC) is needed, the DC output of the fuel cell must be routed through a conversion device called an inverter.

Oxygen enters the fuel cell at the cathode and, it there combines with electrons returning from the electrical circuit and hydrogen ions that have traveled through the electrolyte from the anode. In other cell types the oxygen picks up electrons and then travels through the electrolyte to the anode, where it combines with hydrogen ions and produce water.

The electrolyte plays a key role. It must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction.

Even better, since fuel cells create electricity chemically, rather than by combustion, they are not subject to the thermodynamic laws that limit a conventional power plant (see "Carnot Limit" in the glossary). Therefore, fuel cells are more efficient in extracting energy from a fuel. Waste heat from some cells can also be harnessed, boosting system efficiency still further.

4.7.2TYPES OF FUEL CELLS; DESIGN

Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is created, which can be used to power electrical devices, normally referred to as the load.

At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.

The most important design features in a fuel cell are:

- <u>The electrolyte substance.</u> The electrolyte substance usually defines the type of fuel cell.
- <u>The fuel that is used.</u> The most common fuel is **hydrogen.**
- <u>The anode catalyst</u> breaks down the fuel into electrons and ions. The anode catalyst is usually made up of very **fine platinum powder.**
- <u>The cathode catalyst</u> turns the ions into the waste chemicals like water or carbon dioxide. The cathode catalyst is often made up of **nickel** but it can also be a nano material-based catalyst.

"A typical fuel cell produces a voltage from 0.6 V to 0.7 V at full rated load. Voltage decreases as current increases, due to several factors"

To deliver the desired amount of energy, the fuel cells can be combined in series to yield higher voltage, and in parallel to allow a higher current to be supplied. Such a design is called a **fuel cell stack.** The cell surface area can also be increased, to allow higher current from each cell. Within the stack, reactant gases must be distributed uniformly over each of the cells to maximize the power output.

<u>i) PROTON EXCHANGE MEMBRANE FUEL CELLS (PEMFCS)</u>

In this type of fuel cell, a proton-conducting polymer membrane (the electrolyte) separates the anode and cathode sides.

On the anode side, hydrogen diffuses to the anode catalyst where it later dissociates into protons and electrons.. The protons are conducted through the membrane to the cathode, but the electrons are forced to travel in an external circuit (supplying power) because the membrane is electrically insulating. On the cathode catalyst, oxygen molecules react with the electrons (which have traveled through the external circuit) and protons to form water.

In addition to this pure hydrogen type, there are hydrocarbon fuels for fuel cells, including diesel, methanol (see: direct-methanol fuel cells and indirect methanol fuel cells) and chemical hydrides. The waste products with these types of fuel are carbon dioxide and water. When hydrogen is used, the CO2 is released when methane from natural gas is combined with steam, in a process called steam methane reforming, to produce the hydrogen. This can take place in a different location to the fuel cell, potentially allowing the hydrogen fuel cell to be used indoors—for example, in forklifts.

The different components of a PEMFC are;

- bipolar plates,(metal, coated metal, graphite, flexible graphite, C–C composite, carbon–polymer composites)
- electrodes,
- catalyst,(Platinum and/or similar type of noble metals)
- membrane, (proton exchange membrane sandwiched between two catalyst-coated carbon papers) and
- The necessary hardware.

ii)PHOSPHORIC ACID FUEL CELL (PAFC)

In these cells phosphoric acid is used as a non-conductive electrolyte to pass positive hydrogen ions from the anode to the cathode. These cells commonly work in temperatures of 150 to 200 degrees Celsius. This high temperature will cause heat and energy loss if the heat is not removed and used properly. This heat can be used to produce steam for air conditioning systems or any other thermal energy consuming system. Using this heat in cogeneration can enhance the efficiency of phosphoric acid fuel cells from 40–50% to about 80%.Phosphoric acidis a non-conductive liquid acid which forces electrons to travel from anode to cathode through an external electrical circuit. Since the hydrogen ion production rate on the anode is small, platinum is used as catalyst to increase this ionization rate.

A key disadvantage of these cells is the use of an acidic electrolyte. This increases the corrosion or oxidation of components exposed to phosphoric acid.

HIGH-TEMPERATURE FUEL CELL

iii) SOLID OXIDE FUEL CELLS (SOFC)

Solid oxide fuel cells (SOFCs) use a solid material, most commonly a ceramic material called yttria-stabilized zirconia (YSZ), as the electrolyte. Because SOFCs are made entirely of solid materials, they are not limited to the flat plane configuration of other types of fuel cells and are often designed as rolled tubes. They require high operating temperatures (800–1000 °C) and can be run on a variety of fuels including natural gas.

SOFCs are unique since in those, negatively charged oxygen ions travel from the cathode (positive side of the fuel cell) to the anode (negative side of the fuel cell) instead of positively charged hydrogen ions travelling from the anode to the cathode, as is the case in all other types of fuel cells. Oxygen gas is fed through the cathode, where it absorbs electrons to create oxygen ions. The oxygen ions then travel through the electrolyte to react with hydrogen gas at the anode. The reaction at the anode produces electricity and water as by-products. Carbon dioxide may also be a by-product depending on **the fuel, but the carbon emissions from an SOFC system are less than those from a fossil fuel combustion plant.**

The chemical reactions for the SOFC system can be expressed as follows:

Anode Reaction: $2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$

Cathode Reaction: $O_2 + 4e^- \rightarrow 2O^{2-}$

Overall Cell Reaction: $2H_2 + O_2 \rightarrow 2H_2O$

SOFC systems can run on fuels other than pure hydrogen gas. However, since hydrogen is necessary for the reactions listed above, the fuel selected must contain hydrogen atoms. For the fuel cell to operate, the fuel must be converted into pure hydrogen gas. SOFCs are capable of internally reforming light hydrocarbons such as methane (natural gas), propane and butane. These fuel cells are at an early stage of development.

Challenges exist in SOFC systems due to their high operating temperatures. One such challenge is the potential for carbon dust to build up on the anode, which slows down the internal reforming process. Another disadvantage of SOFC systems is slow start-up time, making SOFCs less useful for mobile applications. Despite these disadvantages, a high operating temperature provides an advantage by removing the need for a precious metal catalyst like platinum, thereby reducing cost. Additionally, waste heat from SOFC systems may be captured and reused, increasing the theoretical overall efficiency to as high as 80%–85%.

The high operating temperature is largely due to the physical properties of the YSZ electrolyte. As temperature decreases, so does the ionic conductivity of YSZ. Therefore, to obtain optimum performance of the fuel cell, a high operating temperature is required

iv)HYDROGEN-OXYGEN FUEL CELL (BACON CELL)

The Hydrogen-Oxygen Fuel Cell was designed and first demonstrated publicly by Bacon in the year 1959. It was used as a primary source of electrical energy in the **APOLLO SPACE PROGRAM**.

- The cell consists of two porous carbon electrodes impregnated with a suitable catalyst such as Pt., Ag, CaO, etc.
- The space between the two electrodes is filled with a concentrated solution of KOH or NaOH which serves as an electrolyte.
- $2H_2$ gas and O_2 gas are bubbled into the electrolyte through the porous carbon electrodes.
- Thus the overall reaction involves the combination of hydrogen gas and oxygen gas to form water.
- The cell runs continuously until the reactant's supply is exhausted.

This type of cell operates efficiently in the temperature range 343 K to 413 K and provides a potential of about 0.9 V.

<u>v)MOLTEN CARBONATE FUEL CELL</u> (MCFC)

Molten carbonate fuel cells (MCFCs) require a high operating temperature, 650 °C (1,200 °F), similar to SOFCs. MCFCs use lithium potassium carbonate salt as an electrolyte, and this salt liquefies at high temperatures, allowing for the movement of charge within the cell – in this case, negative carbonate ions.

Like SOFCs, MCFCs are capable of converting fossil fuel to a hydrogen-rich gas in the anode, eliminating the need to produce hydrogen externally. The reforming process creates CO_2 emissions. MCFC-compatible fuels include natural gas, biogas and gas produced from coal. The hydrogen in the gas reacts with carbonate ions from the electrolyte to produce water, carbon dioxide, electrons and small amounts of other chemicals. The electrons travel through an external circuit creating electricity and return to the cathode. There, oxygen from the air and carbon dioxide recycled from the anode react with the electrons to form carbonate ions that replenish the electrolyte, completing the circuit. The chemical reactions for an MCFC system can be expressed as follows:

Anode Reaction: $CO_3^{2-} + H_2 \rightarrow H_2O + CO_2 + 2e^-$

Cathode Reaction: $CO_2 + \frac{1}{2}O_2 + 2e^- \rightarrow CO_3^{2-}$

Overall Cell Reaction: $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

As with SOFCs, MCFC **disadvantages** include

- Slow start-up times
- Short life span.
- Corrosion of the anode and cathode

Because of their high operating temperature, they have slow start up times. This makes MCFC systems not suitable for mobile applications, and this technology will most likely be used for stationary fuel cell purposes. The main challenge of MCFC technology is the cells' short life span. The high-temperature and carbonate electrolyte lead to corrosion of the anode and cathode. These factors accelerate the degradation of MCFC components, decreasing the durability and cell life.

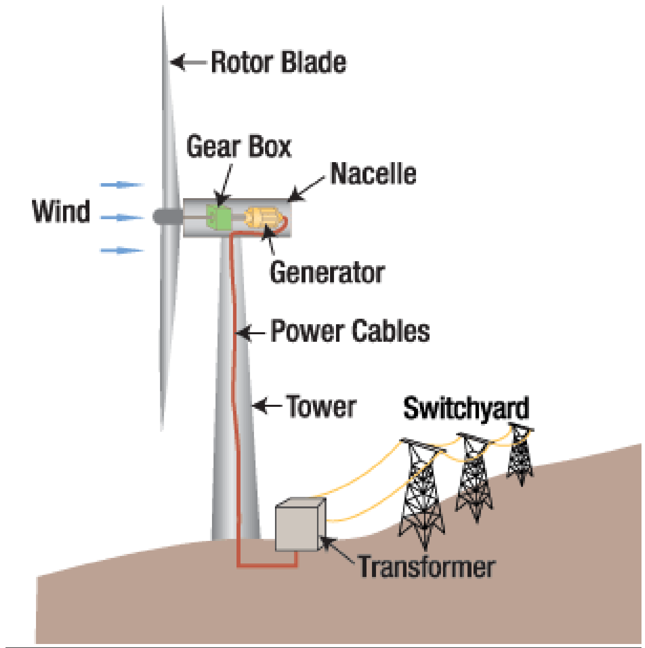
MCFCs hold several **advantages** over other fuel cell technologies, including their resistance to impurities. They are not prone to "carbon coking", which refers to carbon build-up on the anode that result in reduced performance by slowing down the internal fuel reforming process. Therefore, carbon-rich fuels like gases made from coal are compatible with the system. MCFCs also have relatively high efficiencies. They can reach a fuel-to-electricity efficiency of 50%, considerably higher than the 37–42% efficiency of a phosphoric acid fuel cell plant. Efficiencies can be as high as 65% when the fuel cell is paired with a turbine and 85% if heat is captured and used in a Combined Heat and Power (CHP) system.

4.8 WIND ENERGY

Wind power is extracted from air flow using wind turbines or sails to produce mechanical or electrical power. Windmills are used for their mechanical power, wind pumps for water pumping, and sail to propel ships. Wind power as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land.

Wind farms consist of many individual wind turbines which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electricity, competitive with or in many places cheaper than coal, gas or fossil fuel plants. Offshore wind is steadier and stronger than on land, , but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electricity to isolated off-grid locations.

Wind power is very consistent from year to year but has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply.



4.8.1 WIND ENERGY GENERAL PROCESS: HOW IT ACTUALLY WORKS.

The diagram above shows the basic wind turbine which actually moves when the wind flows moving a gear box as well. The generator then converts this mechanical energy into electrical energy and with the help of power cables. The energy is then stored in transformers. Finally, it is transmitted to your homes by a channel of electric lines; stepping-down the voltage at every stage till it reaches your homes.

The wind energy plant should be placed in wide open areas where one can expect maximum wind exposure mostly in meadows and fields near seas. Wind energy plants may also be fixed within the sea maximizing both wind and tidal energy. This produced a considerable amount of energy.

Wind plants that are placed offshore have immense advantages, which are beyond the sea breezes. The seabed is relatively cheaper and since the ocean is not exactly prime real estate, much larger wind farms can be built there without citizens fussing over aesthetics.It also helps bringing the costs down, which is a big positive on a large scale.

ADVANTAGES OF WIND ENERGY

- Wind is a reliable and infinite renewable energy resource
- Wind energy is cost effective, and prices are dropping still
- Wind energy reduces carbon emissions when used instead of fossil fuels
- Few running costs when the turbines are up and running.

- Offshore wind farms can take advantage of offshore wind flow, without affecting the landscape view.

DISADVANTAGES OF WIND ENERGY

- Wind energy can be unpredictable as the amount of electricity generated is dependent on the speed and direction of the wind
- Wind farms can affect the visual appearance of the landscape
- Wind turbines can damage the habitats of birds and marine life.
- Wind farms can be expensive to construct

4.9 SMALL HYDRO PLANTS

Small hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The generating capacity of a small hydro project varies up to 10 megawatts (MW) as the upper limit. Small hydro can be further subdivided into **mini hydro**, usually defined as less than **1,000 kilowatts (kW)**, and **micro hydro** which is less than **100 kW**. Micro hydro is usually the application of hydroelectric power sized for smaller communities, single families or small enterprise.

Small hydro plants may be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Alternatively, small hydro projects may be built in isolated areas that would be uneconomic to serve from a network, or in areas where there is no national electrical distribution network. Since small hydro projects usually have minimal reservoirs and civil construction work, they are seen as having a relatively low environmental impact compared to large hydro. This decreased environmental impact depends strongly on the balance between stream flow and power production. One tool that helps evaluate this issue is the Flow Duration Curve or FDC. The FDC is a Pareto curve of a stream's daily flow rate vs. frequency. Reductions of diversion help the river's ecosystem, but reduce the hydro system's Return on Investment (ROI). The hydro system designer and site developer must strike a balance to maintain both the health of the stream and the economics.

4.9.1 HYDROELECTRIC POWER GENERATION

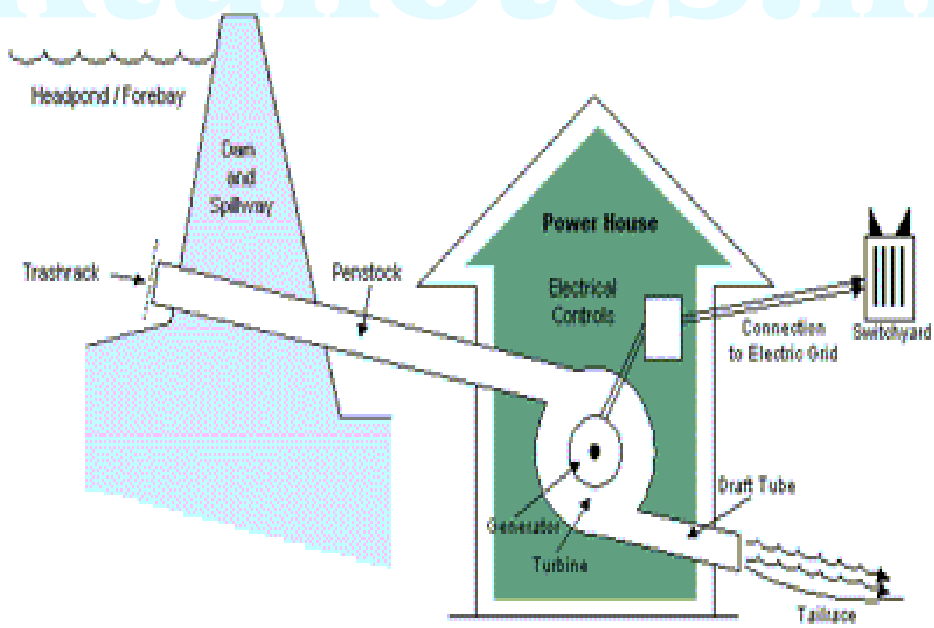
Hydroelectric power is the generation of electric power from the movement of water. A hydroelectric facility requires a dependable flow of water and a reasonable height of fall of water, called the head. In a typical installation, water is fed from a reservoir through a channel or pipe into a turbine. The pressure of the flowing water on the turbine blades causes the shaft to rotate. The rotating shaft is connected to an electrical generator which converts the motion of the shaft into electrical energy.

Small hydro is often developed using existing dams or through development of new dams whose primary purpose is river and lake water-level control, or irrigation. Occasionally old, abandoned hydro sites may be purchased and re-developed, sometimes salvaging substantial parts of the installation such as penstocks and turbines, or sometimes just re-using the water rights associated with an abandoned site. Either of these cost saving advantages can make the ROI for a small hydro site well worth the use of existing site infrastructure & water rights.

Moreover, small hydropower has a huge, as yet untapped potential in most areas of the world and can make a significant contribution to future energy needs. It depends largely on already proven and developed technology, yet there is considerable scope for development and optimization of this technology.

4.9.2 HOW DOES IT WORK?

Hydropower systems use the energy in flowing water to produce electricity or mechanical energy. The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate. When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy. This electrical energy may be used directly, stored in batteries, or inverted to produce utility-quality electricity. A small scale hydroelectric facility requires that a sizable flow of water and a proper height of fall of water, called head, is obtained without building elaborate and expensive facilities. Small hydroelectric plants can be developed at existing dams and have been constructed in connection with river and lake water-level control and irrigation schemes. By using existing structures, only minor new civil engineering works are required, which reduces the cost of this component of a development.



4.9.3 BENEFITS OF SMALL SCALE HYDROPOWER

Hydroelectric systems provide the following general benefits:

- Hydroelectric energy is a continuously renewable electrical energy source.
- Hydroelectric energy is non-polluting - no heat or noxious gases are released.
- Hydroelectric energy has no fuel cost and with low operating and maintenance costs, it is essentially inflation proof.
- Hydroelectric energy technology is a proven technology that offers reliable and flexible operation.
- Hydroelectric stations have a long life and many existing stations have been in operation for more than half a century and are still operating efficiently.
- Hydropower station efficiencies of over 90% are achieved making it the most efficient of energy conversion technologies.
- Hydropower offers a means of responding within seconds to changes in load demand.

4.10 BIOMASS

Biomass is biological material derived from living, or recently living organisms. In the context of biomass as a resource for making energy, it most often refers to plants or plant-based materials which is not used for food or feed, and are specifically called lignocellulose biomass .As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: **thermal, chemical, and biochemical methods**.

There are three sources of biomass in energy product context:

1- **Woody source** of biomass'(Lignocelluloses) such as: Forest residues, Landscaping residues, Energy wood plantations, Residues from food, Industrial wood residue, Waste wood residues
2- 2- **Non Woody** biomass (Oil, sugar, starch) such as: Energy plants from agriculture, Straw and other harvesting residues from agriculture; Residues from food industry, landscaping residues (grass etc.)
3- 3- **Animal/Men(Fats/Proteins),** Farm slurry /excrements, Slaughter waste, Organic waste from households and industry

Wood remains the largest biomass energy source to date; examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switch grass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Plant energy is produced by crops specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are wheat, which typically yield 7.5–8 tonnes of grain per hectare, and straw, which typically yield 3.5–5 tonnes per hectare in the UK. The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Plant biomass can also be degraded from cellulose to glucose through a series of chemical treatments, and the resulting sugar can then be used as a first generation biofuel.

Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Rotting garbage, and agricultural and human waste, all release methane gas—also called landfill gas or biogas. Crops, such as corn and sugar cane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats.

There is research involving algal, or algae-derived, biomass due to the fact that it is a non-food resource and can be produced at rates five to ten times faster than other types of land-based agriculture, such as corn and soy. Once harvested, it can be fermented to produce biofuels such as ethanol, butanol, and methane, as well as biodiesel and hydrogen.

Historically, humans have harnessed biomass-derived energy since the time when people began burning wood to make fire. Even today, biomass is the only source of fuel for domestic use in many developing countries. Biomass is all biologically-produced matter based in carbon, hydrogen and oxygen. The estimated biomass production in the world is 104.9 petagrams (104.9 * 1015 g) of carbon per year, about half in the ocean and half on land.

Wood remains the largest biomass energy source today;examples include

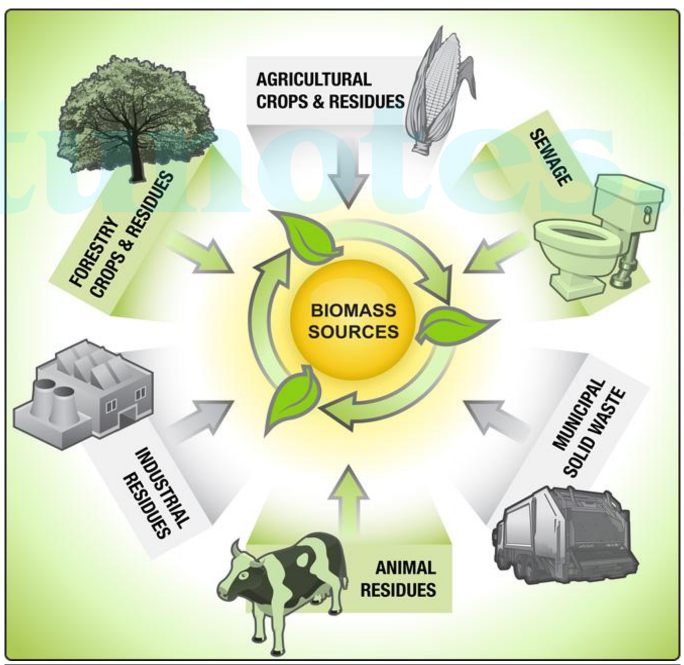
Forest residues (such as dead trees, branches and tree stumps),

Yard clippings, wood chips and even

Municipal solid waste.

Wood energy is derived by using lignocellulosic biomass (second-generation biofuels) as fuel. Harvested wood may be used directly as a fuel or collected from wood waste streams. The largest source of energy from wood is pulping liquor or "black liquor," a waste product from processes of the pulp, paper and paperboard industry.[citation needed] In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo,and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Based on the source of biomass, biofuels are classified broadly into two major categories. First-generation biofuels are derived from sources such as sugarcane and corn starch. Sugars present in this biomass are fermented to produce bioethanol, an alcohol fuel which can be used directly in a fuel cell to produce electricity or serve as an additive to gasoline. However, utilizing food-based resources for fuel production only aggravates the food shortage problem.Second-generation biofuels; on the other hand, utilize non-food-based biomass sources such as agriculture and municipal waste. These biofuels mostly consist of lignocellulosic biomass, which is not edible and is a low-value waste for many industries. Despite being the favored alternative, economical production of second-generation biofuel is not yet achieved due to technological issues. These issues arise mainly due to chemical inertness and structural rigidity of lignocellulosicbiomass.The main contributors of waste energy are municipal solid waste, manufacturing waste, and landfill gas



THE VARIOUS AND FAMOUS EXAMPLES FOR BIOMASS

- Crop residues : burn it in incinerator to produce energy.
- Burning woods : burning woods in order to produce electricity or heat energy.
- Mustard oil : used like oil for electricity or diesel

4.10.1 THE ADVANTAGES FOR BIOMASS ENERGY

- Most of them are renewable, e.g., wood, mustard oil and crop residues.
- Solve energy crisis in the future.
- Some of them are re-using the waste, e.g. crop residues, sewage.
- High energy efficiency.
- Generally it does not polluted the atmosphere as much as oil and coal

4.10.2 THE DISADVANTAGES OF THE USING OF BIOMASS ENERGY

- More serious air pollution was found when burning plants matters, e.g., CO2, CO, solid particulate matter.
- Emission more carcinogens into the air.
- Emission some toxic gases and ash
- It takes too much energy to collect, dry and transport the residues to power plants.
- Reduce soil nutrient replenishment.
- The source of biomass can use fertilize soil, e.g., crop residues and animal manure. Cutting too many woods is a kind of deforestation can cause, soil erosion and natural disasters
- Raising the price of food, wood and wood products indirectly.
- May cause accident.
- It uses large area to grow biomass

4.11 TYPES OF BIO GAS PLANTS

Biogas is a clean and efficient fuel. It is a mixture of methane (CH4), carbon dioxide (CO2), hydrogen (H2) and hydrogen sulphide (H2S)

There are two types of biogas plants in usage for the production of biogas. These are:

- The fixed- dome type of biogas plant
- The floating gas holder type of biogas plant

4.11.1 FIXED DOME TYPE OF BIOGAS PLANT

Raw materials required

Forms of biomass listed below may be used along with water.

- Animal dung
- Poultry wastes
- Plant wastes (Husk, grass, weeds etc.)
- Human excreta

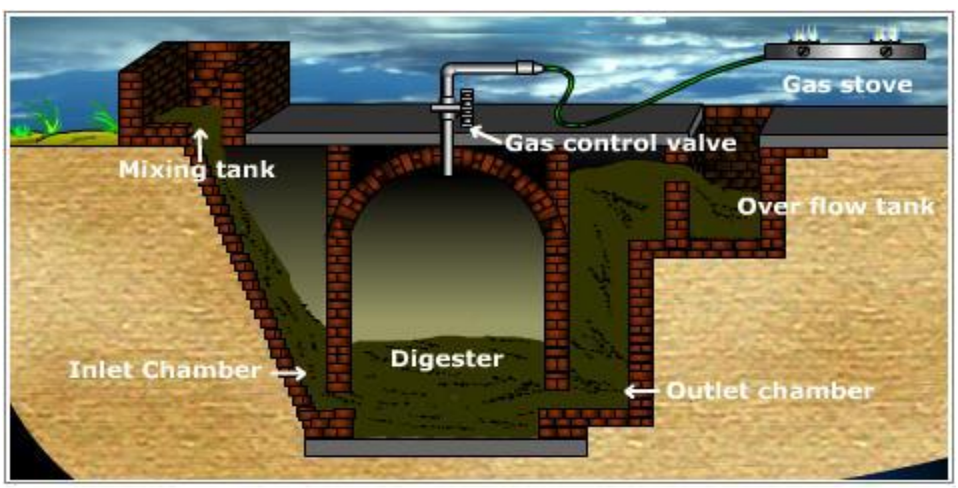
- Industrial wastes(Saw dust, wastes from food processing industries)
- Domestic wastes (Vegetable peels, waste food materials)

Principle

Biogas is produced as a result of anaerobic fermentation of biomass in the presence of water

Working

- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the slurry.
- The slurry is fed into the digester through the inlet chamber.
- When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about two months.
- During these two months, anaerobic bacteria present in the slurry decompose or ferments the biomass in the presence of water.
- As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.
- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
- From the outlet chamber, the spent slurry overflows into the overflow tank.
- The spent slurry is manually removed from the overflow tank and used as manure for plants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas is required.
- To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry



ADVANTAGES OF FIXED DOME TYPE OF BIOGAS PLANT

- Requires only locally and easily available materials for construction.
- Inexpensive.
- Easy to construct.

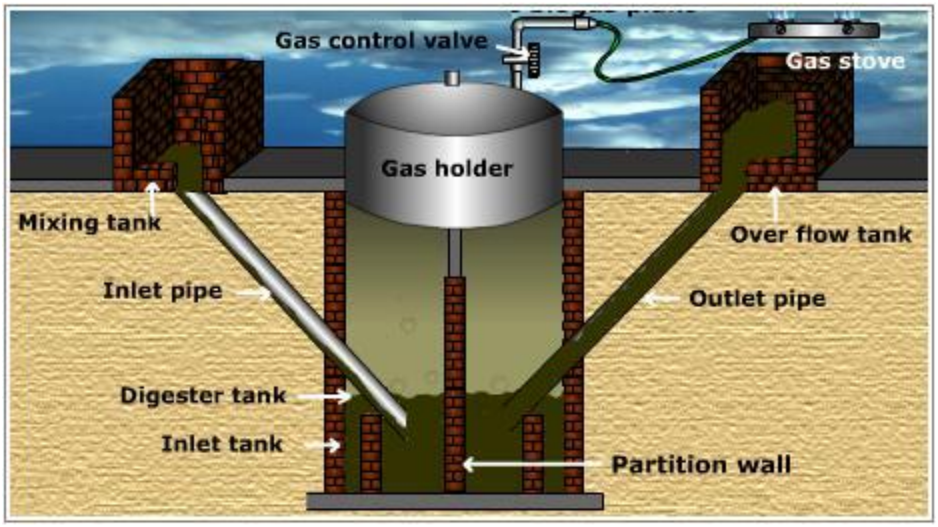
4.11.2 FLOATING GAS HOLDER TYPE OF BIOGAS PLANT

The floating gas holder type of biogas plant has the following chambers/ sections:

- Mixing Tank - present above the ground level.
- Digester tank - Deep underground well-like structure. It is divided into two chambers by a partition wall in between.
- It has two long cement pipes:
  - Inlet pipe opening into the inlet chamber for introduction of slurry.
  - Outlet pipe opening into the overflow tank for removal of spent slurry.
- Gas holder - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester. The gas holder has an outlet at the top which could be connected to gas stoves.
- Over flow tank - Present above the ground level.

<u>**Working**</u>

- Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank.
- The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe.
- The plant is left unused for about two months and introduction of more slurry is stopped.
- During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester.
- Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts moving up.
- The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry.
- The spent slurry is now forced into the outlet chamber from the top of the inlet chamber.
- When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure for plants.
- The gas valve of the gas outlet is opened to get a supply of biogas.
- Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.



4.11.2.1DISADVANTAGES OF FLOATING GAS HOLDER TYPE BIOGAS PLANT

- Expensive
- Steel drum may rust
- Requires regular maintenance

ADVANTAGES OF BIOGAS PLANTS

- Reduces burden on forests and fossil fuels
- Produces a clean fuel - helps in controlling air pollution
- Provides nutrient rich (N & P) manure for plants
- Controls water pollution by decomposing sewage, animal dung and human excreta.

LIMITATIONS OF BIOGAS PLANTS

Initial cost of installation of the plant is high.

Number of cattle owned by an average family of farmers is inadequate to feed a biogas plant.

ADVANTAGES OF BIOGAS AS A FUEL

- High calorific value
- Clean fuel
- No residue produced
- No smoke produced
- Non polluting
- Economical
- Can be supplied through pipe lines
- Burns readily - has a convenient ignition temperature

USES OF BIOGAS

- Domestic fuel
- For street lighting
- Generation of electricity

4.12 BIOFUELS

A biofuel is a fuel that is produced through biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes.Renewable biofuels generally involve carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass. This biomass can be converted to convenient energy containing substances in three different ways: **thermal conversion, chemical conversion,** and **biochemical conversion.** This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

4.12.1 ETHANOL

Ethanol, (C2H5OH), also known as ethyl alcohol, is produced by the fermentation of carbohydrate materials. Today, ethanol is made from starches and sugars, but an advanced conversion technology allows it to be made from more abundant "cellulosic" biomass sources such as grasses, trees, and agricultural residues.

ETHANOL IS USED FOR:

- production of alcoholic beverages
- for industrial purposes (as a solvent, disinfectant, or chemical feedstock)
- as a blending agent with gasoline to increase octane and reduce carbon monoxide and other smog-causing emissions.

Low-level ethanol blends such as E10 (10% ethanol/90% gasoline) can be used in conventional vehicles; while high-level blends, such as E85 (85% ethanol/15% gasoline) can only be used in specially designed vehicles, such as flexible fuel vehicles (FFVs).

4.12.2 BIODIESEL

Biodiesel is a liquid fuel made from vegetable oils and animal fats through a chemical process (Trans esterification) that "reacts" the feedstock with alcohol (usually methanol) to produce chemical compounds known as fatty acid methyl esters (FAME).Biodiesel is the name given to these esters when they are intended for use as transportation fuel. Biodiesel is used in blends with petroleum diesel or in its pure form. Lower-level blends such as B2 (2%

biodiesel/98% diesel) and B5 (5% biodiesel/95% diesel) can be used in any diesel engine. B100 (pure biodiesel) or other high-level biodiesel blends can be used in some engines built since 1994. Biodiesel is also used for space and water heating, in domestic and commercial boilers.

4.12.3 GREEN DIESEL

Green diesel is produced through hydrocracking biological oil feedstocks, such as vegetable oils and animal fats.Hydrocracking is a refinery method that uses elevated temperatures and pressure in the presence of a catalyst to break down larger molecules, such as those found in vegetable oils, into shorter hydrocarbon chains used in diesel engines. It may also be called renewable diesel, hydrotreated vegetable oil or hydrogen-derived renewable diesel.Green diesel has the same chemical properties as petroleum-based diesel.It does not require new engines, pipelines or infrastructure to distribute and use, but has not been produced at a cost that is competitive with petroleum.Gasoline versions are also being developed.

4.12.4 BIOFUEL GASOLINE

In 2013 UK researchers developed a genetically modified strain of Escherichia coli (E.Coli), which could transform glucose into biofuel gasoline that does not need to be blended.

412.5 VEGETABLE OIL

Straight unmodified edible vegetable oil is generally not used as fuel, but lower-quality oil can and has been used for this purpose. Used vegetable oil is increasingly being processed into biodiesel, or (more rarely) cleaned of water and particulates and used as a fuel.

As with 100% biodiesel (B100), to ensure the fuel injectors atomize the vegetable oil in the correct pattern for efficient combustion, vegetable oil fuel must be heated to reduce its viscosity to that of diesel, either by electric coils or heat exchangers.

Vegetable oil can also be used in many older diesel engines that do not use common rail or unit injection electronic diesel injection systems. Due to the design of the combustion chambers in indirect injection engines, these are the best engines for use with vegetable oil. This system allows the relatively larger oil molecules more time to burn.

Oils and fats can be hydrogenated to give a diesel substitute. The resulting product is a straight-chain hydrocarbon with a high cetane number, low in aromatics and sulfur and does not contain oxygen. Hydrogenated oils can be blended with diesel in all proportions. They have several advantages over biodiesel, including good performance at low temperatures, no storage stability problems and no susceptibility to microbial attack.

4.12.6 BIOGAS

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes.It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer.Biogas can be recovered from mechanical biological treatment waste processing systems.

Note: Landfill gas, a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it is a potential greenhouse gas.

Farmers can produce biogas from manure from their cattle by using anaerobic digesters.[

4.12.7 SYNGAS

Syngas, **a mixture of carbon monoxide, hydrogen and other hydrocarbons,** is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is not sufficient to convert the biomass completely to carbon dioxide and water.Before partial combustion, the biomass is dried, and sometimes pyrolysed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted.

carbon monoxide+ hydrogen + hydrocarbons = Syngas

Syngas may be burned directly in internal combustion engines, turbines or high-temperature fuel cells.Syngas can be used to produce methanol, and hydrogen, or converted via the Fischer-Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Gasification normally relies on temperatures greater than 700 °C.

Lower-temperature gasification is desirable when co-producing biochar, but results in syngas polluted with tar.

4.12.8 ALGAE BIOFUELS

Algae have natural oil content greater than 50%, and can be grown on algae ponds at wastewater treatment plants. These oil-rich algae can then be extracted from the system and processed into biofuels, with the dried remainder further reprocessed to create ethanol. The production of algae to harvest oil for biofuels has not yet been undertaken on a commercial scale, but feasibility studies have been conducted to arrive at the above yield estimate. In addition to its projected high yield, algaculture — unlike crop-based biofuels — does not entail a decrease in food production, since it requires neither farmland nor fresh water

4.13 OCEAN ENERGY SOURCES

Types of Ocean Energy

- Thermal energy
- Mechanical energy-From tides

  -From waves

4.13.1 WAVE ENERGY

Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a **wave energy converter** (WEC).

Wave-power generation is not currently a widely employed commercial technology, although there have been attempts to use it In 2008, the first experimental wave farm was opened in Portugal, at the Aguçadoura Wave Park.The major competitor of wave power is offshore wind power, with more visual impact.

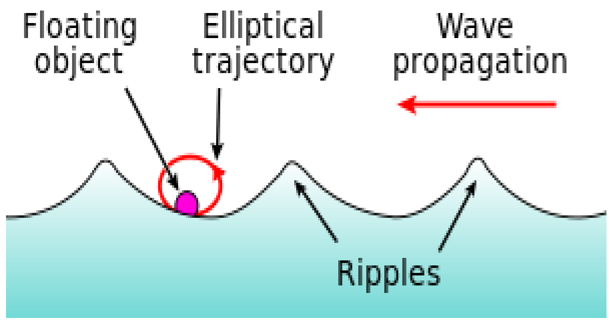
PHYSICAL CONCEPTS

Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves.

Wave height is determined by wind speed, the duration of time the wind has been blowing, fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. When this limit has been reached the sea is said to be "fully developed".

In general, larger waves are more powerful but wave power is also determined by wave speed, wavelength, and water density.Oscillatory motion is highest at the surface and diminishes exponentially with depth. However, for standing waves (clapotis) near a reflecting coast, wave energy is also present as pressure oscillations at great depth, producing microseisms.These pressure fluctuations at greater depth are too small to be interesting from the point of view of wave power.

The waves propagate on the ocean surface, and the wave energy is also transported horizontally with the group velocity. The mean transport rate of the wave energy through a vertical plane of unit width, parallel to a wave crest, is called the wave energy flux (or wave power, which must not be confused with the actual power generated by a wave power device).



Kinetic energy (movement) exists in the moving waves of the ocean. That energy can be used to power a turbine. In this simple example, to the right, the wave rises into a chamber. The rising water forces the air out of the chamber. The moving air spins a turbine which can turn a generator.

When the wave goes down, air flows through the turbine and back into the chamber through doors that are normally closed.This is only one type of wave-energy system. Others actually use the up and down motion of the wave to power a piston that moves up and down inside a cylinder. That piston can also turn a generator.Most wave-energy systems are very small. But, they can be used to power a warning buoy or a small light house.

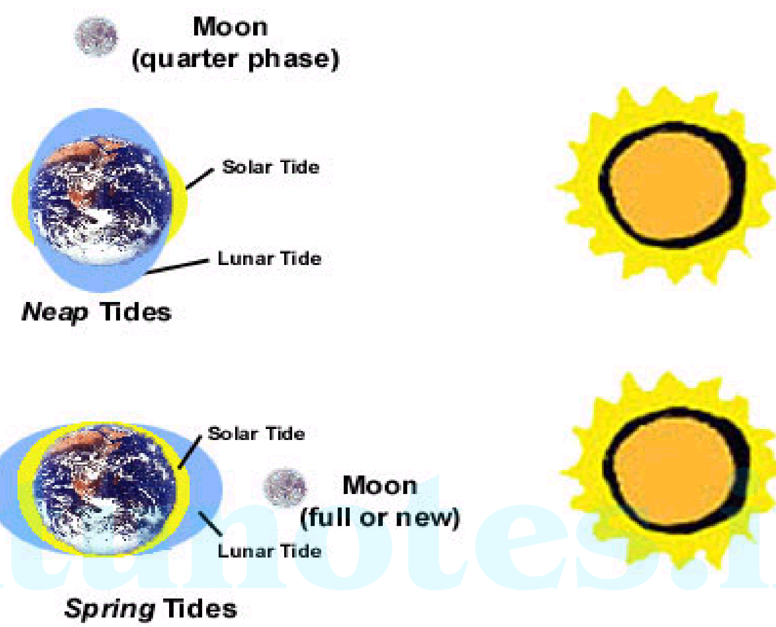
4.13.2 TIDAL ENERGY

Another form of ocean energy is called tidal energy. When tides come into the shore, they can be trapped in reservoirs behind dams. Then when the tide drops, the water behind the dam can be let out just like in a regular hydroelectric power plant.

Tidal energy has been used since about the 11th Century, when small dams were built along ocean estuaries and small streams. The tidal water behind these dams was used to turn water wheels to mill grains.

In order for tidal energy to work well, you need large increases in tides. An increase of at least 16 feet between low tide to high tide is needed. There are only a few places where this tide change occurs around the earth. Some power plants are already operating using this idea. Tidal power, also called tidal energy, is a form of hydropower that converts the energy of tides into useful forms of power, mainly electricity.

Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Among sources of renewable energy, tidal power has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

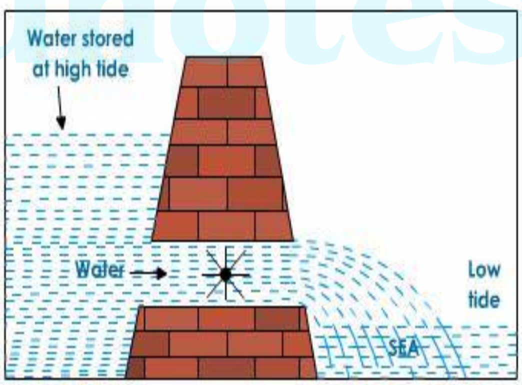


4.13.2.1 ADVANTAGES

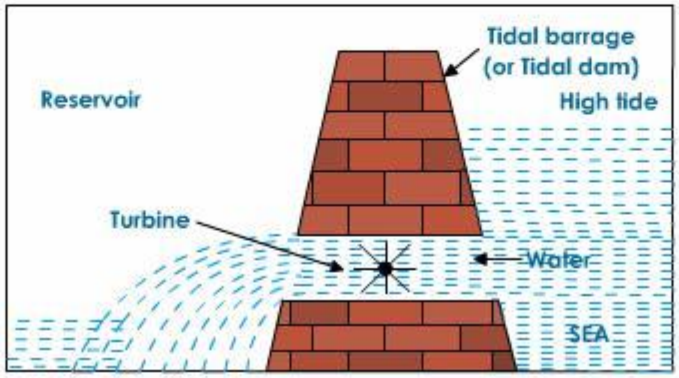
- No pollution
- Renewable resource
- More efficient than wind because of the density of water
- Predictable source of energy vs. wind and solar
- Second generation has very few disadvantages
  - Does not affect wildlife
  - Does not affect silt deposits
  - Less costly – both in building and maintenance

4.13.2.2 DISADVANTAGES

- Presently costly
  - Expensive to build and maintain
  - A 1085MW facility could cost as much as 1.2 billion dollars to construct and run
- Connection to the grid
- Technology is not fully developed
- Barrage style only produces energy for about 10 hours out of the day
- Barrage style has environmental affects
  - Such as fish and plant migration
  - Silt deposits
  - Local tides change- affects still under study



At low tide, stored water flows out from reservoir into sea and turns the turbine



At high tide,water flows from sea into reservoir and turns the turbine

4.14 GEOTHERMAL ENERGY

Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet (20%) and from radioactive decay of materials (80%).The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface.

Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation. Temperatures at the core–mantle boundary may reach over 4000 °C (7,200 °F).The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle convecting upward since it is lighter than the surrounding rock. Rock and water is heated in the crust, sometimes up to 370 °C (700 °F).

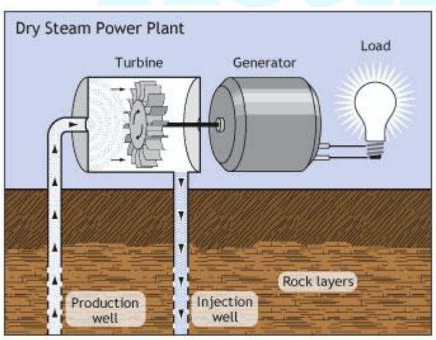
Geothermal power is cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. As a result, geothermal power has the potential to help mitigate global warming if widely deployed in place of fossil fuels.

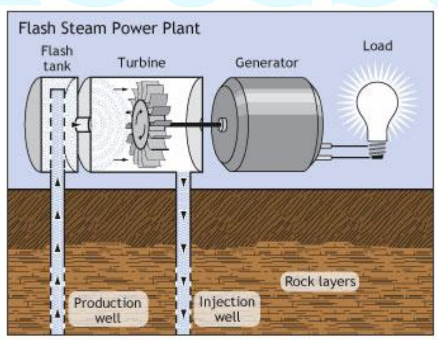
4.14.1 HOW GEOTHERMAL ENERGY IS CAPTURED

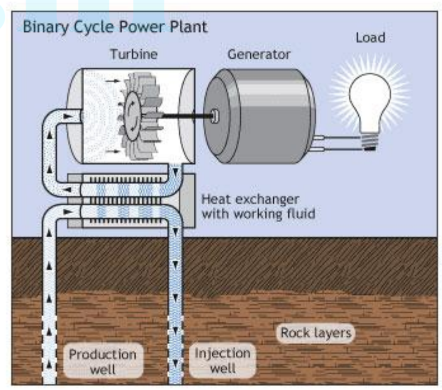
Geothermal springs for power plants. Currently, the most common way of capturing the energy from geothermal sources is to tap into naturally occurring "hydrothermal convection" systems, where cooler water seeps into Earth's crust, is heated up, and then rises to the surface. Once this heated water is forced to the surface, it is a relatively simple matter to capture that steam and use it to drive electric generators. Geothermal power plants drill their own holes into the rock to more effectively capture the steam.

There are three basic designs for geothermal power plants, all of which pull hot water and steam from the ground, use it, and then return it as warm water to prolong the life of the heat source.

- In the simplest design, known as dry steam, the steam goes directly through the turbine, then into a condenser where the steam is condensed into water.
- In a second approach, very hot water is depressurized or "flashed" into steam which can then be used to drive the turbine.
- In the third approach, called a binary cycle system, the hot water is passed through a heat exchanger, where it heats a second liquid—such as isobutane—in a closed loop. Isobutane boils at a lower temperature than water, so it is more easily converted into steam to run the turbine. These three systems are shown in the diagrams below.







The choice of which design to use is determined by the resource. If the water comes out of the well as steam, it can be used directly, as in the first design. If it is hot water of a high enough temperature, a flash system can be used; otherwise it must go through a heat exchanger. Since there are more hot water resources than pure steam or high-temperature water sources, there is more growth potential in the binary cycle, heat exchanger design.

The largest geothermal system now in operation is a steam-driven plant in an area called the Geysers, north of San Francisco, California. Despite the name, there are actually no geysers there, and the heat that is used for energy is all steam, not hot water. Although the area was *known for its hot springs as far back as the mid-1800s, the first well for power production was not drilled until 1924. Deeper wells were drilled in the 1950s, but real development didn't occur until the 1970s and 1980s. By 1990, 26 power plants had been built, for a capacity of more than 2,000 MW.*

4.14.2 DIRECT USE OF GEOTHERMAL HEAT.

Geothermal springs can also be used directly for heating purposes. Geothermal hot water is used to heat buildings, raise plants in greenhouses, dry out fish and crops, de-ice roads, and improve oil recovery, aid in industrial processes like pasteurizing milk, and heat spas and water at fish farms.

In Iceland, virtually every building in the country is heated with hot spring water. In fact, Iceland gets more than 50 percent of its primary energy from geothermal sources. In Reykjavik, for example (population 118,000), hot water is piped in from 25 kilometers away, and residents use it for heating and for hot tap water.

4.14.3 GROUND-SOURCE HEAT PUMPS.

A much more conventional way to tap geothermal energy is by using geothermal heat pumps to provide heat and cooling to buildings. Also called ground-source heat pumps, they take advantage of the constant year-round temperature of about 50°F that is just a few feet below the ground’s surface. **Either air or antifreeze liquid is pumped through pipes that are buried underground, and re-circulated into the building**. In the summer, the liquid moves heat from the building into the ground. In the winter, it does the opposite, providing pre-warmed air and water to the heating system of the building.

In the simplest use of ground-source heating and cooling, a tube runs from the outside air, under the ground, and into a building's ventilation system. More complicated, but more effective, systems use compressors and pumps—as in electric air conditioning systems—to maximize the heat transfer

4.15 ENERGY CONSERVATION

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

Even though energy conservation reduces energy services, it can result in increased environmental quality, national security, personal financial security and higher savings.It is at the top of the sustainable energy hierarchy.It also lowers energy costs by preventing future resource depletion.

Some energy conservation methods are:

- **Energy taxes**
  Some countries which employ energy or carbon taxes to motivate energy users to reduce their consumption. Carbon taxes can allow consumption to shift to nuclear power and other alternatives that carry a different set of environmental side effects and limitations. Meanwhile, taxes on all energy consumption stand to reduce energy use across the board, while reducing a broader array of environmental consequences arising from energy production.

- **Building Design**
  One of the primary ways to improve energy conservation in buildings is to use an energy audit. An energy audit is an inspection and analysis of energy use and flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s). This is normally accomplished by trained professionals and can be part of some of the national programs discussed above. In addition, recent development of smartphone apps enable homeowners to complete relativily sophisticated energy audits themselves
- **Transportation**
  In the United States, suburban infrastructure evolved during an age of relatively easy access to fossil fuels, which has led to transportation-dependent systems of living. Zoning reforms that allow greater urban density as well as designs for walking and bicycling can greatly reduce energy consumed for transportation. The use of telecommuting by major corporations is a significant opportunity to conserve energy, as many Americans now work in service jobs that enable them to work from home instead of commuting to work each day.

- **Consumer products**
  Consumers are often poorly informed of the savings of energy efficient products. A prominent example of this is the energy savings that can be made by replacing incandescent light bulbs with more modern alternatives. When purchasing light bulbs, many consumers opt for cheap incandescent bulbs, failing to take into account their higher energy costs and lower lifespans when compared to modern compact fluorescent and LED bulbs. Although these energy-efficient alternatives have a higher upfront cost, their long lifespan and low energy use can save consumers a considerable amount of money. The price of LEDs has also been steadily decreasing in the past five years, due to improvement of the semiconductor technology. Many LED bulbs on the market qualify for utility rebates that further reduce the price of purchase to the consumer

QUESTIONS

WIND MILLS IN KERALA

55 MW production of wind power is installed in Kerala. The first wind farm of the state was set upat Kanjikode in Palakkad district

They generate a total of 600 MW of power.

State	Capacity (MW), as of March 31, 2015
Tamil Nadu	7253
Gujarat	3414
Maharashtra	2976
Rajasthan	2820
Karnataka	2409
Andhra Pradesh	753
Madhya Pradesh	439
Kerala	55
Others	4.30
Total	**21264**

SMALL HYDRO ELECTRIC PROJECTS (52.85 MW)

- Kallada (15 MW)
- Peppara (3 MW)
- Malankara (10.5 MW)
- Madupatty (2 MW)
- Malampuzha (2.5 MW)
- Lower Meenmutty (3.5 MW)
- Chembukadavu - 1 (2.7 MW)
- Chembukadavu - 2 (3.7 MW)
- Urumi -1 (3.75 MW)
- Urumi -2 (2.4 MW)
- Kuttiyadi Tail Race (3.75 MW)
- Peechi (1.25 MW)