Biyani's Think Tank

Concept based notes

Non-Conventional Energy Sources

(B.Tech)

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Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the "Teach Yourself" style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, *Chairman* & Dr. Sanjay Biyani, *Director* (*Acad.*) Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this Endeavour. They played an active role in coordinating the various stages of this Endeavour and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

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Author

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Syllabus

4CH6.3(ME) - NON-CONVENTIONAL ENERGY SOURCES

Unit – I

Introduction: Energy scene of supply and demand in India and the world, energy consumption in various sectors, potential of non-conventional energy resources. Detailed study of the following sources with particular reference to India.

Solar Energy: Solar radiation and its measurement, limitations in the applications of Solar Energy, Solar collectors – types, and constructional details. Solar water heating, applications of Solar Energy for heating, drying, space cooling, water desalination, solar concentrators, photovoltaic power generation using silicon cells.

Unit – II

Bio-Fuels: Importance, combustion, pyrolysis and other thermo chemical processes for biomass utilization. Alcoholic fermentation, anaerobic digestion for biogas production.

Unit – III

Wind Power: Principle of energy from wind, windmill construction and operational details and electricity generation and mechanical power production.

Tidal Power: Its meaning, causes of tides and their energy potential, enhancement of tides, power generation from tides and problems. Principles of ocean thermal energy conversion (OTEC) analysis and sizing of heat exchangers for OTEC.

Unit – IV

Geothermal Energy: Geo technical wells and other resources dry rock and hot aquifer analysis , harnessing geothermal energy resources.

Unit – V

Energy Storage and Distribution: Importance, biochemical, chemical, thermal, electric storage. Fuel cells, distribution of energy.

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Unit 1

Introduction and Solar Energy

Q1. Define energy and its types. What are the various types of energy resources?

Ans:

Energy can be defined as the ability to do work. If an object or organism does work (exerts a force over a distance to move an object) the object or organism uses energy. Because of the direct connection between energy and work, energy is measured in the same unit as work: joules (J). In addition to using energy to do work, objects gain energy because work is being done on them.

Energy is all around us. we can hear energy as sound. we can see energy as light and we can feel it as wind. we use energy when you hit a softball, lift your book bag, compress a spring. Living organisms need energy for growth and movement.

Types of energy:

The five main forms of energy are:

- Heat
- Chemical
- Electromagnetic
- Nuclear
- Mechanical

Heat Energy

The internal motion of the atoms is called heat energy, because moving particles produce heat. Heat energy can be produced by friction. Heat energy causes changes in temperature and phase of any form of matter.

Chemical Energy

Chemical Energy is required to bond atoms together. And when bonds are broken, energy is released. Fuel and food are forms of stored chemical energy.

Electromagnetic Energy

Power lines carry electromagnetic energy into your home in the form of electricity. Light is a form of electromagnetic energy. Each color of light (Roy G Bv) represents a different

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amount of electromagnetic energy. Electromagnetic Energy is also carried by X-rays, radio waves, and laser light.

Nuclear Energy

The nucleus of an atom is the source of nuclear energy. When the nucleus splits (fission), nuclear energy is released in the form of heat energy and light energy. Nuclear energy is also released when nuclei collide at high speeds and join (fuse). The sun's energy is produced from a nuclear fusion reaction in which hydrogen nuclei fuse to form helium nuclei.

Mechanical Energy

When work is done to an object, it acquires energy. The energy it acquires is known as mechanical energy. When you kick a football, you give mechanical energy to the football to make it move.

E.g.When you throw a balling ball, you give it energy. When that bowling ball hits the pins, some of the energy is transferred to the pins (transfer of momentum).

There is a **Energy Conservation law**, which states that:

Energy can neither be created nor be destroyed it can be converted into one form to another.

Energy can be changed from one form to another. Changes in the form of energy are called energy conversions.

All forms of energy can be converted into other forms.

- The sun's energy through solar cells can be converted directly into electricity.
- Green plants convert the sun's energy (electromagnetic) into starches and sugars (chemical energy).
- In an electric motor, electromagnetic energy is converted to mechanical energy.
- In a battery, chemical energy is converted into electromagnetic energy.
- The mechanical energy of a waterfall is converted to electrical energy in a generator.

The most common energy conversion is the conversion between potential and kinetic energy.

All forms of energy can be in either of two states:

- Potential
- Kinetic

Kinetic Energy

The energy of motion is called kinetic energy. The faster an object moves, the more kinetic energy it has. The greater the mass of a moving object, the more kinetic energy it has. Kinetic energy depends on both mass and velocity.

K.E. = mass x velocity

Potential Energy

Potential Energy is stored energy. Stored chemically in fuel, the nucleus of atom, and in foods. Or stored because of the work done on it:

- Stretching a rubber band.
- Winding a watch.
- Pulling back on a bow's arrow.
- Lifting a brick high in the air.

Classification of energy resources:

- Commercial
- Non - commercial
- Renewable
- Non – renewable

There are two types of energy sources:

Conventional sources:

Energy sources which are available in less amount and will one day be exhausted, are known as conventional sources of energy. E.g. fossil fuels

Non - conventional sources:

The energy sources which are renewable and can be regenerated are known as renewable or non-conventional sources of energy.

As the population is increasing the energy consumption also is increasing. Hence we need such sources of energy which can be renewed from time to time and they can meet our needs regularly.

The different sources of energy are:

1. Fossil fuels
2. Biomass
3. Hydro power plant
4. Wind energy

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5. Solar energy
6. Geothermal energy
7. Ocean thermal energy
8. Tidal energy
9. Wave energy
10. Nuclear energy

Q2. Describe solar energy and solar radiations.

Ans:

Solar energy is the ultimate source of energy from millions of years and it is a renewable energy. This energy consists of radiant light and heat energy from the sun. Out of all energy emitted by sun only a small fraction of energy is absorbed by the earth. Just this tiny fraction of the sun's energy that hits the earth is enough to meet all our power needs. Using present solar techniques some of the solar energy reaching the earth is utilized for generating electricity etc…. Even then the energy demand met by using solar energy is very less.

The fossil fuels are non renewable sources so we can not depend on them forever. Though nuclear energy is a clean and green energy ,as said by Dr.A.P.J Abdul Kalam, there are always some problems associated with it. So the only option we have is solar energy because it is a nonpolluting and silent source of electricity and also low maintainence and long lasting energy.

Solar radiation is potential energy source for power generation through use of solar collector and photovoltaic cells. Solar energy can be used as thermal energy source for ***solar heating***, ***Airconditioning*** and ***cooling systems***. Solar radiation has important effects on both the heat gain and heat loss of a building.

Solar Radiation

The Intensity of solar radiation incident on a surface is important in the design of solar collectors, photovoltaic cells, solar heating and cooling systems, and thermal management of building. This effect depends on both the location of the sun in the sky and *the clearness of the atmosphere* as well as on the nature and orientation of the building.

Black body emission

The thermal radiation emitted by a black substance covers a range of wavelength (λ), referred as spectral distribution. The total black body emissive power is obtained by integrating the spectral emissive power over the entire range of wavelengths.

The sun gives off 3.90×10^{26} Watts (Universe 4th edition, p585). The earth intercepts energy equal to a disk equal to the earth's diameter. Earth's radius is 3,393,000 meters (WGS84 value is 6,378,137 m/2). Earth's solar interception area is (3.14)(3,393,000)^2. This equals 3.62×10^{13} m^2 . The amount of power crossing earth's orbit is 1388 watts / m^2

.Therefore: the earth intercepts $5.02x10^{16}$ watts. We see that the earth intercepts 50 quadrillion watts of solar power each day. **Extraterrestrial Radiation:**

Solar radiation that would be received in the absence of earth atmosphere. Extraterrestrial solar radiation exhibit a spectral distribution over a ranger of wavelength: 0.1- 2.5 μm and Includes ultraviolet, visible and infrared rays.

Traterrestrial Radiation:

Solar radiation that would be received in the presence of earth atmosphere.

Solar Radiation Intensity at Earth Surface:

Solar radiation incident on a surface at earth has three different components:

1. **Direct radiation:**
The solar radiation received from the sun without having been scattered by the atmosphere.

2. **Diffuse radiation:**
Radiation received and remitted in all directions by earth atmosphere:

3. **Reflected radiation:**
Radiation reflected by surrounding surfaces.

Q3. What are the different types of solar collectors plates.

Ans:

1. Solar Thermal Energy:
Converts solar radiation in thermal heat energy

- Active Solar Heating

- Passive Solar Heating

- Solar Thermal Engine

2. Solar Photovoltaics

Converts solar radiation directly into electricity

The basic purpose of a solar thermal energy system is to collect solar radiation and convert into useful thermal energy. The system performance depends on several factors, including availability of solar energy, the ambient air temperature, the characteristic of the energy requirement, and especially the thermal characteristics of solar system itself. The solar collection system for heating and cooling are classified as passive or active.

Active System

Active systems consist of components which are to a large extent independent of the building design. Often require an auxiliary energy source (Pump or Fan) for transporting the solar energy collected to its point of use. Active system are more easily applied to existing buildings .

Passive System

Passive systems collect and distribute solar energy without the use of an auxiliary energy source. Dependent on building design and the thermal characteristics of the material used.

For applications such as air conditioning, central power generation, and numerous industrial heat requirements, flat plate collectors generally cannot provide carrier fluids at temperatures sufficiently elevated to be effective. They may be used as first-stage heat input devices; the temperature of the carrier fluid is then boosted by other conventional heating means. Alternatively, more complex and expensive concentrating collectors can be used. These are devices that optically reflect and focus incident solar energy onto a small receiving area. As a result of this concentration, the intensity of the solar energy is magnified, and the temperatures that can be achieved at the receiver (called the "target") can approach several hundred or even several thousand degrees Celsius. The concentrators must move to track the sun if they are to perform effectively.

Flate plate collector:

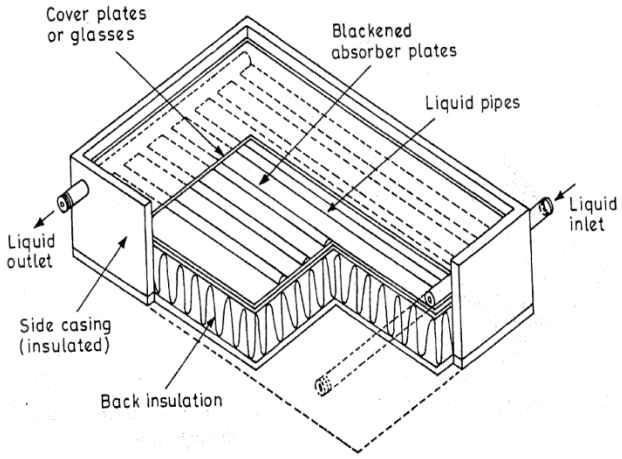
These are the main parts of a Flat Plate Collector:

- Glazing
  - This is the outer part of the system and is made up of one or more sheets of material that transmits radiation. Usually the glass is used for the material to maximize the amount of radiation admitted to the collector while minimizing heat loss. Transmits up to 90% of incident short wave radiation, negligible emission of long wave radiation (like a greenhouse). If the Plastic is used then high transmittance of short wave radiation, but sensitivity to temperature limits usefulness.
- Absorbing Plate
  - Absorbing plate used to absorb the radiations and convert it to the heat. Then this heat is transfer to the tube. Minimize loss of heat to atmosphere and collector. Usually use either copper, aluminum or steel with black coating to maximize absorption
- Fluid Tube
  - This allows for flow of heat transferring the liquid. It has two terminal in and out.
- Insulation

- Insulation is done for retain the heat within collector. Insulation material should be of minimal weight and maximum thermal insulation. Typically use fiberglass, or mineral wool as they are also inexpensive.

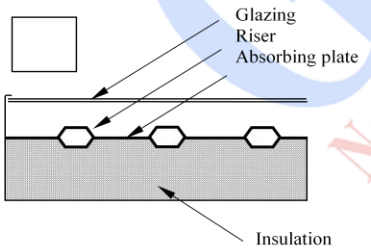
- Casing
  - Casing is the part of the system which holds the entire assembly together.

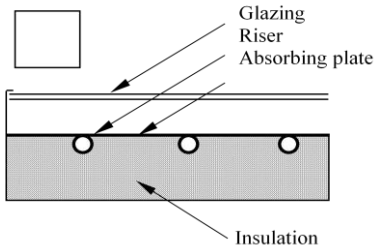
Solar flate plate collector:



The useful energy decreases with increasing temperature difference and minimizing thermal loss to surroundings is critical for optimum performance. Heat loss is a function of temperature difference between collector and ambient.

Types of flat-plate collectors Water systems:





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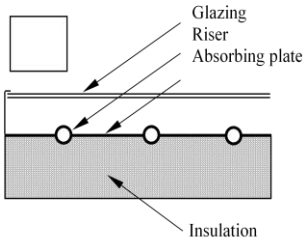
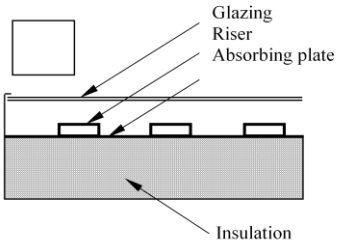
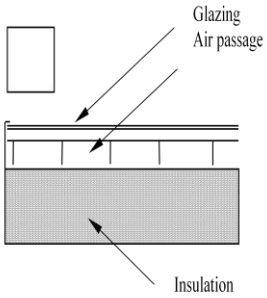
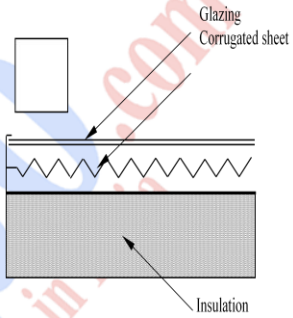




Types of flat-plate collectors Air systems





Q4. Describe concentrating collector.

Ans:

For applications such as air conditioning, central power generation, and numerous industrial heat requirements, flat plate collectors generally cannot provide carrier fluids at temperatures sufficiently elevated to be effective. They may be used as first-stage heat input devices; the temperature of the carrier fluid is then boosted by other conventional heating means. Alternatively, more complex and expensive concentrating collectors can be used. These are devices that optically reflect and focus incident solar energy onto a small receiving area. As a result of this concentration, the intensity of the solar energy is magnified, and the temperatures that can be achieved at the receiver (called the "target") can approach several hundred or even several thousand degrees Celsius. The concentrators must move to track the sun if they are to perform effectively.

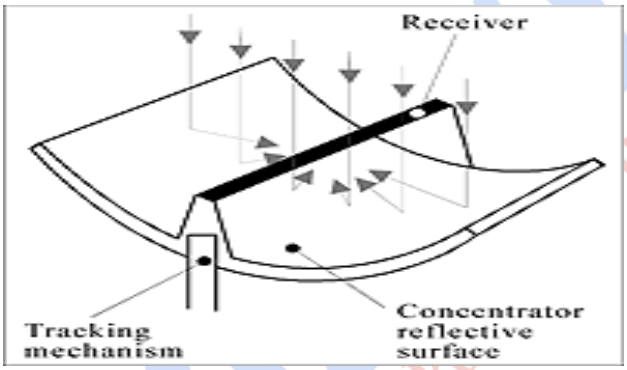
Concentrating, or focusing, collectors intercept direct radiation over a large area and focus it onto a small absorber area. These collectors can provide high temperatures more efficiently than flat-plate collectors, since the absorption surface area is much smaller. However, diffused sky radiation cannot be focused onto the absorber. Most concentrating collectors require mechanical equipment that constantly orients the collectors toward the sun and keeps the absorber at the point of focus. Therefore; there are many types of concentrating collectors.

There are four basic types of concentrating collector:

- Parabolic trough system
- Parabolic dish
- Power tower
- Stationary concentrating collectors

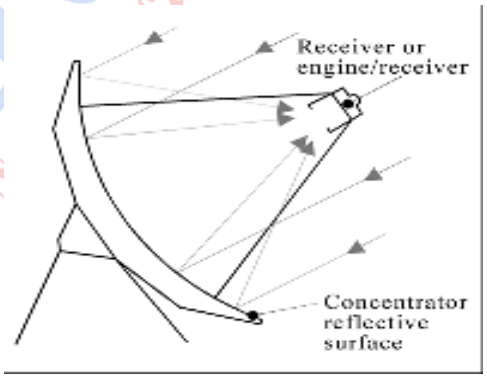
Parabolic trough system:

Parabolic troughs are devices that are shaped like the letter "u". The troughs concentrate sunlight onto a receiver tube that is positioned along the focal line of the trough. Sometimes a transparent glass tube envelops the receiver tube to reduce heat loss.



Parabolic dish systems :

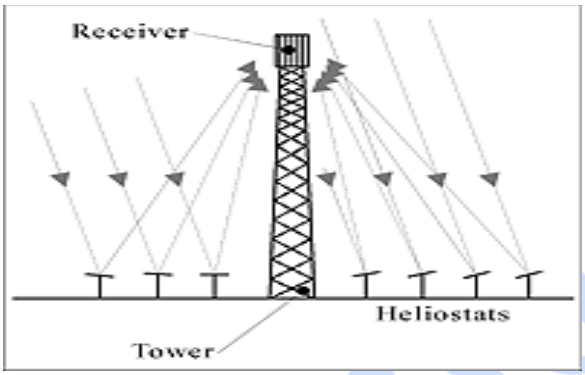
A parabolic dish collector is similar in appearance to a large satellite dish, but has mirror-like reflectors and an absorber at the focal point. It uses a dual axis sun tracker.



A parabolic dish system uses a computer to track the sun and concentrate the sun's rays onto a receiver located at the focal point in front of the dish. In some systems, a heat engine, such as a Stirling engine, is linked to the receiver to generate electricity. Parabolic dish systems can reach 1000 °C at the receiver, and achieve the highest efficiencies for converting solar energy to electricity in the small-power capacity range.

Power tower system:

A heliostat uses a field of dual axis sun trackers that direct solar energy to a large absorber located on a tower. To date the only application for the heliostat collector is power generation in a system called the power tower.



Stationary concentrating solar collectors:

Stationary concentrating collectors use compound parabolic reflectors and flat reflectors for directing solar energy to an accompanying absorber or aperture through a wide acceptance angle. The wide acceptance angle for these reflectors eliminates the need for a sun tracker. This class of collector includes parabolic trough flat plate collectors, flat plate collectors with parabolic boosting reflectors, and solar cooker. Development of the first two collectors has been done in Sweden. Solar cookers are used throughout the world, especially in the developing countries.

Working principles of concentrating collectors:

Unlike solar (photovoltaic) cells, which use light to produce electricity, concentrating solar power systems generate electricity with heat. Concentrating solar collectors use mirrors and lenses to concentrate and focus sunlight onto a thermal receiver, similar to a boiler tube. The receiver absorbs and converts sunlight into heat. The heat is then transported to a steam generator or engine where it is converted into electricity. There are three main types of concentrating solar power systems: parabolic troughs, dish/engine systems, and central receiver systems.

These technologies can be used to generate electricity for a variety of applications, ranging from remote power systems as small as a few kilowatts (kW) up to grid connected applications of 200-350 megawatts (MW) or more. A concentrating solar power system that produces 350 MW of electricity displaces the energy equivalent of 2.3 million barrels of oil.

Q5. Describe measuring instruments for solar radiations.

Ans: These are the following instruments used for measuring the solar radiations:

Pyranometers:

Radiometers designed for measuring the irradiance on a plane surface, normally from solar radiation and lamps. The instruments are used in meteorological research, solar energy research, material testing, climate control in greenhouses, building physics, science and many other applications.

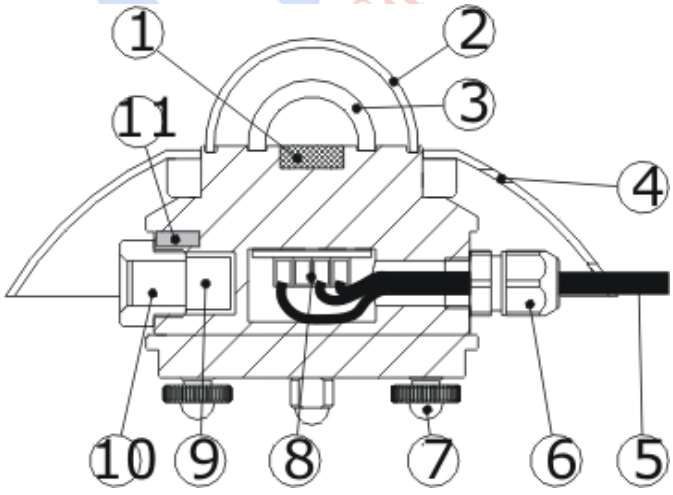
To make a measurement of irradiance, it is required by definition that the response to "beam" radiation varies with the cosine of the angle of incidence, so that there will be a full response when the solar radiation hits the sensor perpendicularly (normal to the surface, sun at zenith, 0 degrees angle of incidence)

- zero response when the sun is at the horizon (90 degrees angle of incidence, 90 degrees zenith angle) and 0.5 at 60 degrees angle of incidence.

Therefore, a pyranometer should have a so-called "directional response" or "cosine response" that is close to the ideal cosine characteristic.

In order to attain the proper directional and spectral characteristics, a pyranometer's main components are:

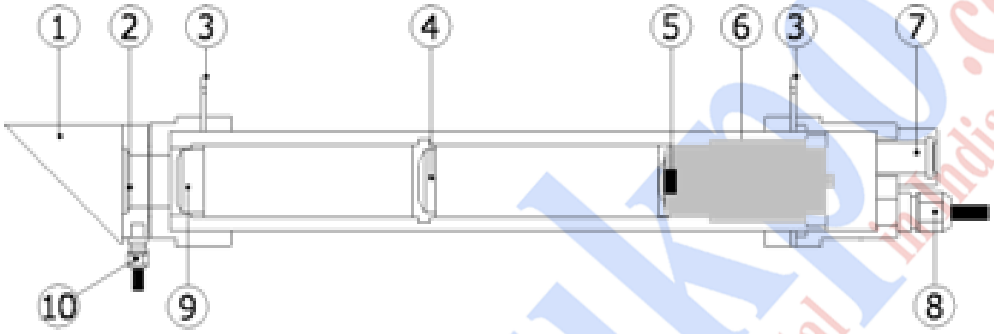
- A thermopile sensor with a black coating. This sensor absorbs all solar radiation, has a flat spectrum covering the 300 to 50,000 nm range, and has a near-perfect cosine response.
- A glass dome: limits the spectral response from 300 to 2,800 nanometers (cutting off the part above 2,800 nm), while preserving the 180 degrees field of view. Another function of the dome is that it shields the thermopile sensor from convection.
- The black coating on the thermopile sensor absorbs the solar radiation. This radiation is converted to heat. The heat flows through the sensor to the pyranometer housing. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation.



1) sensor, (2, 3) glass domes, (5) cable, standard length 5 m, (9) desiccant.

Pyrheliometers:

This is designed for unattended normal incidence direct solar radiation measurement research. It is an instrument designed specifically to measure the direct beam solar irradiance with a field of view limited to 5°. This is achieved by the shape of the collimation tube, with precision apertures, and the detector design. Example of a pyrheliometer on a solar tracker which keeps the instrument pointed at the sun. A black shadow band keeps the pyranometer shaded, so that it measures diffuse radiation only. The global solar radiation is then calculated from direct and diffuse radiation.



Pyrheliometer: (1) protection cap, (2) window with heater, (3) sight, (5) sensor, (7) humidity indicator, (10) cable for heater

Pyrgeometers:

- This is designed for IR (infrared) radiation measurement, for both atmospheric and material testing research applications. It is designed to measure the atmospherically Far Infrared Radiation. The instruments have a silicon window with solar blind filter on the inside to block all solar radiation. The outside of the window is coated to protect it from environmental influences. A socket is fitted for the signal cable with waterproof plug. It can be used for the permanent outdoor use under all weather conditions. An internal temperature sensor is available to calculate the downward Far Infrared irradiance. The atmosphere and the pyrgeometer (in effect the earth surface) exchange long wave IR radiation.

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Radiometers:

A radiometer is a device for measuring the radiant flux (power) of electromagnetic radiation. Generally, the term *radiometer* denotes an infrared radiation detector, yet it also includes detectors operating on any electromagnetic wavelength.

A common example is the Crookes radiometer, an early-model device wherein a rotor (having vanes which are dark on one side, and light on the other) in a partial vacuum spins when exposed to light. A common myth (one originally held even by Crookes) is that the momentum of the absorbed light on the black faces makes the radiometer operate. If this were true however, the radiometer would spin away from the non-black faces, since the photons bouncing off those faces impart even more momentum than the photons absorbed on the black faces.

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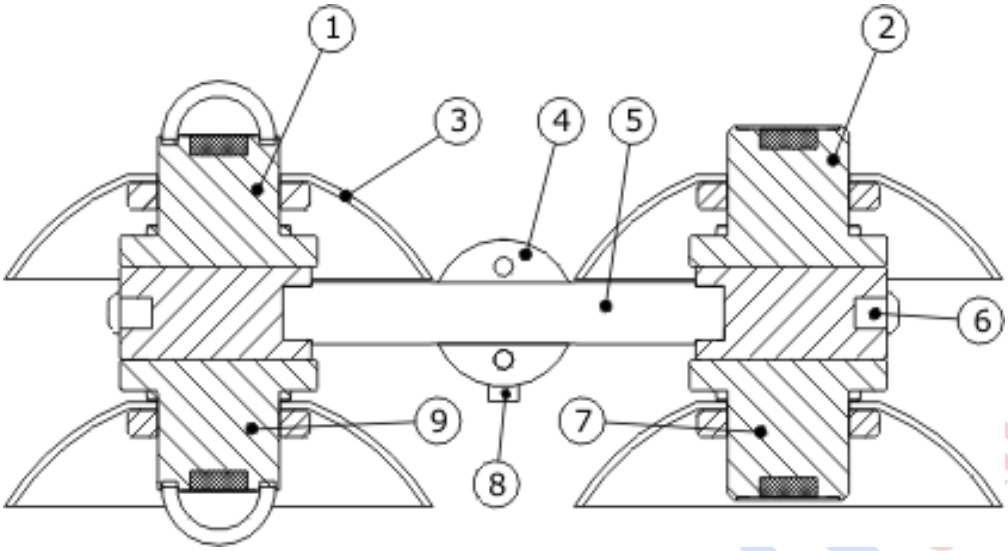


Cross section of a 4-component net-radiometer clearly showing the instrument main components: (1) SW_{in} solar radiation sensor or pyranometer, (2) LW_{in} far infrared radiation sensor or pyrgeometer (3) radiation shield, (4) leveling assembly for *x* and *y* axis, block plus bolts for *x*-axis adjustment (5) leveling assembly for *x*and *y* axis, horizontal rod (6) connection body, containing Pt100 temperature sensor, heater and hole for users own temperature sensor (add cable gland M8) (7) LW_{out} far infrared radiation sensor or pyrgeometer, (8) leveling assembly for *x* and *y* axis, bolts for *y*-axis adjustment (9) SW_{out} solar radiation sensor or pyranometer .

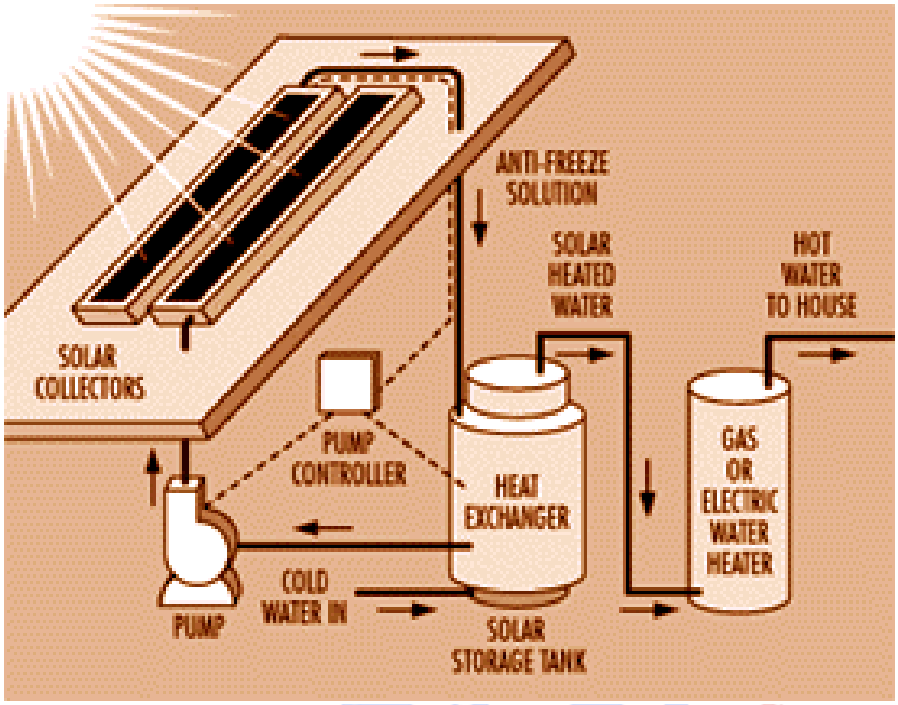
Q6. Describe in detail solar water heating.

Ans: **Heating Water**

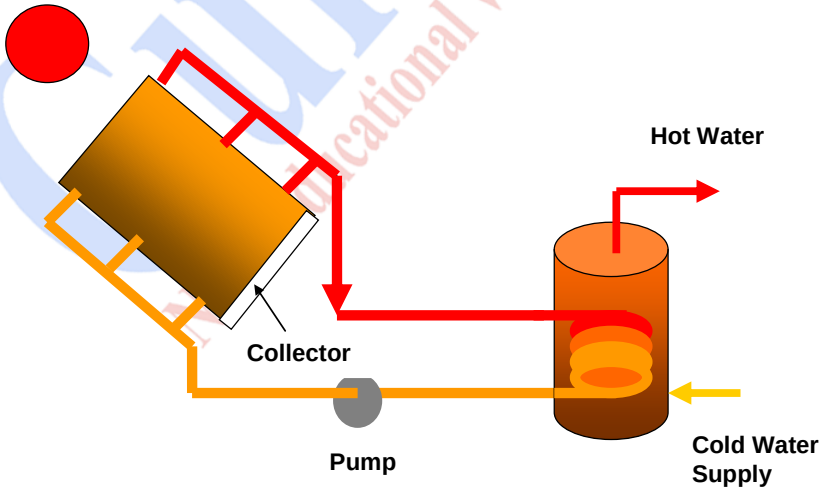
There are two methods of heating water: passive (no moving parts) and active (pumps).

In both, a flat-plate collector is used to absorb the sun's energy to heat the water. The water circulates throughout the closed system due to convection currents. Tanks of hot water are used as storage.

Active System uses antifreeze so that the liquid does not freeze if outside temp. drops below freezing.



It uses solar collector mounted on roof top to gather solar radiation. It has a low temperature of range: 100 C. the applications involves: domestic hot water or swimming pool heating.



Unit2

Bio-Fuels

Q1. What is biomass and what are the resources of biomass.

Ans:

Biomass is a renewable energy source that is derived from living or recently living organisms. Biomass includes biological material, not organic material like coal. The energy derived from biomass is mostly used to generate electricity or to produce heat. The thermal energy is extracted by means of combustion, torrefaction, pyrolysis, and gasification. Biomass can be chemically and biochemically treated to convert it to a energy-rich fuel.

Types of bio mass are given below:

- Wood fuel
- Rubbish
- Alcohol fuels
- Crops
- Landfill gas

Waste-based

Exploited – animal manures (household biogas), molasses (ethanol), sugar bagasse* (cogeneration)

Un-used – Sisal*, coffee, tea, municipal wastes, rice husks, sugar bagasse*, horticultural wastes, wheat straws, molasses*, market wastes, saw dust, abattoir wastes,.

Plant-based

Exploited - fuelwood and charcoal extensively used

Un-used* - Prosopis Juliflora (ironwood/mesquite), sweet sorghum, water hyacinths, cassava and other liquid biofuels.

Q2. Describe the process of direct combustion.

Ans:

Conversion from biomass to heat requires some extraction if the fuel stream is contaminated with polluting substances.

Typical processes are the following:

- Direct combustion

- Anaerobic Digestion
- Fermentation
- Pyrolysis

Direct Combustion:

Refuse Derived Fuel (RDF) can be fired (burned) directly or in combination with conventional fuels. Some processing, such as cleaning, chopping, etc. may be needed for handling or air pollution avoidance. Fluidized grate furnaces blow air in beneath the grate, and this keeps the burning mass in seething flotation as it burns.

Anaerobic Digestion:

When Bacteria produce acetic acid (found in vinegar) than anaerobic digestion process occurred. And the quqntity of methane gas is found 50% to 80%, $\$2.50/kft^3$ (1976).

Fermentation:

The Enzymes can change cellulose into sugars, which can then be fermented into alcohol. Cane sugar, $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$. The Fermentation of corn or other biomass will produce ethanol. The use of food stocks in this way might be seen as a poor use of food. Brewery spillage or waste and outdated soda can be filtered, cleaned, and reprocessed to produce fuel. It is denatured with 15% gasoline to discourage drinking and avoid Federal liquor law taxes. Fermentation of "stillage" refuse can also produce methane.

Pyrolysis:

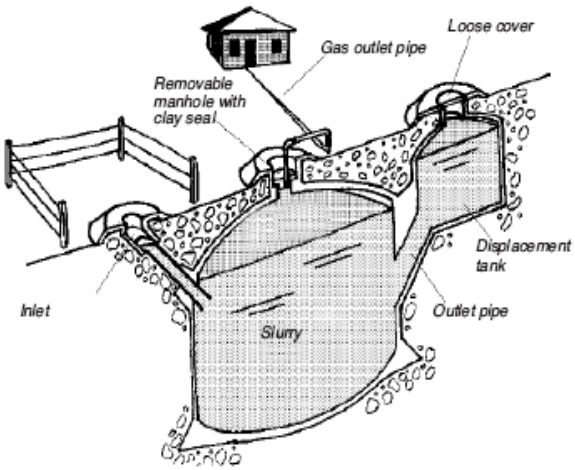
Fast pyrolysis is heating biomass without oxygen to decompose it into vapors, aerosols and char. The liquid has ~one-half the heating value of fuel oil. The process is tuned to produce liquid rather than charcoal. Low-quality "producer" gas can be cleaned to remove CO_2 and N_2, then this "synthesis" gas reacted as $2H_2 + CO \rightarrow CH_3OH$ to yield methanol .

Q3. Describe production of biogas in detail.

Ans:

Biogas is produced by the breakdown of organic waste by bacteria without oxygen (**anaerobic digestion** or fermentation). Leftover food from houses, shops, restaurants and factories.

Biogas is made by fermenting organic waste in a **biogas digester.**



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Unit 3

Wind and Tidal Power

Q1 Describe principle of energy from wind.

Ans

All renewable energy (except tidal and geothermal power), ultimately comes from the sun. The earth receives 1.74 x 10^{17} watts of power (per hour) from the sun. About one or 2 percent of this energy is converted to wind energy (which is about 50-100 times more than the energy converted to biomass by all plants on earth. Differential heating of the earth's surface and atmosphere induces vertical and horizontal air currents that are affected by the earth's rotation and contours of the land → WIND. ~ e.g.: Land Sea Breeze Cycle.

Winds are influenced by the ground surface at altitudes up to 100 meter. Wind is slowed by the surface roughness and obstacles. When dealing with wind energy, we are concerned with surface winds. A wind turbine obtains its power input by converting the force of the wind into a torque (turning force) acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed. The kinetic energy of a moving body is proportional to its mass (or weight). The kinetic energy in the wind thus depends on the density of the air, i.e. its mass per unit of volume.
In other words, the "heavier" the air, the more energy is received by the turbine at 15° Celsius air weighs about 1.225 kg per cubic meter, but the density decreases slightly with increasing humidity.

A typical 600 kW wind turbine has a rotor diameter of 43-44 meters, i.e. a rotor area of some 1,500 square meters. The rotor area determines how much energy a wind turbine is able to harvest from the wind. Since the rotor area increases with the square of the rotor diameter, a turbine which is twice as large will receive 2^2 = 2 x 2 = four times as much energy. To be considered a good location for wind energy, an area needs to have average annual wind speeds of at least 12 miles per hour.

Q2 Describe windmill construction and operational details.

Ans

A Windmill captures wind energy and then uses a generator to convert it to electrical energy. The design of a windmill is an integral part of how efficient it will be. When designing a windmill, one must decide on the size of the turbine, and the size of the generator.

Wind Turbine

LARGE TURBINES:

Able to deliver electricity at lower cost than smaller turbines, because foundation costs, planning costs, etc. are independent of size. Well-suited for offshore wind plants. In areas where it is difficult to find sites, one large turbine on a tall tower uses the wind extremely efficiently.

SMALL TURBINES:

Local electrical grids may not be able to handle the large electrical output from a large turbine, so smaller turbines may be more suitable. High costs for foundations for large turbines may not be economical in some areas. And there should be landscape consideration.

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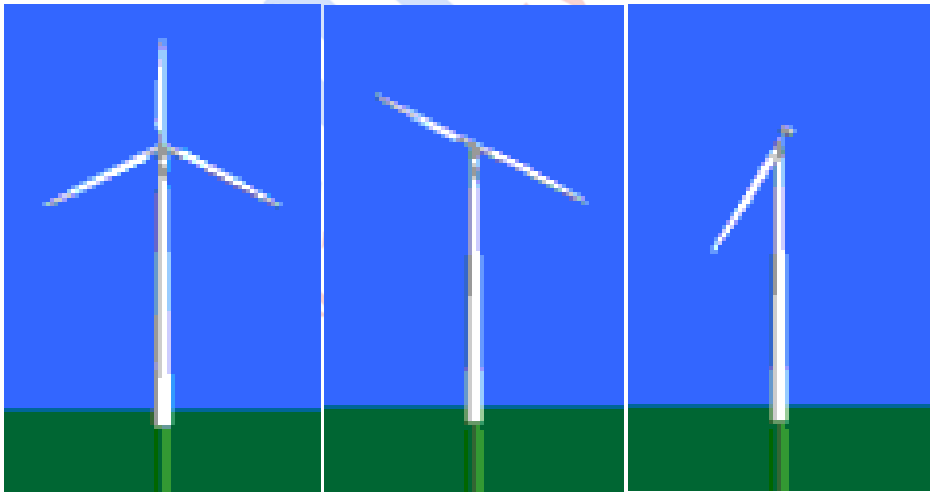
Wind Turbines: Number of Blades

Most common design is the three-bladed turbine. The most important reason is the **stability** of the turbine. A rotor with an odd number of rotor blades (and at least three blades) can be considered to be similar to a disc when calculating the dynamic properties of the machine. A rotor with an even number of blades will give stability problems for a machine with a stiff structure. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower.



Q3 How to produce electricity from wind turbine, describe in detail.

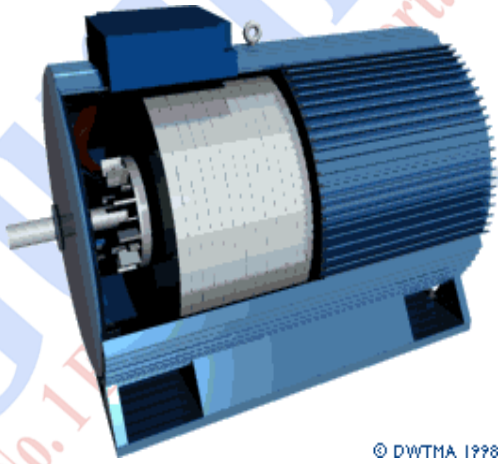
Ans: A Windmill captures wind energy and then uses a generator to convert it to electrical energy. The design of a windmill is an integral part of how efficient it will be. When designing a windmill, one must decide on the size of the turbine, and the size of the generator.

The Wind power generators convert wind energy (mechanical energy) to electrical energy. The generator is attached at one end to the wind turbine, which provides the mechanical energy. At the other end, the generator is connected to the electrical grid. The generator needs to have a cooling system to make sure there is no overheating.

SMALL GENERATORS:

They Require less force to turn than a larger ones, but give much lower power output. They are less Less efficient. i.e.. If you fit a large wind turbine rotor with a small generator it will be producing electricity during many hours of the year, but it will capture only a small part of the energy content of the wind at high wind speeds.

LARGE GENERATORS: They are Very efficient at high wind speeds, but unable to turn at low wind speeds. i.e.. If the generator has larger coils, and/or a stronger internal magnet, it will require more force (mechanical) to start in motion.



A windmill built so that it too severely interrupts the airflow through its cross section will reduce the effective wind velocity at its location and divert much of the airflow around itself, thus not extracting the maximum power from the wind. At the other extreme, a windmill that intercepts a small fraction of the wind passing through its cross section will reduce the wind's velocity by only a small amount, thus extracting only a small fraction of the power from the wind traversing the windmill disk. Modern Windmills can attain an efficiency of about 60 % of the theoretical maximum.

Q4. What is meant for tidal power and what are the causes of it?

Ans:

The Tidal power facilities harness the energy, from the rise and fall of tides. Tidal energy is also called tidal power and it is considered a clean renewable energy because during its transformation no pollutant substances are produced. It is a form of hydropower that takes profit from the energy of tides and with the help of an alternator it is possible to transform it into electricity or other useful forms of power. It is quite interesting to explain that tides are produced by the Sun and the Moon in combination with Earth's rotation movement, as shown is the figure n°1. All of them interact via gravitational forces. This is what tidal energy generators use to produce energy. It is well known that if the water level is higher and/or tidal currents are faster, the potential will be greater and it will be possible to obtain a bigger amount of energy.

There are Two types of tidal plant facilities.

- Tidal barrages
- Tidal current turbines

Ideal sites are located at narrow channels and experience high variation in high and low tides. The Gravitational pull of the sun and moon and the pull of the centrifugal force of rotation of the earth-moon system. When a landmass lines up with the earth-moon system, the water around it is at high tide. When a landmass is at 90° to the earth-moon system, the water around it is at low tide.

There are two high tides and two low tides during each period of rotation of the earth. The **Spring and Neap tides** depend on the orientation of the sun, moon, and the earth. High spring tides occur when the sun and moon line up with the earth. This occurs whether they are either on same or opposite side. The Low neap tides occur when the sun and moon line up at 90° to each other. Flood Currents: currents moving in the direction of the coast. Ebb Currents: the current receding from the coast.

Q5. What are the types of tides formation system.

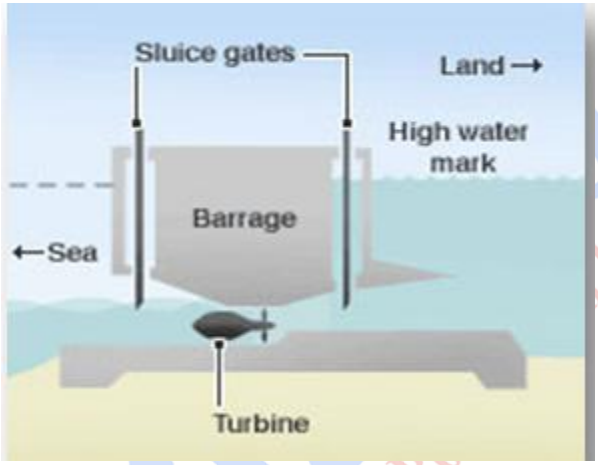
Ans There are 2 types of tides formation:

Single basin system-

Ebb generation: During flood tide basin is filled and sluice gates are closed , trapping water. Gates are kept closed until the tide has ebbed sufficiently and thus turbines start spinning and generating electricity. Flood generation: The basin is filled through the turbine which generate at flood tide.

Two way generation: Sluice gates and turbines are closed until near the end of the flood tide when water is allowed to flow through the turbines into the basin creating electricity. At the point where the hydrostatic head is insufficient for power generation the sluice gates are opened and kept open until high tide when they are closed. When the tide outside the barrage has dropped sufficiently water is allowed to flow out of the basin through the turbines again creating electricity.

Double-basin system: There are two basins, but it operates similar to en ebb generation, single-basin system. The only difference is a proportion of the electricity is used to pump water into the second basin allowing storage.



Q5. What is the ocean thermal energy conversion system.

Ans:

Ocean thermal energy conversion (OTEC) is a method for generating electricity which uses the temperature difference that exists between deep and shallow waters.

Thermal energy- form of energy that manifests itself as an increase of temp. it is aMethod for generating electricity. This Runs a heat engine- a physical device that converts thermal energy to mechanical output and Uses temp. difference that exists b/w deep & shallow waters. The Temperature difference between warm surface water and cold deep water must be >20°C (36°F) for OTEC system to produce significant power.

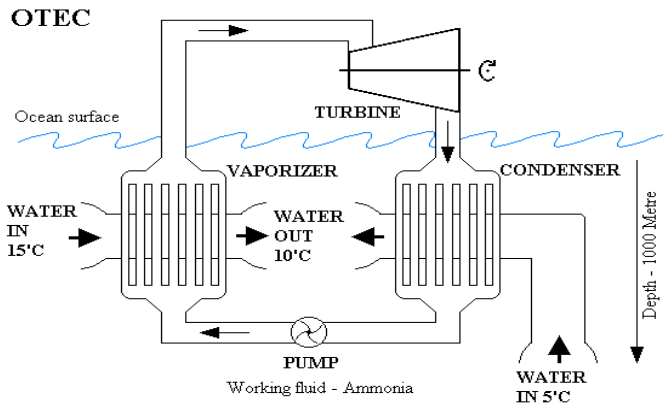
Ocean Thermal Energy Conversion produces electricity from the natural thermal gradient of the ocean, using the heat stored in warm surface water to create steam to drive a turbine, while pumping cold, deep water to the surface to re-condense the steam.

There are Three types of OTEC systems: open, closed, and hybrid.

Closed Cycle OTEC:

- In closed-cycle OTEC, warm seawater heats a working fluid, such as ammonia, with a low boiling point, such as ammonia, which flows through a heat exchanger (evaporator). The ammonia vapor expands at moderate pressures turning a turbine, which drives a generator which produces energy. The vapor is then condensed in another heat exchanger (condenser) by the cold, deep-ocean water running through a cold water pipe. The working fluid (ammonia) is then cycled back through the system, being continuously recycled.

OTEC: Closed Cycle

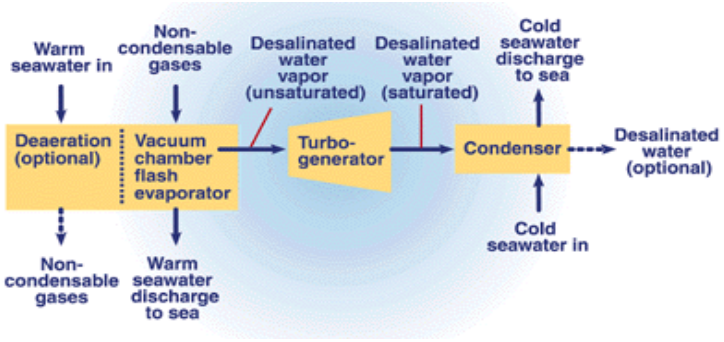


Open Cycle OTEC:

In an open-cycle OTEC plant, warm seawater from the surface is the working fluid that is pumped into a vacuum chamber where it is flash- evaporated to produce steam at an absolute pressure of about 2.4 kilopascals (kPa). The resulting steam expands through a low-pressure turbine that is hooked up to a generator to produce electricity. The steam that exits the turbine is condensed by cold, deep-ocean water, which is returned to the environment.

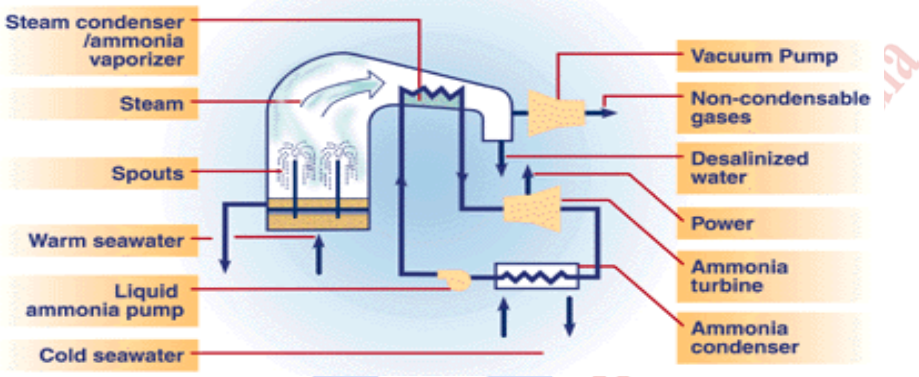
If a surface condenser is used, the condensed steam remains separated from the cold ocean water and can be collected as a ready source of desalinated water for commercial, domestic or agricultural use.

In an open-cycle plant, the warm water, after being vaporized, can be re-condensed and separated from the cold seawater, leaving behind the salt and providing a source of desalinated water fresh enough for municipal or agricultural use.



OTEC Hybrid Cycle System:

Hybrid plants, combining benefits of the two systems, would use closed-cycle generation combined with a second-stage flash evaporator to desalinate water.



Unit 4

Geothermal Energy

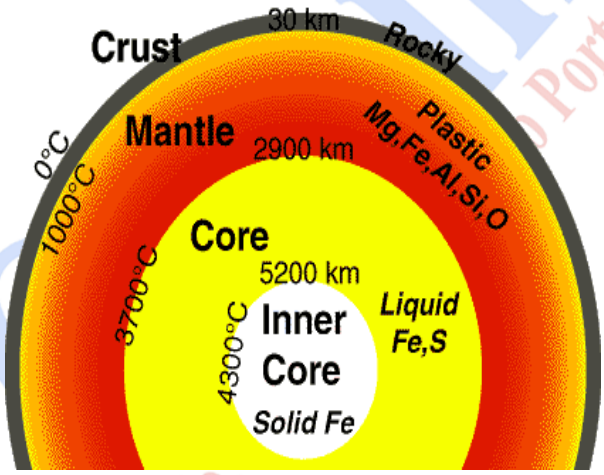
Q1 What are the resources of geothermal energy?

Ans:

It is Geo (Greek for earth) Thermal (heat) . and the Temp. of Shallow Crust (upper 10 ft.) Constant 55-75°F (13-24°C) Up to 14,400°F (8,000°C) at Molten Core (approx. 4,000 mi. to center of core. Earth's Crust Thickness: 3 to 35 Mi. and the Temperature Increases With Depth Gradient: 50-87°F / Mile (17-30°C / km)

Basic Geothermal Systems Take Advantage of:

- Heat Differential Between Ground and Indoor Air Temperatures – Heat Pump
- Earth as a Natural Heat Source – Power Plants



Geothermal Sources are Classified Based on: (1) Temperature, (2) Physical State of H_20 (i.e. water or steam), and (3) Type of Energy Usage

Primary Classification is Resource Temperature:

- Low Temperature Reservoir: 50-200 °F (10-94 °C)
- High Temperature Reservoir: >200 °F

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Q2: What are the Basic Types of Geothermal Reservoirs, describe them.

Ans:

There are 3 General Classes of Geothermal Uses

Ground Source Heat Pump

Direct Source

Commercial Electricity Generation: Power Plants

- Need High Capacity Geothermal Reservoir; Generally Water / Steam >200°F

Low Temperature Reservoirs:

They are Available almost anywhere on earth. The Predominantly Used for Heat Pumps is Space Heating

Other Common Uses:

- Hot Water Production
- Piped Under Roads / Sidewalks (Klamath Falls, Oregon)
- In Greenhouses to Grow Flowers, etc.
- Industrial Uses: dry wood, pasteurize milk, grow fish, etc.

High Temperature Reservoirs:

They Can Occur Within a Couple of Miles of Earth's Surface Where Earth's Crust Is Very Thin – i.e., Closer to Molten Magma at Core. They are Suitable for Commercial Production of Electricity. The Power Plants Need High Capacity Geothermal Reservoir – Water / Steam >220°F (105°C). they have Greatest Potential for Energy Output.

Hot Geothermal Fluids Near Surface (<1-2 mi.)

They Preferably in Excess of 300°F, but Electrical Generation Is Occurring at Temps. In the Low 200's°F. the Proximity to Population Base. They have Low Mineral and Gas Content. And they are Located on Private Land. They have Proximity to Transmission Lines.

Heat Pump Components:

These have 3 Main Parts:

- Underground Piping
- Pump / Heat Exchanger System

- Indoor Distribution System

System "Concentrates" Natural Heat Instead of Production of Heat by Combustion.

Q3: What are types of geothermal power plant.

Ans:

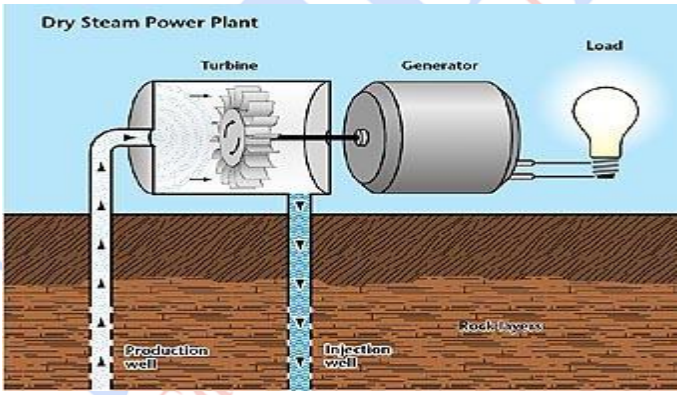
Different Types of Plants are Required to Take Advantage of the Particular Characteristics of Each Specific Geothermal Site.

Main Types of Geothermal Power Plants are:

- Dry Steam
- Flash Steam
- Binary Cycle

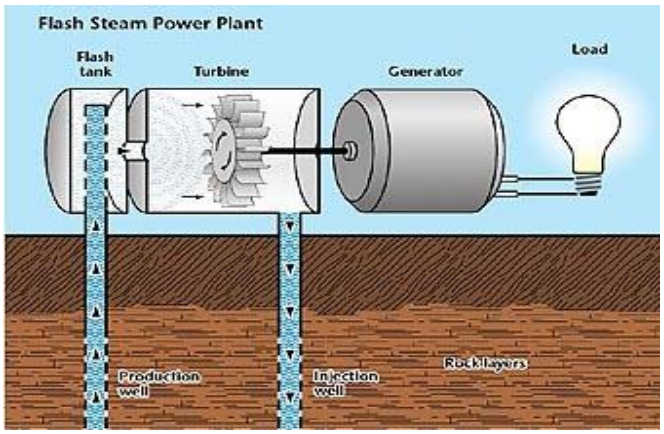
Dry Steam Geothermal Plants:

They Uses Steam From Geothermal Reservoir Directly and Only Requires Removal of Rock Fragments From Steam Prior to Entering Turbines. There Only Emissions Are Water Vapor .



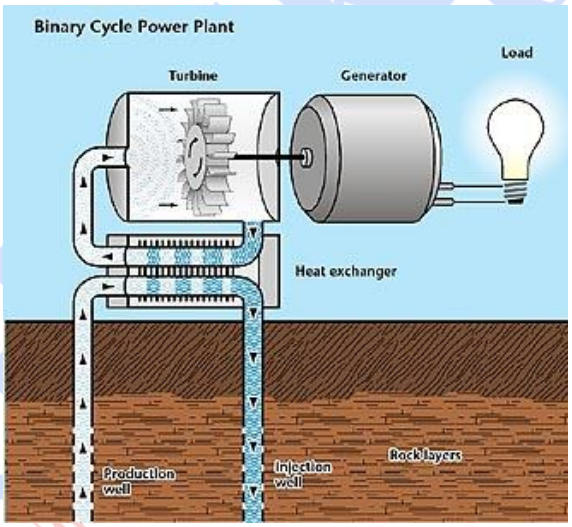
Flash Steam Geothermal Power Plants

The Injection of Deep, High-pressure Water Into Low-pressure Tanks; Water "Flashes" to Steam Used to Drive Turbines and the Excess Water Returned to Maintain Pressure in Reservoir .



Binary Cycle Geothermal Power Plants

Moderately Hot Water (<175 °C) Passed Through Heat Exchanger. The Heat Transferred to Secondary Fluid (Low B.P. Fluids (i.e., Propane or Isobutane) Which Is Vaporized ("Flashed") .



They have Higher Capital Cost and Needs High Efficiency Equip. the Water Never Contacts Turbine/generator Units. The Water Returned Directly to Reservoir and there is No Plant Emission.

Unit 5

Energy Storage and Distribution

Q1 What is energy storage system and describe its types.

Ans

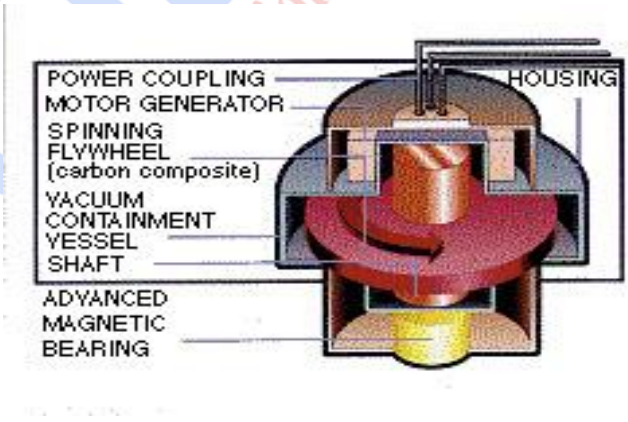
Energy Storage System can be classified as:

- Mechanical Energy Storage.
- Magnetic Energy Storage.
- Thermal Energy Storage.
- Chemical Energy Storage.

Mechanical Energy Storage:

Fly Wheels

Principle: Energy is stored in the form of Mechanical Energy. They are Light weight fiber composite materials are used to increase efficiency. They have Energy density =0.05MJ/Kg, η=0.8



Compressed Air Energy Storage:

it Uses off-peak electricity to compress air and store it in airtight underground caverns. When the air is released from storage, it expands through a combustion turbine to create

electricity. its Energy density is = 0.2~2 MJ/Kg, η=0.5

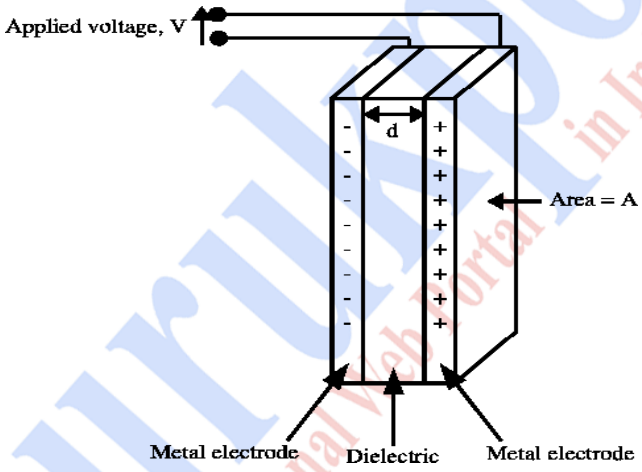
Magnetic Energy Storage

SMES systems store energy in a magnetic field created by the flow of direct current in a coil of superconducting material that has been cryogenically cooled.

Principle: it works at At low-temperatures, electric currents encounter almost no resistance. it Stores energy in the magnetic field. it is Environmental friendly and Highly efficient.

Super Capacitors:

it Uses thin film polymers for the dielectric layer andCarbon nanotubes and polymers are practical for super capacitors . In future - carbon nanotubes with ceramics . it Reduce the effect of fluctuations . it has Longer life time which reduces maintenance costs.



Electrochemical Storage:

Types of Batteries: they have Small Capacities.

Lead-Acid Batteries:

They use a chemical reaction to do work on charge and produce a voltage between their output terminals. and their Energy density is 0.6 MJ/Kg. their Efficiency of the cell is only 15%. they have Large Scale production.

Thermal Energy Storage

In this we are Using methods of heat exchange

1. Aquifer thermal storage: in this there is Usage of underground water

2. Duct thermal storage: in this there is Usage of Plastic Tubes

Environmental impact

Eg: De-ice frozen roads

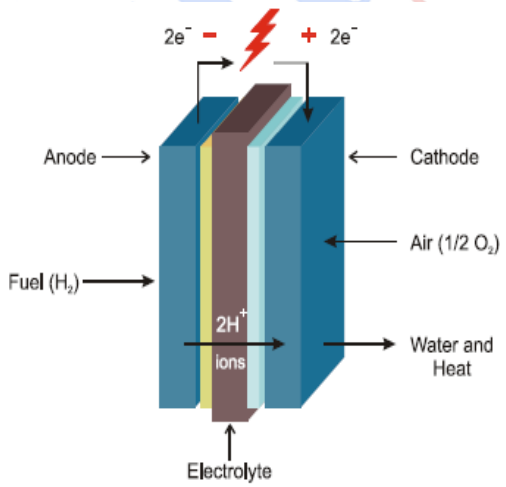
Application of Thermal Energy Storage:

Air Conditioning:

It act as A salt hydrate acts as a cool heat sink for the air conditioner working fluid. The stored heat is rejected from the salt hydrate during night to heat the surrounding air. the Energy density = 0.25MJ/Kg, η=0.8. E.g.: Sodium Sulfate Decahydrate.

Q2: What is fuell cell and what are their types?

Ans: A fuel cell is a device that converts chemical energy into electrical energy, water, and heat through electrochemical reactions. Fuel and air react when they come into contact through a porous membrane (electrolyte) which separates them.This reaction results in a transfer of electrons and ions across the electrolyte from the anode to the cathode. If an external load is attached to this arrangement, a complete circuit is formed and a voltage is generated from the flow of electrical current. The voltage generated by a single cell is typically rather small (< 1 volt), so many cells are connected in series to create a useful voltage.



Types of fuel cells:

Classified on the basis of operating conditions and various electrolytes used.

- Alkaline fuel cells (AFC)
- Polymer electrolyte membrane (PEM)
- Phosphoric acid fuel cells (PAFC)
- Molten carbonate fuel cells (MCFC)
- Solid oxide fuel cells (SOFC)
- Regenerative fuel cells

Advantages:

- No green house gases
- Not much political dependence
- More operating time.

Disadvantages:

- Storage of Hydrogen due to highly inflammable nature of H_2. Though metal hydrides($FeTiH_{1.7}$) and NH_3 can be alternative.
- High capital cost due to Platinum catalyst used in the process.

Q3. What is the basic working principle of a fuel cell.

Ans:

All fuel cells have the same basic operating principle.

An input fuel is catalytically reacted (electrons removed from the fuel elements) in the fuel cell to create an electric current. Fuel cells consist of an electrolyte material which is sandwiched in between two thin electrodes (porous anode and cathode).

The input fuel passes over the anode (and oxygen over the cathode) where it catalytically splits into ions and electrons.

The electrons go through an external circuit to serve an electric load while the ions move through the electrolyte toward the oppositely charged electrode.

At the electrode, ions combine to create by-products, primarily water and CO_2. Depending on the input fuel and electrolyte, different chemical reactions will occur.

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Anode: $H_2 \longrightarrow 2H^+ + 2e^-$

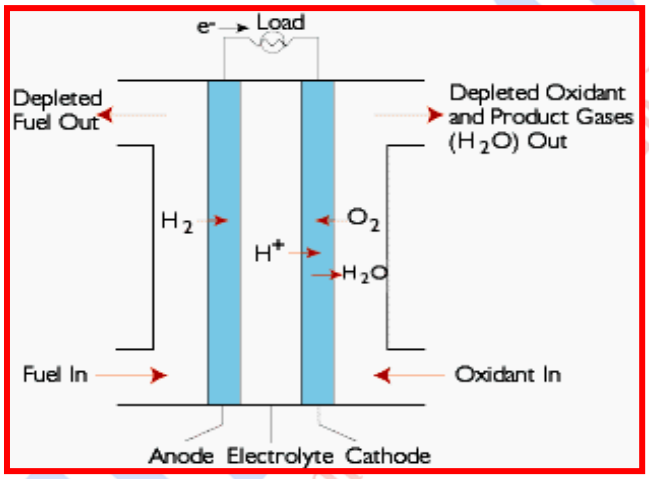
Cathode: $1/2\ O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

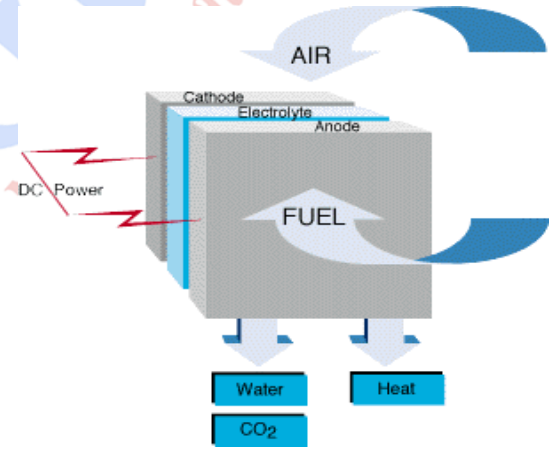
At the anode:

Hydrogen is split into two hydrogen ions (H^+), which pass through the electrolyte to the cathode, and two electrons which pass through the external circuit (electric load) to the cathode.

At the cathode:

the hydrogen, electrons and oxygen combine to form water.





Q4. What is the difference between battery and fuel cell.

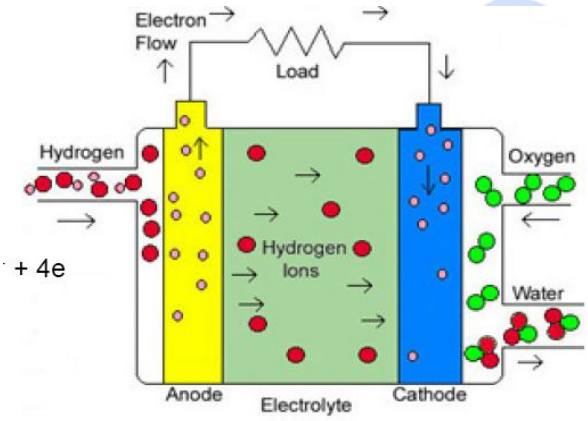
Ans:

Basic operating principles of both are very similar, but there are several intrinsic differences:

Hydrogen fuel cell:

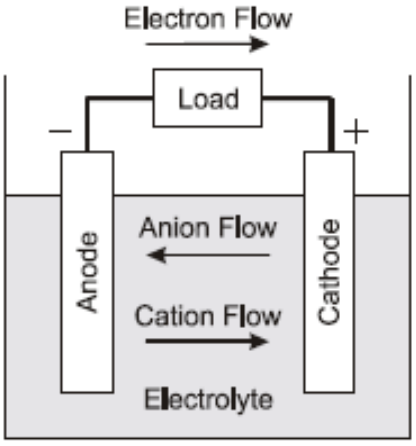
it has Open system. and the Anode and cathode are gases in the contact with a platinum catalyst.

in fuel cell the Reactants are externally supplied, and there is no recharging required for any type of fuel cell.



Galvanic cell (battery):

It has Closed system and the Anode and cathode are metals. the Reactants are internally consumed, no external supply required. They does need periodic recharging.



Importance:

they are Reliable and affordable energy storage is a prerequisite for using renewable energy.

The Energy storage therefore has a pivotal role in the future.

the Energy storage is the most promising technology currently available to meet the ever increasing demand for energy.

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Multiple Choice Questions

1. Which of the following is a nonrenewable energy resource?
   a) Solar
   b) coal
   c) hydroelectric
   d) wind

2. Which of the following is NOT a renewable source of energy?
   a) Geothermal
   b) Propane
   c) Solar
   d) Wind

3. Which of the following methods can be called passive solar energy collection? using heat absorbing construction material
   a) otec
   b) photovoltaic cell
   c) rooftop solar

4. A major disadvantage of solar power is what?
   a) cost effectiveness
   b) efficiency level
   c) variation inb sunshine around the world

5. A major advantage of solar power is what?
   a) high pollution
   b) prohibited cost
   c) local, decentralized control over the world

6. The amount of oil that may become available for use is called oil _____.
   a) reserves
   b) reservoirs
   c) trap
   d) resources

7. Of the following choices, which best describes or defines BIOMASS?
   a) A.Massive living things
   b) B. Inorganic matter that can be converted to fuel
   c) C. Organic matter that can be converted to fuel
   d) D. Petroleum

8. Windmill towers are generally more productive if they are?
   a) higher, to minimize turbulence nad maximize wind speed

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b) lower to minimize turbulence nad maximize wind speed
c) lower to increase the heat convection from ground

9. What is A major disadvantage to using wind to produce electricity ?
   a) emission is produced once in a place
   b) the initial startup cost
   c) energy efficiency compared to conventional energy sources

10. Potential energy sources from oceans are ?
   a) chemoluminescent bacteria
   b) motion of currents, waves and tides, ocean thermal energy
   c) magnetic field generators

11. Of the following choices, which best describes or defines GEOTHERMAL ENERGY?
   a) Heat energy from volcanic eruptions.
   b) Heat energy from hot springs.
   c) Heat energy from inside the earth.
   d) Heat energy from rocks on Earth's surface

12. The current practice of geothermal power generation may not provide a practical renewable energy source because _____?
   a) heated ground water is much faster them it recharged
   b) magma is used faster than it recharged
   c) power plant has high maintenance cost

13. Of the following choices, which best describes or defines ELECTRICITY?
   a) Chemical energy
   b) Moving electrons
   c) Potential energy
   d) Power

14. Which of the following is NOT a fossil fuel?
   a) Biomass
   b) Coal
   c) Natural gas
   d) Petroleum

15. What is One difficulty with the process of using hydrogen as a power source ?
   a) less efficient
   b) requires energy investment to start the process
   c) has high volatile and dangerous componenet

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16. What is one advantage of using hydrogen cell?
    a) Energy efficient
    b) non polluting
    c) ease of transporting or storage

17. What is The chemical product of using hydrogen as an energy source?
    a) ingestion
    b) combustion
    c) water molecules
    d) electrolysis

18. A coal deposit that is not economical to mine today would be considered part of our _____
    a) coal reserves
    b) coal resources
    c) coal reservoirs
    d) none of these

19. What is the leading source of energy used in the United States today?
    a) coal
    b) Oil Resource
    c) natural gas
    d) nuclear gas

20. The first oil well was drilled in the United States in _____.
    a) 1829
    b) 1859
    c) 1929
    d) 1959

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