TUTORIAL - 7

Importance of Non-Conventional Energy Sources in Energy Conservation

1. With help of neat sketch explain working of Floating Dom-KVIC Biogas plant OR With neat sketch explain Biogas plant.

Different models of Floating Dom type bio-gas plants are developed in various criteria. A popular model developed in India by Khadi village industries commission (KVIC) is shown in fig.

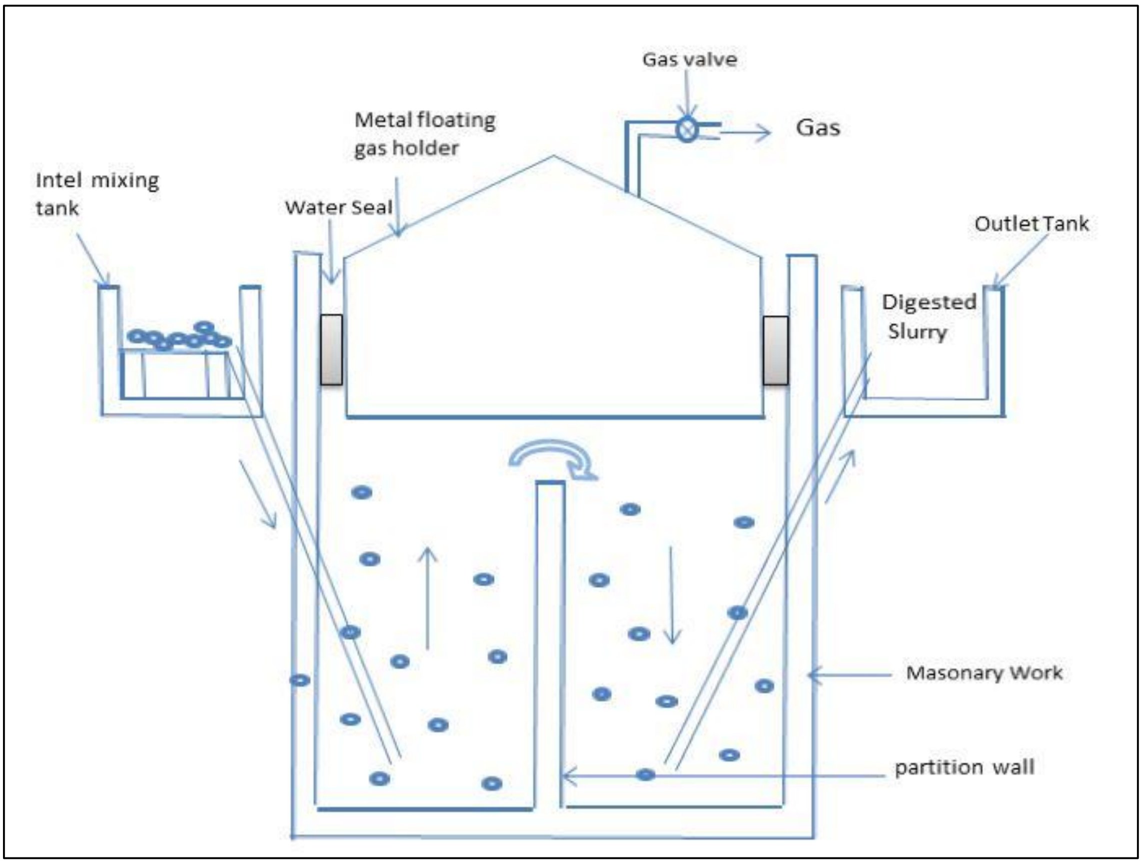


Figure: KVIC Biogas plant

It comprised of masonry digester with an inlet on one side for feeding slurry and an outlet on the other side for removing digested slurry. The feeding of animal slurry is usually done once in a day. This gas collects in a steel gas holder, which is inverted over the slurry and moves up and down depending upon the accumulation and discharge of gas guided by a central guide pipe. The movable gas holder is made up of steel. The gas holder is painted by anti-corrosive painting at least once in a year. This plant helps to achieve more consistent gas pressure, which can be adjusted by regulating weight. A partition wall is provided in the digester. The bifurcation of a digester chamber through a partitioning wall provides optimum conditions for growth of acid formers and methane formers as requirements of PH values for this bacteria are different. Therefore this plant operates very well with good bio-gas yield. The floating gas holder builds gas pressure of about 10 cms of water column, sufficient to supply gas up to 100 metre. Gas pressure also forces out the spent slurry through a sludge pipe. The diameter of the digester of the gas plant from 1.2 to 6 metre and its height varies from 3 to 6 metre. The mid steel gas holders are prone to corrosion thus needs a painting at regular intervals. This problem can be overcome by using fibre glass reinforced plastic (FRP) material for construction of gas holders.

- **Working of a Biogas Plant**

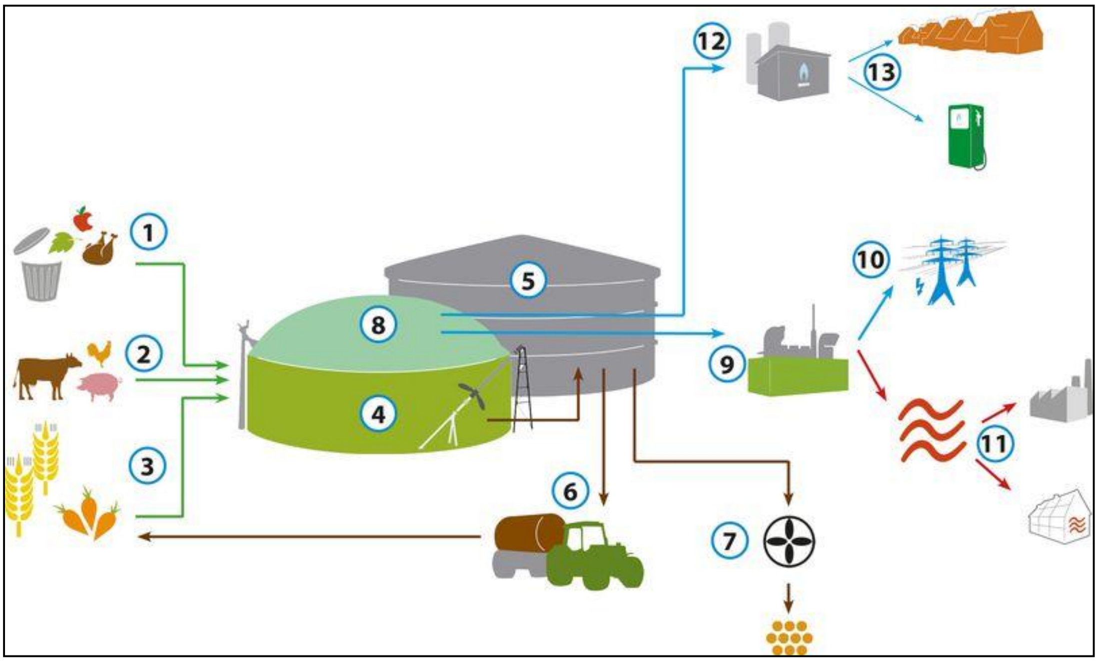


Figure: Working of a Biogas Plant

1. Organic input materials such as foodstuff remnants, fats or sludge can be fed into the biogas plant as substrate.
2. Renewable resources such as corn, beets or grass serve as feed both for animals such as cows and pigs as well as for the microorganisms in the biogas plant.
3. Manure and dung are also fed into the biogas plant.
4. In the fermenter, heated to approx. 38-40 °C, the substrate is decomposed by the microorganisms under exclusion of light and oxygen. The final product of this fermentation process is biogas with methane as the main ingredient. But aggressive hydrogen sulphide is also contained in the biogas. A fermenter made of stainless steel has the clear advantage that it withstands the attacks of the hydrogen sulphide and is usable for decades. Furthermore, a stainless steel fermenter provides the opportunity to operation the biogas plant also in the thermophile temperature range (up to 56 °C).
5. Once the substrate has been fermented, it is transported to the fermentation residues end storage tank and can be retrieved from there for further utilisation.
6. The residues can be utilised as high quality fertiliser. The advantage: Biogas manure has a lower viscosity and therefore penetrates into the ground more quickly. Furthermore, the fermentation residue quite often has a higher fertiliser value and is less intense to the olfactory senses.
7. But drying it and subsequently using it as dry fertiliser is also an option.
8. The biogas generated is stored in the roof of the tank.
9. From tank biogas is burned in the combined heat and power plant (CHP) to generate electricity and heat.
10. The electric power is fed directly into the power grid.
11. The heat generated can be utilised to heat building or to dry wood or harvest products.
12. Processing of biogas.
13. Gas supply to the national grid or gas filling stations.

Advantages:

- It gives higher gas production
- It works under constant pressure naturally
- There is no problem of gas leakage
- There is no problem of mixing of bio-gas with external air, thus no danger of explosion

Disadvantages:

- It's initial cost is high
- There is loss of heat through metal gas holder
- The outlet pipe is flexible, it requires regular attention
- Its maintenance cost is high.

2. Discuss Solar Energy.

Solar energy is the most readily available and free source of energy since prehistoric times. It is estimated that solar energy equivalent to over 15,000 times the world's annual commercial energy consumption reaches the earth every year. India receives solar energy in the region of 5 to 7 kWh/m2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometre land area. Solar energy can be utilised through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

➢ **Solar Thermal Energy Application**

In solar thermal route, solar energy can be converted into thermal energy with the help of solar collectors and receivers known as solar thermal devices. The Solar-Thermal devices can be classified into three categories:

- Low-Grade Heating Devices - up to the temperature of 100°C.
- Medium-Grade Heating Devices -up to the temperature of 100°-300°C
- High-Grade Heating Devices -above temperature of 300°C

Low-grade solar thermal devices are used in **solar water heaters, air-heaters, solar cookers and solar dryers** for domestic and industrial applications.

➢ **Solar water heaters**

Most solar water heating systems have two main parts: **a solar collector and a storage tank**. The most common collector is called a flat-plate collector. It consists of a thin, flat, rectangular box with a transparent cover that faces the sun, mounted on the roof of building or home. Small tubes run through the box and carry the fluid - either water or other fluid, such as an antifreeze solution – to be heated. The tubes are attached to an absorber plate, which is painted with special coatings to absorb the heat. The heat builds up in the collector, which is passed to the fluid passing through the tubes. An insulated storage tank holds the hot water. It is similar to water heater, but larger is size. In case of systems that use fluids, heat is passed from hot fluid to the water stored in the tank through a coil of tubes. Solar water heating systems can be either active or passive systems. The active system, which are most common, rely on pumps to move the liquid between the collector and the storage tank. The passive systems rely on gravity and the tendency for water to naturally circulate as it is heated. A few industrial application of solar water heaters are listed below:

- **Hotels:** Bathing, kitchen, washing, laundry applications
- **Dairies:** Ghee (clarified butter) production, cleaning and sterilizing, pasteurization
- **Textiles**: Bleaching, boiling, printing, dyeing, curing, ageing and finishing
- **Breweries & Distilleries**: Bottle washing, worth preparation, boiler feed heating
- **Chemical /Bulk drugs units**: Fermentation of mixes, boiler feed applications
- **Electroplating/galvanizing units**: Heating of plating baths, cleaning, degreasing applications
- **Pulp and paper industries**: Boiler feed applications, soaking of pulp.

➢ **Solar Cooker**

Solar cooker is a device, which uses solar energy for cooking, and thus saving fossil fuels, fuel wood and electrical energy to a large extent. However, it can only supplement the cooking fuel, and not replace it totally. It is a simple cooking unit, ideal for domestic cooking during most of the year except during the monsoon season, cloudy days and winter months 12.

Box type solar cookers: The box type solar cookers with a single reflecting mirror are the most popular in India. These cookers have proved immensely popular in rural areas where women spend considerable time for collecting firewood. A family size solar cooker is sufficient for 4 to 5 members and saves about 3 to 4 cylinders of LPG every year. The life of this cooker is up to 15 years.

Parabolic concentrating solar cooker: A parabolic solar concentrator comprises of sturdy Fibre Reinforced Plastic (FRP) shell lined with Stainless Steel (SS) reflector foil or aluminised polyester film. It can accommodate a cooking vessel at its focal point. This cooker is designed to direct the solar heat to a secondary reflector inside the kitchen, which focuses the heat to the bottom of a cooking pot. It is also possible to actually fry, bake and roast food. This system generates 500 kg of steam, which is enough to cook two meals for 500 people. This cooker costs upward of Rs.50, 000.

3. Discuss Wind Energy – As source of Energy.

➢ **Wind Energy and Wind Power**

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

➢ How Wind Power Is Generated?

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity to power homes, businesses, schools, and the like.

➢ Wind Turbines

Wind turbines, like aircraft propeller blades, turn in the moving air and power an electric generator that supplies an electric current. Simply stated, a wind turbine is the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

➢ Wind Turbine Types

Modern wind turbines fall into two basic groups; the horizontal-axis variety, like the traditional farm windmills used for pumping water, and the vertical-axis design, like the eggbeater-style Darrieus model, named after its French inventor. Most large modern wind turbines are horizontal-axis turbines.

➢ Turbine Components

Horizontal turbine components include:

- Blade or rotor, which converts the energy in the wind to rotational shaft energy;
- A drive train, usually including a gearbox and a generator;
- A tower that supports the rotor and drive train; and
- Other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

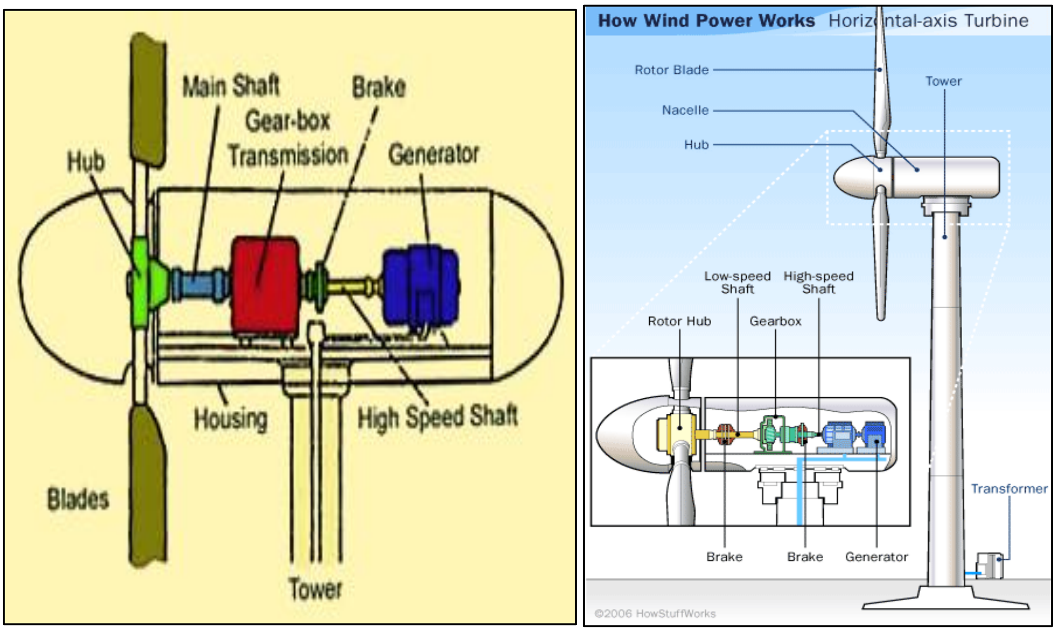


Figure: Wind Turbine Schematic Diagram

➢ Turbine Configurations

Wind turbines are often grouped together into a single wind power plant, also known as a wind farm, and generate bulk electrical power. Electricity from these turbines is fed into a utility grid and distributed to customers, just as with conventional power plants.

➢ Wind Turbine Size and Power Ratings

Wind turbines are available in a variety of sizes, and therefore power ratings. The largest machine has blades that span more than the length of a football field, stands 20 building stories high, and produces enough electricity to power 1,400 homes. A small home-sized wind machine has rotors between 8 and 25 feet in diameter and stands upwards of 30 feet and can supply the power needs of an all-electric home or small business. Utility-scale turbines range in size from 50 to 750 kilowatts. Single small turbines, below 50 kilowatts, are used for homes, telecommunications dishes, or water pumping.

Wind energy is very abundant in many parts of the United States. Wind resources are characterized by wind-power density classes, ranging from class 1 (the lowest) to class 7 (the highest). Good wind resources (e.g., class 3 and above, which have an average annual wind speed of at least 13 miles per hour) are found in many locations (see United States Wind Energy Resource Map). Wind speed is a critical feature of wind resources, because the energy in wind is proportional to the cube of the wind speed. In other words, a stronger wind means a lot more power.

➢ Advantages and Disadvantages of Wind-Generated Electricity

1. A Renewable Non-Polluting Resource

Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. According to the U.S. Department of Energy, in 1990, California's wind power plants offset the emission of more than 2.5 billion pounds of carbon dioxide, and 15 million pounds of other pollutants that would have otherwise been produced. It would take a forest of 90 million to 175 million trees to provide the same air quality.

2. Cost Issues

Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators. Roughly 80% of the cost is the machinery, with the balance being site preparation and installation. If wind generating systems are compared with fossil-fueled systems on a "life-cycle" cost basis (counting fuel and operating expenses for the life of the generator), however, wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses.

3. Environmental Concerns

Although wind power plants have relatively little impact on the environment compared to fossil fuel power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and birds and bats having been killed (avian/bat mortality) by flying into the rotors. Most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

4. Supply and Transport Issues

The major challenge to using wind as a source of power is that it is intermittent and does not always blow when electricity is needed. Wind cannot be stored (although wind-generated electricity can be stored, if batteries are used), and not all winds can be harnessed to meet the timing of electricity demands. Further, good wind sites are often located in remote locations far from areas of electric power demand (such as cities). Finally, wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued than electricity generation. However, wind turbines can be located on land that is also used for grazing or even farming.

4. Explain Tidal power plant.

For centuries, mankind has exploited this massive energy source. In the recent years, we have learnt how to generate electricity from it. 450 TWh is the estimated yearly potential of electric power that can be produced from tidal energy. In addition to this comes a large and not yet estimated potential in river flows.

➢ **What is Tidal Energy?**

Tidal energy or tidal power can be defined as the energy that is the result of the moon and the sun's gravitational influence on the ocean. Height differences between high and low tides create tidal currents in coastal areas, and these currents can be strong enough to drive turbines. Tidal energy has been used for other purposes since the Roman times. If you want to learn more about these methods go to The History of Tidal Energy (coming soon). This article will focus solely on tidal power generation.

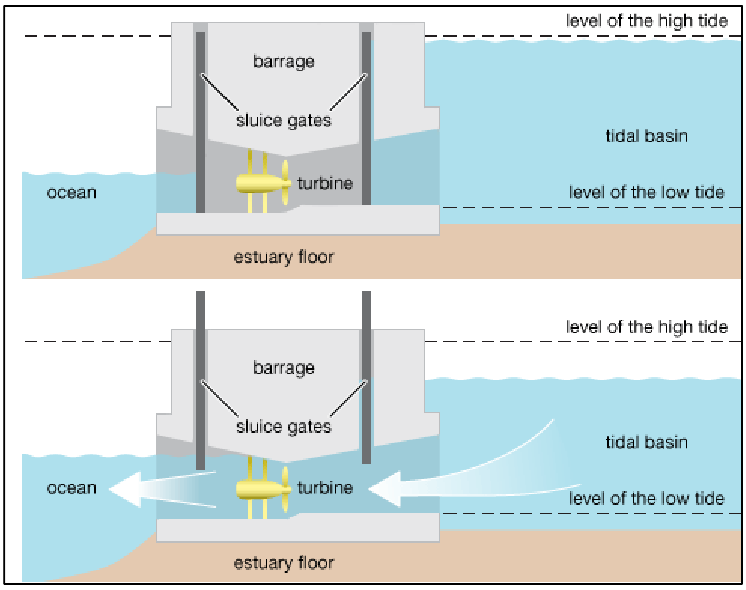


Figure: Tidal Power Plant

➢ **Where is Tidal Energy Used?**

As tidal power generation is relatively new, there are not a lot of tidal energy companies out there developing investing in this technology yet. However, there are several tidal power plants in use and more is coming. Some of these are solely for research and experimental purposes, but the number of commercial tidal energy power plants is increasing.

La Rance tidal power station was the first large large-scale tide energy project and was opened already in 1966. It lays in the water-rich river Rance in the north-western France. This is a tidal power plant with a total installed capacity of 240 MW capacity generated from 24 turbines. Annual production of electricity is about. 0.6 TWh (600 GWh), which means that the average effect of day throughout the year is 68 MW. La Rance is a form of what we call a tidal barrage power plant.

- **Tidal Barrage Energy**

A tidal barrage power plant consists of three main parts: The first being the barrage itself, holding the water back during high tide. The second part is the sluice gate that let water through the third part, the turbine and generator, resulting in electricity generation. The sluice gates are left open during high tide and closed during low tide to create a water level differential, creating a potential difference that powers the turbine when the water is released.

- **Tidal Stream Generator**

Tidal stream generators are very similar to wind turbines except their below the water surface instead of above or on land. The turbine and generator converts the movement of water coming from change in tide, the kinetic energy, into electricity. Water is 830 times denser than air and therefore can generate electricity at lower speeds than wind turbines.

- **Dynamic Tidal Power**

Dynamic tidal power is still in the development stage. The theory of this technology is that we can exploit tidal flows and their interaction between potential and kinetic energy.

- **Advantages of Tidal Energy**

There are several advantages with tidal power generation. The greatest benefit after the fact that tidal energy is both a renewable and a green energy source is the incredible potential it possess. The large density of water, almost 1 000 times greater than in air, results in very large amounts of energy to get out of the tidal currents even if the speed is low. Tidal currents are very predictable, and therefore very favorable with respect to the planning of production and maintenance.

5. Discuss advantages of renewable energy sources.

- The renewable energy sources replenish in relatively short time and thus will always be available. Hence, they are inexhaustible.
- They are available in nature free of cost.
- They produce no or very little pollution. Thus, by and large, they are environment friendly.
- They increase flexibility and supply security because they can be produced locally.
- They can be built on or close to the site where the energy is required, this minimises transmission costs.
- They can reduce petroleum oil import bill for country like India.

6. Discuss Ocean Thermal Energy Conversion (O.T.E.C.) plant.

The ocean and the seas are constantly receiving solar radiation and act as the largest natural solar collector. An ocean as a collector has an enormous storage capacity. Ocean thermal energy conversion is a new technology, needed to be harnessed especially in India where the coastline is about 6000 km. According to ministry of new and renewable energy the overall potential of ocean thermal energy in the country may be in excess of 50,000 MW. There is an enormous opportunity to tap this renewable source of energy.

Ocean thermal energy exists in the form of temperature difference between the warm surface water and the colder water. The surface water works as a heat source and the deep water as a heat sink to convert part of the heat to mechanical energy and hence into electrical energy. A minimum temperature difference of 20° C is required for practical energy conversion. The facility proposed to achieve this conversion is known as OTEC.

Solar radiation flux incident on the ocean surface. Therefore, in most tropical and some subtropical areas the temperature of water at the surface of sea is about 27° C and the temperature of the cold deep sea water at a depth of 1 km is about 7°C . The density of water decreases with an increase in temperature and vice versa. Therefore, the water at the top surface is lighter than the water at some depth which is heavier. Thus, in tropical waters there other is heat sink at the depth of about 7° C.

In the range of temperature of warm water T1 in the upper surface layer and cold water(T2) in the depth of the tropical ocean , the Carnot cycle efficiency is given by

$$\eta_c = 1 - \frac{T_2}{T_1}$$

If T1 = 27°C = 300 K, T2 = 7°C = 280 K

$$\therefore \eta_c = 1 - \frac{300}{280} = 7.1428\%$$

The efficiency of an OTEC power plant is less than the Carnot cycle and it is given by

$$\eta_{OTEC} = EF \times \eta_c$$

Where; EF=Relative efficiency factor (0.4 to 0.6)

Solar energy absorption by the water takes place according to Lamports' Law of absorption which states that each layer of equal thickness absorbs the same fraction of absorption which states that each layer of equal thickness absorbs the same fraction of light passes through it. If I is the intensity of radiation and ' x' is the depth of water then

$$\frac{dI_x}{dx} = \mu I ,$$

Or

$$I_x = I_o e^{-\mu x}$$

Where: I0 = Intensity of radiation at the surface where x=0,

Ix = Intensity of radiation at a distance 'x', below the surface.

μ = absorption coefficient.

The intensity falls exponentially with depth 'x' and depending upon μ, almost all of the absorption occurs very close to the surface waters. Therefore, maximum temperature occurs just below the surface due to heat and mass transfer at the surface itself.

- **Open cycle Ocean Thermal Energy Conversion (OTEC) System:-**

  An open cycle OTEC is also known as **Claude cycle**. The arrangement of the open cycle OTEC power plant is shown in following fig. The system incorporates a de – aerator to remove some of the non – condensable gases entrained with the warm surface seawater.

  The degassed warm water then flows to the flash evaporator. The flush evaporator chamber is maintained under saturation pressure corresponding to that water temperature. Low – pressure steam obtained is separated and passed through a turbine to extract energy.

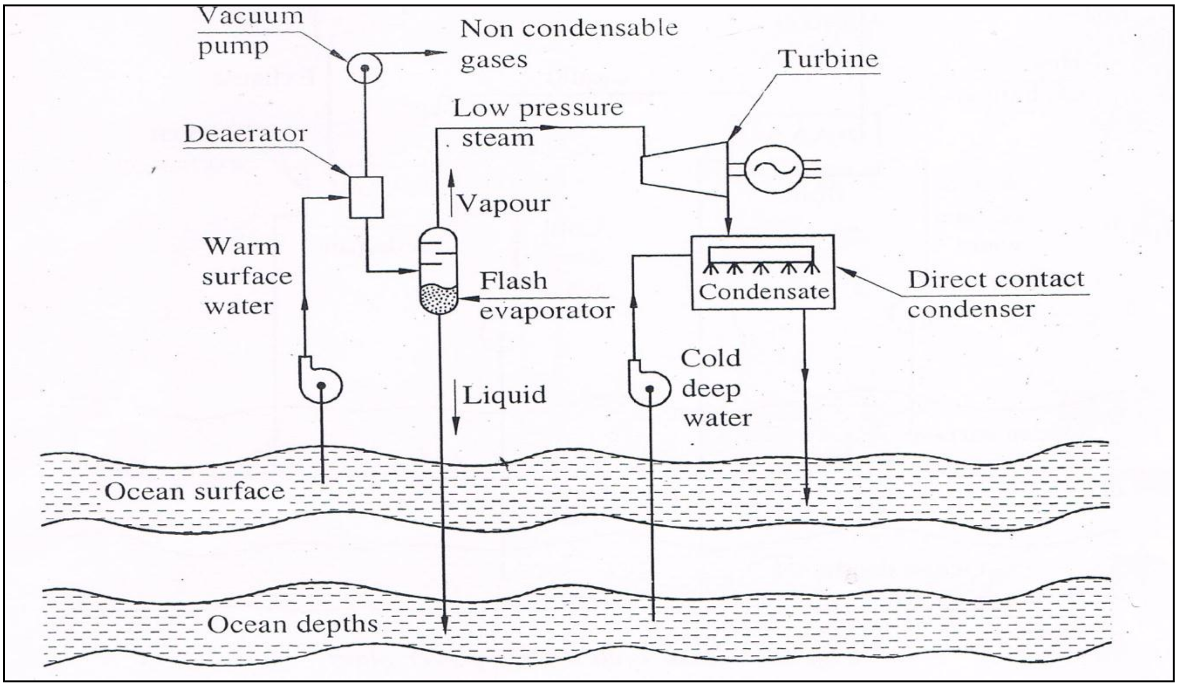


Figure: Open cycle OTEC

The exhaust of the turbine is condensed in a direct contact condenser. Cold water drawn from a depth of about 1 km is used as cooling water in a direct contact condenser. The resulting mixture of used cooling water and condensate is disposed in the sea. If a surface contact condenser is employed, the condensate could be used as desalinated water. Thus, an open cycle OTEC plant can provide a substantial quantity of desalinated water. In this cycle, the operating pressures of working fluid in boiler, turbine, and condenser are much lower and its specific volume is much higher. Such high specific volumes result in larger turbine size and hence, more costly.

- **Closed cycle OTEC system:-**

A closed cycle OTEC is also known as **Anderson cycle.** The arrangement of the cycle is shown in fig. In this cycle, warm surface water is used to evaporate a low boiling point working fluid such as ammonia, Freon, propane, etc.

Warm water from ocean surface is circulated through a pump to a heat exchanger which acts as boiler to generate Freon vapour at high pressure. This vapour expands in the vapour turbine to develop mechanical power. It is used to drive an electric generator which produces electric energy.

Freon vapour from turbine at low pressure is condensed in the condenser with the help of cold water drawn from the depth of ocean through a pump. The Freon condensate is pumped again into the boiler.

Because of the low quality of the heat, large surface areas of heat exchanges are required to transfer significant amount of heat, large amount of water needs to be circulated.

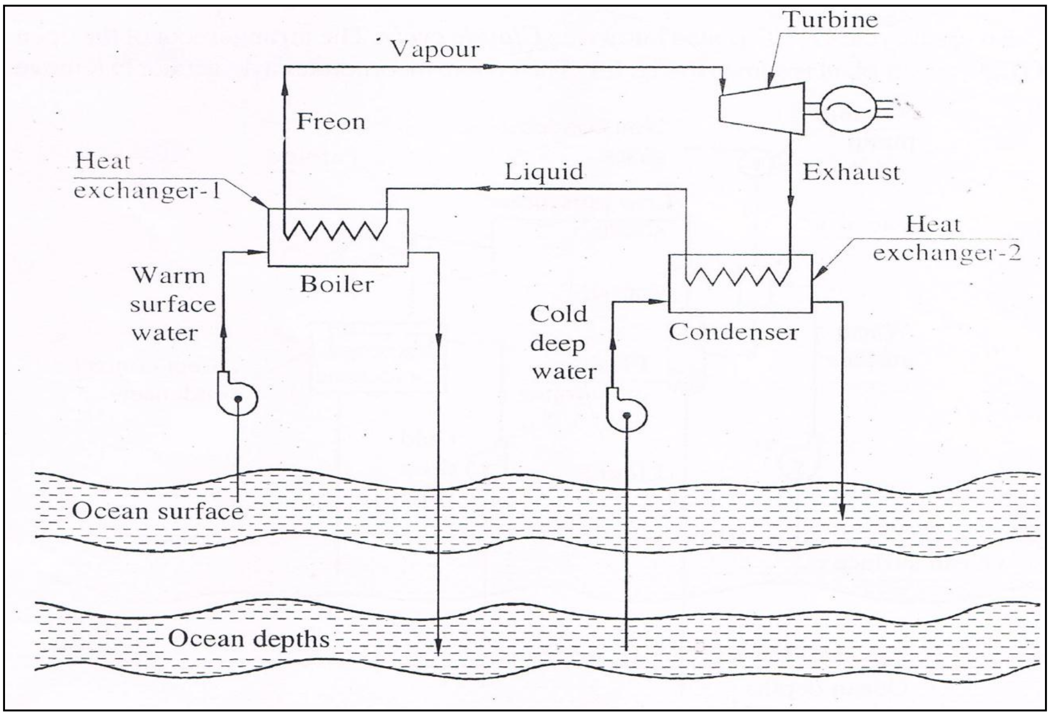


Figure: Closed OTEC

The operating pressures of the working fluid at the boiler and condenser are much higher and its specific volume is much lower as compared to that of water in an open cycle system.

Such pressures and specific volumes result in turbine that is much smaller in size and hence it is compared to that in an open cycle system. The overall efficiency of such plant is very wide in range of 2 to 3 % only.

- **Hybrid cycle OTEC:-**

The raw ocean water which is pumped into evaporator and condenser contains microorganisms which stick on the water stick on the water side of both the heat exchangers. This biological impurity of sea water that deposits and grows on the evaporator and condenser metal surfaces, creating thermal resistance for heat transfer , is known as **bio-fouling.**

The hybrid cycle is an attempt to combine the best features and avoid the worst features of the open and closed cycles. The arrangement of this cycle is shown in fig. Warm water from the ocean surface is flash evaporated under vacuum.

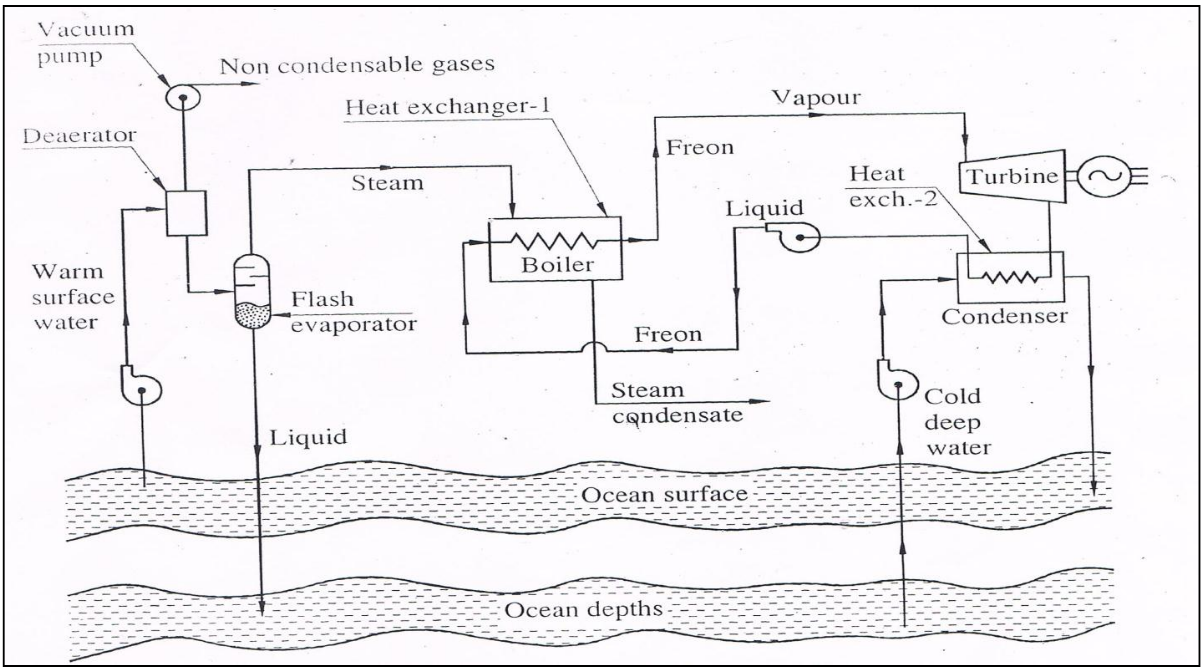


Figure: Hybrid OTEC

Low pressure steam obtained is separated and passed through a Freon evaporator. The heat of steam is then transferred to Freon. The evaporator is isolated from the sea water, thus, bio – fouling of evaporator can be avoided. Remaining cycle is same as closed cycle OTEC.

7. Explain method to capture wind energy to get electricity.

Wind energy is basically harnessing of wind power to produce electricity. The kinetic energy of the wind is converted to electrical energy. The kinetic energy of the wind is converted to electrical energy. When solar radiation enters the earth's atmosphere, different regions of the atmosphere are heated to different degrees because of earth curvature. This heating is higher at the equator and lowest at the poles. Since air tends to flow from warmer to cooler regions, this causes what we call winds, and it is these airflows that are harnessed in windmills and wind turbines to produce power.

The basic wind energy conversion device is the wind turbine. Although various designs and configurations exist, these turbines are generally grouped into two types:

1. Vertical-axis wind turbines, in which the axis of rotation is vertical with respect to the ground (and roughly perpendicular to the wind stream).

- Advantages of Vertical Axis
  - Can place generator on ground.

– You don't need a yaw mechanism for wind angle.

- Disadvantages of Vertical Axis
  – Lower wind speeds at ground level.
  – Less efficiency.
  – Requires a "push".

2. Horizontal-axis turbines, in which the axis of rotation is horizontal with respect to the ground (and roughly parallel to the wind stream.).

- Advantages of Horizontal Axis
  – Higher wind speeds
  – Great efficiency

- Disadvantages of Horizontal Axis
  – Angle of turbine is relevant
  – Difficult access to generator for repair

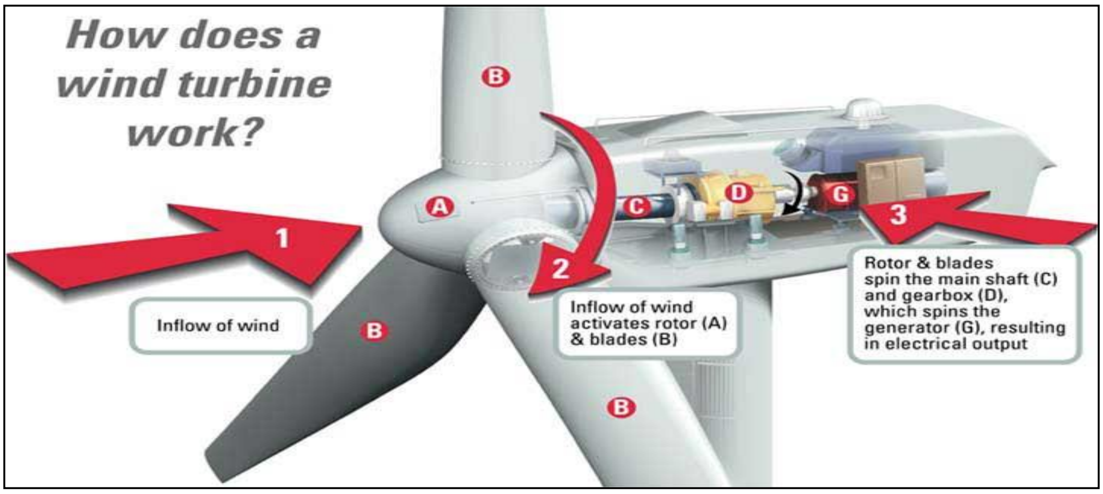


Figure: Wind Turbine Working

The Figure illustrates the two types of turbines and typical subsystems for an electricity generation application. The subsystems include a blade or rotor, which converts the energy in the wind to rotational shaft energy; a drive train, usually including a gearbox and a generator, a tower that supports the rotor and drive train, and other equipment, including controls, electrical cables, ground support equipment, and interconnection equipment.

Wind electric generator converts kinetic energy available in wind to electrical energy by using rotor, gear box and generator.

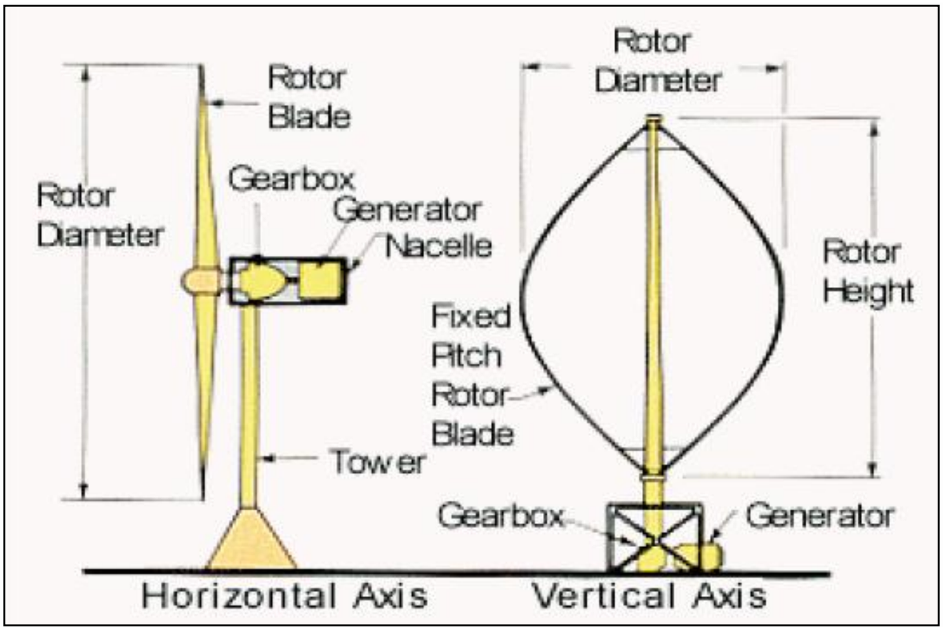


Figure: Wind Turbine Configurations

8. What is the necessity of energy storage? OR Why energy storage is required?

Energy storage takes energy and stores it for use at a later time. This can be accomplished many ways: chemically (e.g. batteries), gravitationally (e.g. pumped hydro), mechanically (e.g. flywheels) and thermally (e.g. molten salt). Energy Storage became a dominant factor in economic development with the widespread introduction of electricity Unlike other common energy storage in prior use such as wood or coal, electricity must be used as it is being generated, or converted immediately into another form of energy such as potential, kinetic or chemical. For example the pumped-storage hydroelectricity in Norway has a capacity of 30 GW, which could be expanded to 60 GW, which would be enough to be the battery

As energy storage technology may be applied to a number of areas that differ in power and energy requirements. it includes batteries (both conventional and advanced), flywheels, electrochemical capacitors, superconducting magnetic energy storage (SMES), power electronics, and control systems. The need to promote more energy storage is related to the increase in intermittent wind and solar and to the demand peak increase. When the intermittent renewable share is lower than 15% to 20 % of the overall electricity consumption, the grid operators are able to compensate the intermittency. This is not the case when the share exceeds 20-25%, as is reached at times in Denmark, Spain and Germany. Energy storage can provide multiple benefits to both the power industry and its customers. Among these benefits are:

- Improved power quality and the reliable delivery of electricity to customers;
- Improved stability and reliability of transmission and distribution systems;
- Increased use of existing equipment, thereby deferring or eliminating costly upgrades;
- Improved availability and increased market value of distributed generation sources.

9. What are the different methods of energy storage? OR State the types of energy storage and explain any one.

Following are the energy storage methods:

1. Chemical energy storage
2. Electrochemical energy storage
3. Electrical energy storage
4. Mechanical energy storage
5. Thermal energy storage

Following are the description of methods of energy storage:

1. Chemical energy storage:

Chemical energy is a form of potential energy, storage of which further depends on its source. We know the following methods or mediums for chemical energy storage:

- **Hydrogen:** Although the colourless, odourless, tasteless and non-toxic gas has potentials as a source of energy, it is primarily used as an energy storage medium for subsequent use. Examples include underground hydrogen storage involving the use of underground caverns and empty gas and oil fields to store grid energy for intermittent energy resources such as wind power and solar energy for instance.
- **Biofuels and biomass:** They do not refer to energy storage as such but are rather examples of chemical energy storage. When wood logs or biofuels are burned, they release energy that is stored in the bonds of molecules and atoms.
- **Liquid nitrogen:** Just like hydrogen, liquid nitrogen shows potentials as a source of energy but instead, it is used as a form of energy storage. It can be used to generate electricity or refrigeration and cooling.
- **Oxy-hydrogen:** It is a mixture of oxygen and hydrogen which when ignited, releases high pressure and high temperature steam that can be used to generate electricity.
- **Hydrogen peroxide:** it is best known for its uses as bleach and cleaning agent although it is also used as rocket fuel vanadium pent oxide; it is used in vanadium redox batteries, a type of flow batteries that are used to store various forms of chemical energy including electric power produced by wind farms.

2. Electrochemical energy storage: It involves the use of various devices which convert chemical energy into electricity. Examples include:

- **Battery:** It is a widely used device that converts stored chemical energy into electricity. Two basic types of batteries exist which known as the primary batteries or non-rechargeable batteries and secondary batteries which can be recharged and used multiple times.

- **Fuel cell:** It refers to a device which converts chemical energy into electricity through chemical reaction. Several different types of fuel cells exist but all feature a cathode, anode and an electrolyte.

3. Electrical energy storage: It involves the use of an electric field to store energy. Examples include:

- **Capacitor and super capacitor (double-layer capacitor):** Both are electrical components that are used to store electric charge but as its name reveals, super capacitor can store more electric charge. Capacitor is typically used a short-term backup power, while super capacitor can also be used to power large engines including vehicles. But it is also often used to run low-power devices such as portable media players, PC Cards, etc..

- **Superconducting magnetic energy storage (SMES):** It refers to a relatively new technology which stores electricity from the grid within a magnetic field that is created by the flow of current in a coil.

4. Thermal energy storage: It refers to methods that are used to store thermal energy in order to use it to cool or heat buildings when the temperature inside is above or below the internal energy in the stored substance.

- **Hot water storage tank:** It refers to a water tank that stores hot water for space heating, washing, bathing, etc.. Hot water storage tanks are a common feature of wood furnaces and solar thermal collectors.

- **Storage heater:** It is an electric heater that stores energy during the evening or night and releases heat during the day when the price of base load electricity is higher. Storage heaters work by accumulating heat in ceramic material or clay bricks.

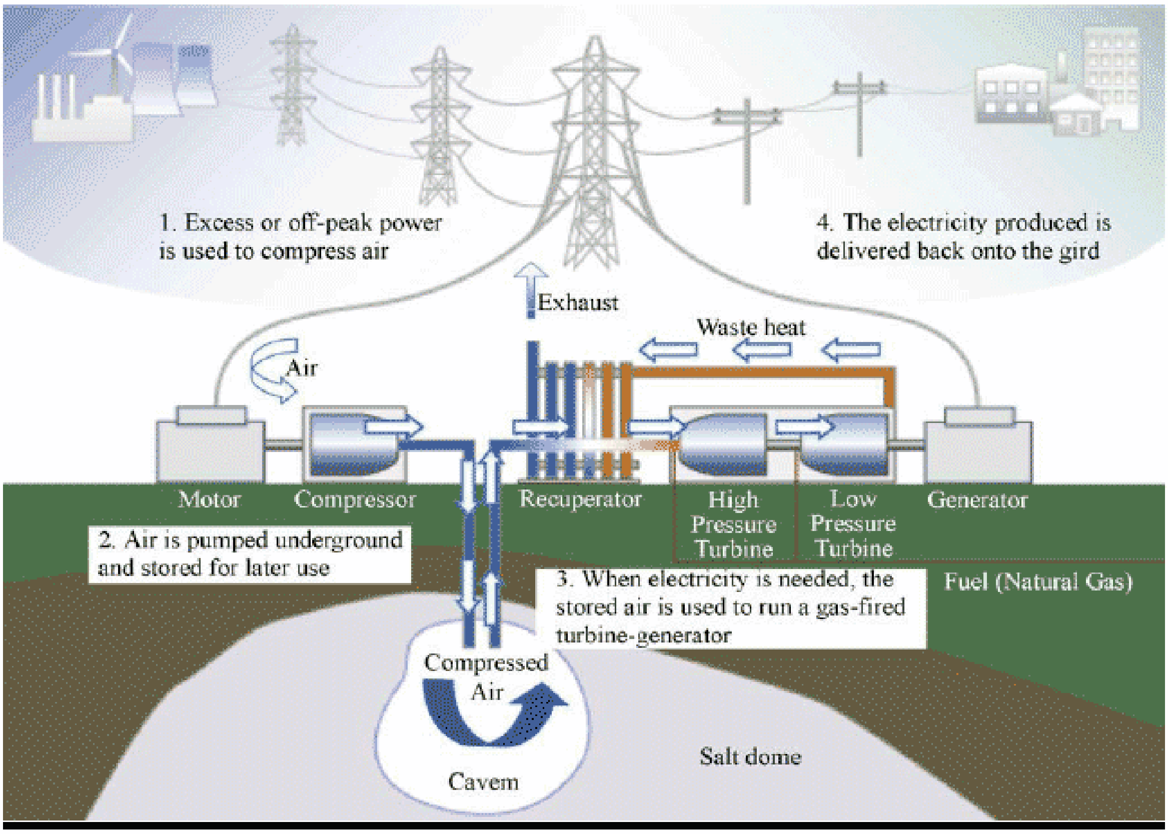
- **Steam accumulator:** It refers to a steel tank that contains steam under pressure. It is used to balance between supply and demand by accepting steam when the supply is greater than demand and to release it when demand exceeds the supply.

5. Mechanical energy storage: Methods to store energy that is produced by motion include:

- **Hydraulic accumulator:** It is a storage reservoir which stores non-compressible fluid under pressure. There are several types of hydraulic accumulators but the most widely used is the so-called compressed gas accumulator which contains gas under pressure, usually nitrogen.

- **Flywheel energy storage:** Like its name suggests, it is a method to store energy through a flywheel. This type of mechanical energy storage is used to store grid energy and energy that is generated by wind farms but it also shows potentials in transportation and as an emergency power source.

10. Explain compressed air energy storage (C.A.E.S.).



CAES technology has been in use for 30 years. A CAES plant stores electrical energy in the form of air pressure, then recovers this energy as an input for future power generation. CAES plants can be divided into the following proven components:

- **Power system:** turbine(s), generator and the recuperator or selective catalytic reduction (SCR) unit.
- **Compression system**: complete with coolers.
- **Containment vessel** (or cavern) with airflow piping
- **Control equipment:** switchgear, substation, cooling system etc.

In essence, the CAES cycle is a variation of a standard gas turbine generation cycle. In a typical gas fired generation cycle, the turbine is physically connected to an air compressor. When gas is combusted in the turbine, approximately two-thirds of the turbine's energy goes back into air compression.

In a CAES plant, the compression cycle is separated from the combustion and generation cycle. Off-peak or excess electricity is used to pre-compress air, which is then held for storage, typically in an underground cavern.

When the CAES plant regenerates the power, the compressed air is released from the cavern and heated through a recuperator before being mixed with fuel (e.g. natural gas) and expanded through a turbine to generate electricity. Because the turbine's output no longer needs to be used to drive an air compressor, the turbine can generate almost three times as much electricity as the same size turbine in a simple cycle configuration. This uses far less fuel per MWh produced. The stored compressed air takes the place of gas that would otherwise have been burned in the generation cycle and used for compression power.

Economics of CAES:

Compressed air energy storage is the only other commercially available technology (besides pumped-hydro) able to provide the very-large system energy storage deliverability (above 100MW in single unit sizes). Since CAES facilities have no need for air compressors tied to the turbines, they can produce two to three times as much power as conventional gas turbines for the same amount of fuel.

The business proposition for compressed air storage derives from the savings from mitigating external costs associated with production, such as transmission or integration costs; and the benefit from making the power worth more, such as by adding capacity value or by shaping the power flow over time to meet peaking requirements.

Capacity value can be thought of as the value of being able to guarantee that megawatts can be made available to serve peak load for long-term planning purposes, and megawatts of capacity can therefore replace/defer the construction of the next physical generation asset. Firming value is the value of being able to guarantee the provision of energy, ancillary services, and short-term capacity such that better commitment decisions can be made. .

It doesn't matter whether the energy is coming from a renewable conversion system, from storage, or from both. The important factor is the net energy delivered to the grid. Due to economies of scale, a smaller CAES plant would be unlikely to demonstrate economic viability, since the capital costs per kW would be disproportionately high.

11.Discuss solar energy storage methods.

The fundamental drawback of any renewable energy is its intermittent nature. Wind and solar power installations generate power only intermittently and with a highly variable output. Solar power is available only 6-8 hours during the day. Also conditions like cloud covers, dust accumulation and other weather related events can create significance fluctuations in solar power. When the wind is blowing or the sun is shining, excess power should be stored and made available during suboptimal generating conditions or during peak demand. Reliance on solar or wind can thus affect grid stability and hence can put limits on the development of solar energy. Hence the requirement of energy storage has led to greater demand for alternative energy storage facilities to support the grid.

There is always a mismatch between availability of solar energy and energy demand on the system. The available energy is either surplus or deficient to meet the demand if the solar energy is utilized directly by the system. In order to balance generation with consumption and to maintain grid stability, it is necessary to store excess at appropriate times and supply this energy.

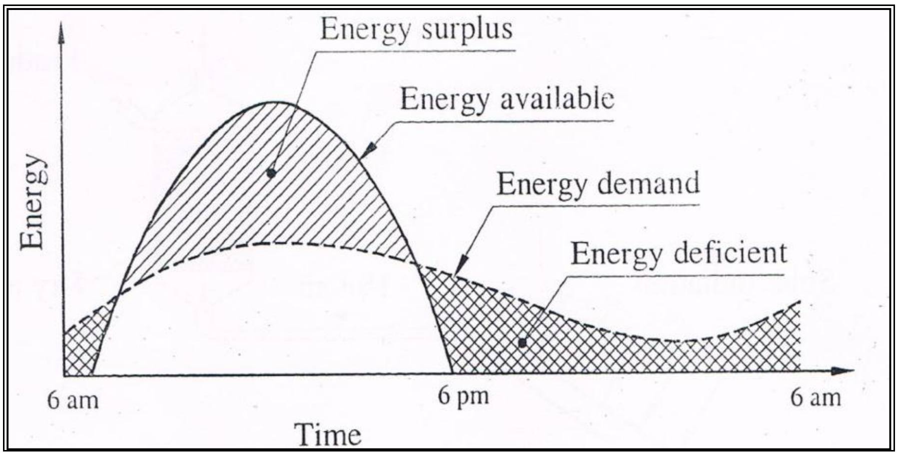


Figure: Variation of availability of solar energy and demand

Energy storage is accomplished devices or physical media that store energy when excess energy available and to perform useful operation or supply the energy at a later time. Energy storage devices can manage the amount of power required to supply customers at times when need is greatest, which is during peak load. These devices can also help make renewable energy, whose power output cannot be controlled by grid operators, smooth and dispatch able.

Advantages of Energy Storage:

a. Energy storage helps make renewable energy resources more viable.
b. The size and cost of equipments of power plant can be reduced by 20 to 40 percent.
c. Reduces use of power plants which produces more emissions.
d. Increases load factor of generation up to 25 percent.
e. Delays the need for additional power plants.
f. Energy storage reduces size of standby or peak load units.
g. Energy storage provides a quantifiable return on investment.

Energy Storage methods:

(1) Liquid storage system:

Liquid storage system utilizes heat capacity of liquid medium like water, molten salt, solar pond, oil, liquid metals, etc. To store thermal energy. Water is most commonly used medium in a sensible liquid heat storage system for storing thermal energy at low temperatures because of its low cost, highest specific heat, high density, high thermal conductivity, easy to handle, nontoxic, noncombustible etc. It has added advantages that it can also act as the heat transfer medium for heat flow to and from the storage, thus eliminating for a heat exchanger. However, it is corrosive, and the temperature range is limited between 0°C and 100°C unless antifreeze additive are added or it is pressurized.

Most small and medium solar water heating and space heating systems use hot water insulated storage tanks located either inside or outside the buildings. Storage in this manner is economical only for a few days since heat losses become prohibitive over long durations. The sizes of the tanks used vary from a few hundred liters to a few thousand cubic meters. An approximate thumb rule followed for fixing the size is to use about 75 to 100 liters of storage per square meter of collector area.

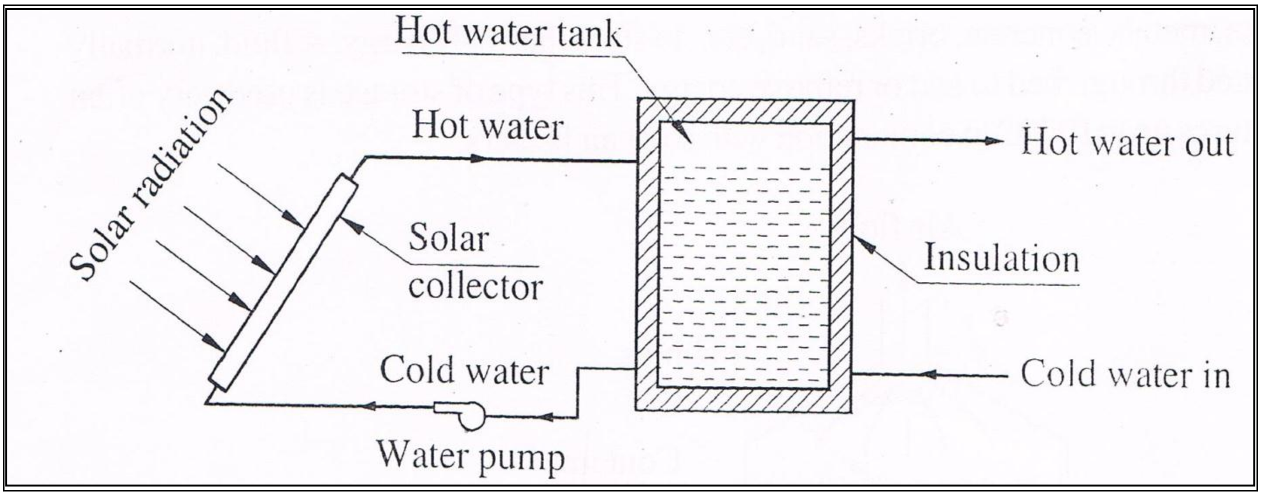


Figure: Short term thermal energy water storage

Large size and long term storage of hot water in underground reservoirs is possible without the use of special insulating materials. Heat losses are small due to smaller surface to volume ratio. Water may be stored in aquifers which are confined between impermeable layers above and below as shown in fig. Here cold ground water from zone-A of an aquifer is heated by passing it through a heat exchanger and returned to zone-B where it is stored. During the discharging, the hot water from zone-B flows back through the heat exchanger where it gives out the stored heat and returns to zone-A. The heat from such aquifers can be retrieved with negligible losses which may be of the order of 1% only.

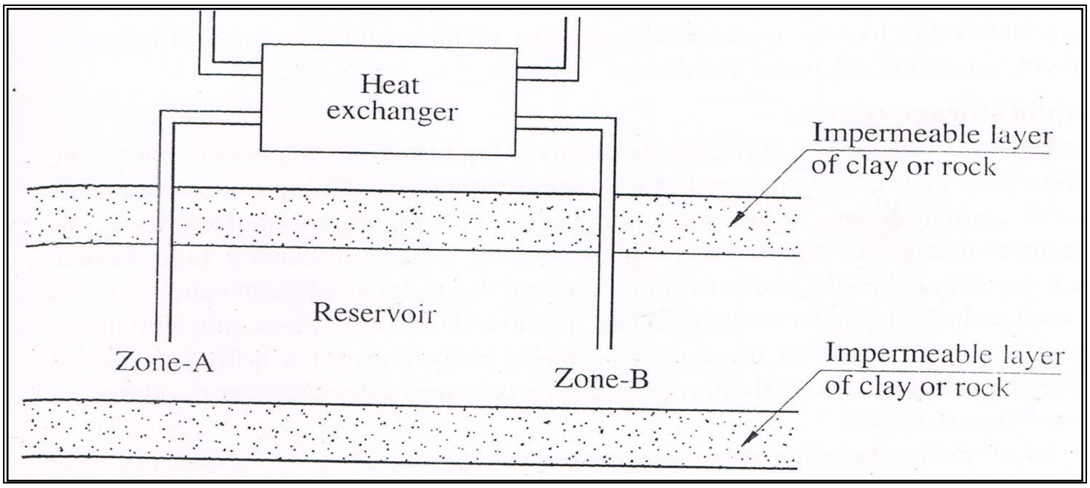


Figure: Long term thermal energy water storage in underground layers

(2) Solar pond:

In the continuous or discontinuous energy supply system, the energy storage is required to balance the energy of mismatches between the demand and the supply of energy. Especially in solar energy system the energy available only particular duration and only day time, hence thermal energy storage is required to improve performance and reducing total cost. In this contest, attention has been focused on the possibility of using large area of water pond of small depth for absorbing and storing solar radiation instead of using flat plate collector and hot water storage tanks.

However, experience shows that the water in such a pond usually heats up only a few degrees because of the heat loss occur due to natural convection currents which are set into motion as soon as heat is absorbed at the bottom of the pond. One would obtain a significant rise in the water temperature only if the natural convection could be prevented.

An artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection is called solar pond. A solar pond is a pool of salt water which acts as a large scale solar thermal energy collector as well as integral heat storage for supplying thermal energy. It consists of an axpanse of water about a meter or two in depth in which salts like sodium or magnesium chloride are dissolved. The salt water naturally forms a vertical salinity gradient also known as a “halocline”, in which low-salinity water floats on top of high-salinity water. The layers of salt solutions has a uniformly high salt concentration.

A schematic diagram of solar pond is shown in fig. It about 2 m deep with a thick durable plastic liner laid at the bottom. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, concentration varying from 20% to 30%.There are 3 distinct layers of water in the pond as:

(1) The top layer-**Surface convective zone**: Normally, it has small thickness, about 0.3m to 0.5m.It has a low, uniform concentration as well as a fairly uniform temperature close to atmospheric temperature.

(2) An intermediate insulating layer with a salt gradient-**Non -convective zone:** It has much thicker, about 1.0m to 1.5m and occupies more than half the depth of the pond. Both concentration and temperature increases with depth in this zone. This layer establishes a density gradient that prevents heat exchange by natural convection.

(3) The bottom layer-**Lower convection or storage zone:** Normally, it has a thickness about 0.5m to 1m and high salt content. Both concentration and temperature are nearly constant in this zone. This zone serves as the main heat collection as well as thermal storage medium.

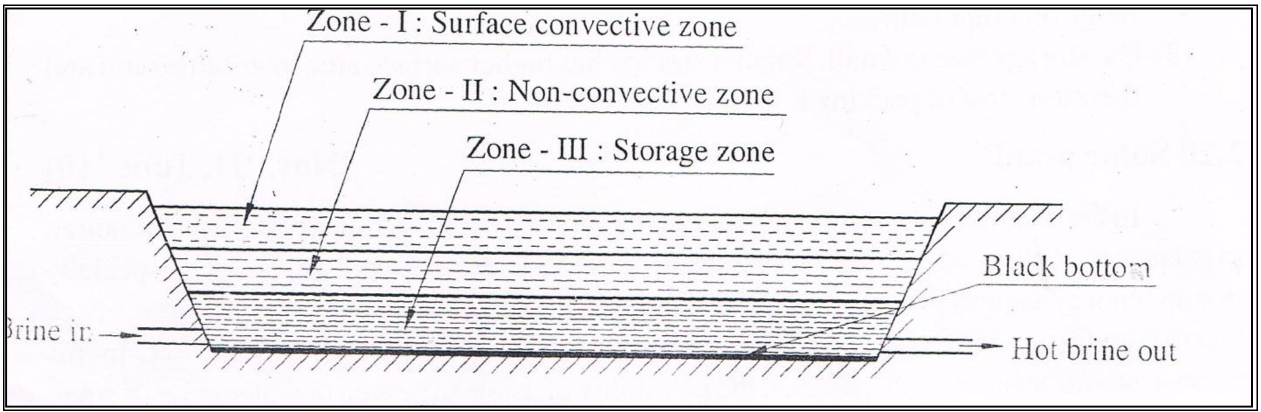


Figure: Typical solar pond

If the water is relatively translucent, and the pond’s bottom has high optical absorption then nearly all of the incident solar radiation will go into heating the bottom layer. When solar energy is absorbed in the water, its temperature increases which causes thermal expansion and reduced density. If the water were fresh the low-density water would float to the surface, causing circulation of water by convection.

The temperature gradient alone causes a density gradient that decreases with depth. The situation is changed the pond contains salts water at bottom with layer of fresh water above it. In this case the salinity gradient forms a density gradient that increases with depth and this counteracts the temperature gradient, thus preventing heat in the lower layers from moving upwards by convection and leaving the pond. Because of its salt content, the solar pond bottom is dense than the cooler fresh water at the top, and hence it does not tend to rise. A relatively stable layer of heated salt water is thus produced at the bottom of the pond with a lighter layer of cooler fresh water, which acts as a heat insulator, above it. Normally, the temperature at the bottom of the pond will rise to over 90℃ while the temperature at the pond is usually around 30℃.The temperature and concentration profile for typical 2m depth solar pond is shown in fig.

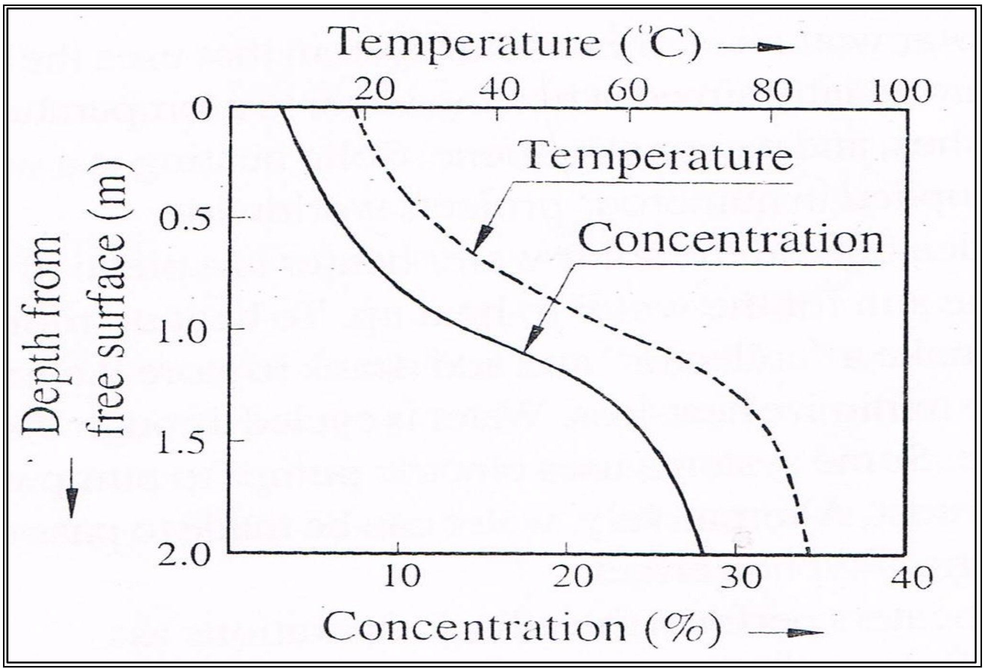


Figure: Temperature and concentration profile for a typical solar pond

The solar pond can be used for various applications, such as heating and cooling of buildings, industrial process heating, desalination, refrigeration, heating animal housing, **d**rying crops on forms, heat for biomass conversion and solar power generation. The heat trapped in the salty bottom layer can be used for many different purposes, such as the heating of buildings or industrial hot water or to drive an organic Rankwise cycle turbine or Stirling engine for generating electricity.

The first solar pond in India was built at Bhuj. The project was sanctioned under the National Solar Pond Programme by the Ministry of Non-convention Energy Sources in 1987 and completed in 1993 after a sustained collaborative effort by TERI the Gujarat Energy Development Agency, and the GDDC(Gujarat Dairy Development corporation Ltd).The solar pond successfully demonstrated the expediency of the technology by supplying 80,000 litres of hot water daily to the plant. The solar pond functioned effortlessly till the year 2000 when serve financial losses crippled GDDC.

12. Explain how Green House concept saves energy <u>OR</u> Explain Greenhouse concept.

A **greenhouse** also called a **glasshouse** is a building in which plants are grown. These structures range in size from small sheds to industrial-sized buildings. A miniature greenhouse is known as a cold frame. A greenhouse is a structural building with different types of covering materials, such as a glass or plastic roof and frequently glass or plastic walls; it heats up because incoming visible sunshine is absorbed inside the structure. Air warmed by the heat from warmed interior surfaces is retained in the building by the roof and wall; the air that is warmed near the ground is prevented from rising indefinitely and flowing away. This is not the same mechanism as the "greenhouse effect".

Life on earth is made possible by energy from the sun, which arrives mainly in the form of visible light. About 30 percent of the sunlight is scattered back into space by outer atmosphere.

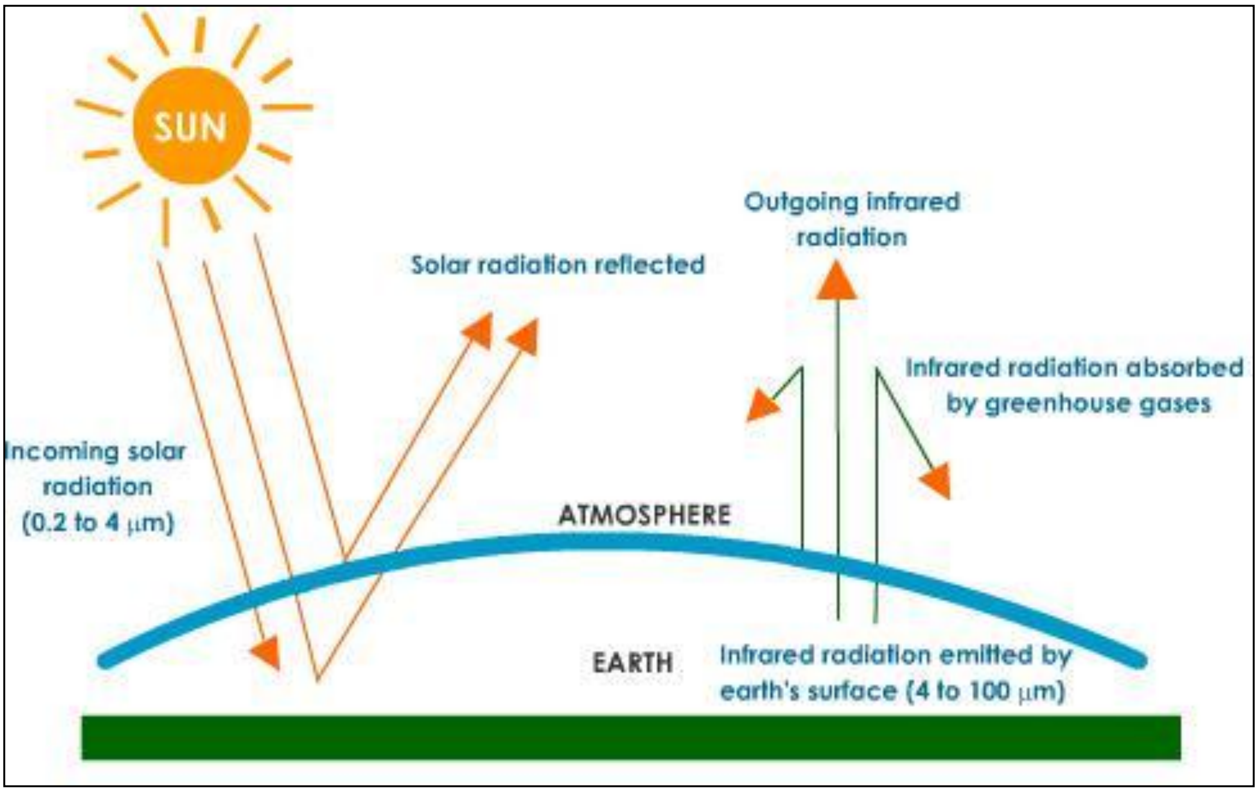


Figure: The Greenhouse Effect

And the balance 70 percent reaches the earth's surface, which reflects it in form of infrared radiation. The escape of slow moving infrared radiation is delayed by the greenhouse gases. A thicker blanket of greenhouse gases traps more infrared radiation and increase the earth's temperature.

Greenhouse gases makeup only 1 percent of the atmosphere, but they act as a blanket around the earth, or like a glass roof of a greenhouse and keep the earth 30 degrees warmer than it would be otherwise - without greenhouse gases, earth would be too cold to live.

Human activities that are responsible for making the greenhouse layer thicker are emissions of carbon dioxide from the combustion of coal, oil and natural gas; by additional methane and nitrous oxide from farming activities and changes in land use; and by several man made gases that have a long life in the atmosphere.

The increase in greenhouse gases is happening at an alarming rate. If greenhouse gases emissions continue to grow at current rates, it is almost certain that the atmospheric levels of carbon dioxide will increase twice or thrice from pre-industrial levels during the 21st century. Even a small increase in earth's temperature will be accompanied by changes in climate such as cloud cover, precipitation, wind patterns and duration of seasons. In an already highly crowded and stressed earth, millions of people depend on weather patterns, such as monsoon rains, to continue as they have in the past. Even minimum changes will be disruptive and difficult.

Carbon dioxide is responsible for 60 percent of the "enhanced greenhouse effect". Humans are burning coal, oil and natural gas at a rate that is much faster than the rate at which these fossil fuels were created. This is releasing the carbon stored in the fuels into the atmosphere and upsetting the carbon cycle (a precise balanced system by which carbon is exchanged between the air, the oceans and land vegetation taking place over millions of years). Currently, carbon dioxide levels in the atmospheric are rising by over 10 percent every 20 years.