Non Conventional Energy Sources

Unit-1: Introduction

Syllabus

- Various Non-Conventional energy sources,
- Need, Availability, Classification, Relative merits & demerits,
- Energy Storage, Distribution and Conservation.

Book: Non-Conventional Energy Sources by G.D. Rai, Khanna Publication, 4e

Motivation

- While fossil fuels are the main fuel for thermal power, there is fear that they will get exhausted eventually in this century.
- Therefore other systems based on non-conventional and renewable sources are being tried by many countries. These are solar, wind, sea/ocean, tidal, geothermal and biomass energies.
- The need of today is the transition from dependence on fossil fuels and nuclear energy to the renewable energy sources.

Introduction

- **Energy** - Energy can be defined as the ability (or) capacity to do work.
- **Different forms of energy:**

(1) Chemical energy	-	due to chemical reaction
(2) Electrical energy	-	due to flow of electron
(3) Heat energy	-	due to thermal vibration
(4) Light energy	-	due to radiation of light
(5) Mechanical energy	-	due to moving parts
(6) Nuclear energy	-	due to nuclear reaction

etc.

Introduction

- ***The SI unit of Energy is Joule (or) N/m***
- **Law of conservation of Energy:** According to law of conservation of energy, Energy can neither be created nor destroyed. But, one form of energy can be converted to another form.
- **Examples:**

  1. A heater convert electrical energy into heat energy.
  2. A battery converts chemical energy into electrical energy.

  etc.

Energy Sources

- The available energy sources can be divided into three categories.

1. ***Primary Energy Sources***
2. ***Secondary Energy Sources***
3. ***Supplementary Energy Sources***

Primary Energy Sources

- The energy sources which provide a net supply of energy are defined as Primary Sources.
- Examples are Coal, Oil, Natural Gas and Nuclear.
- The energy required to produce energy from these sources is very less as compared to the energy produced by them.
- Energy Yield Ratio of these sources is very high.

Energy Yield Ratio is defined as the ratio of energy fed back by the material to the energy taken from the environment.

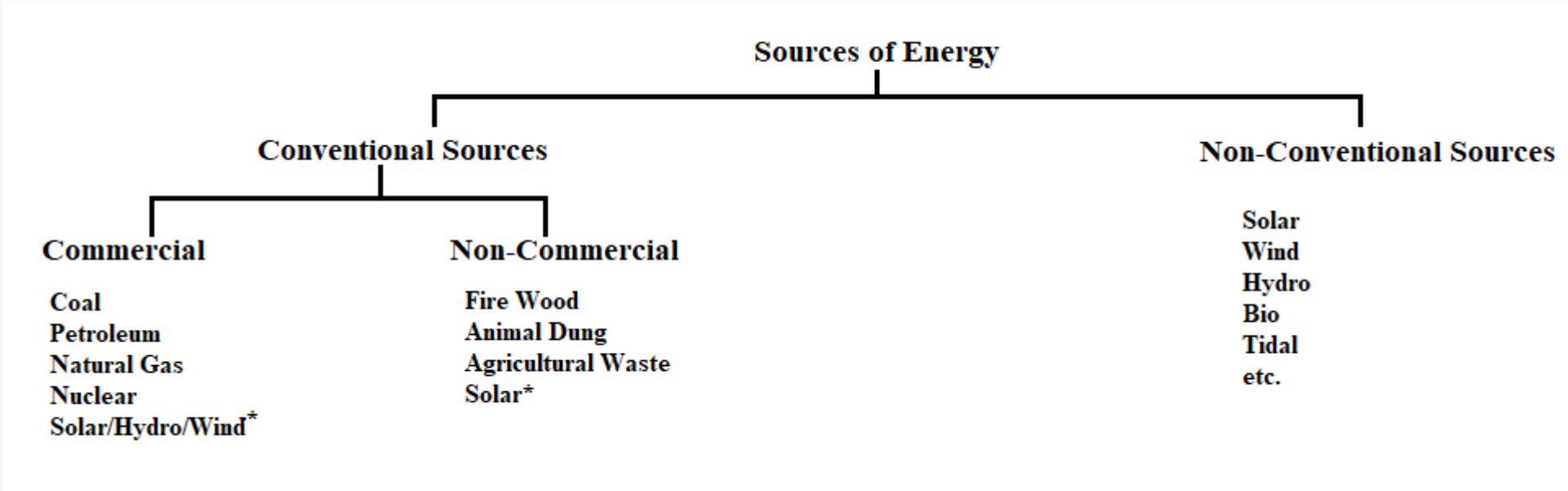
Secondary Energy Sources

- These sources produce no net energy.
- Examples include Solar, Wind, Water (Hydro, Tidal, Wave etc.)
- These sources produce no harm to the environment and earth, and so they must be more preferable source of energy for us.
- But due to low Energy Yield Ratio (as compared to the Primary Sources) they are not that efficient.

Supplementary Sources

- For these energy sources the net energy yield is zero and they require highest amount of investment.
- Thermal Insulation is an example of this type.

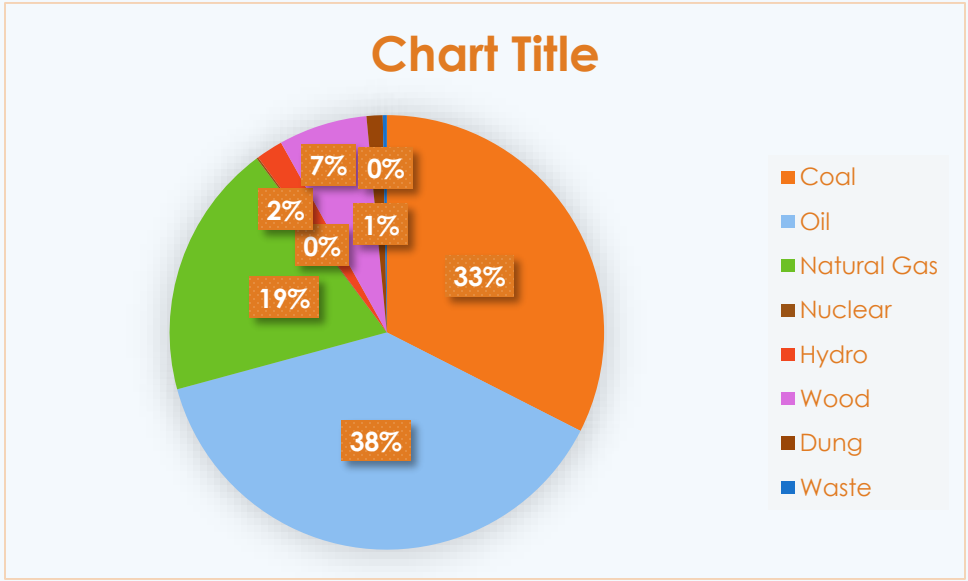
Energy Sources



Energy Sources

- Table below gives the % usage of various energy sources

Coal	32.5%	92% (commercial)
Oil	38.3%	
Natural Gas	19.0%	
Nuclear	0.13%	
Hydro	2.0%	
Wood	6.6%	8% (non-commercial)
Dung	1.2%	
Waste	0.3%	



(source: Book)

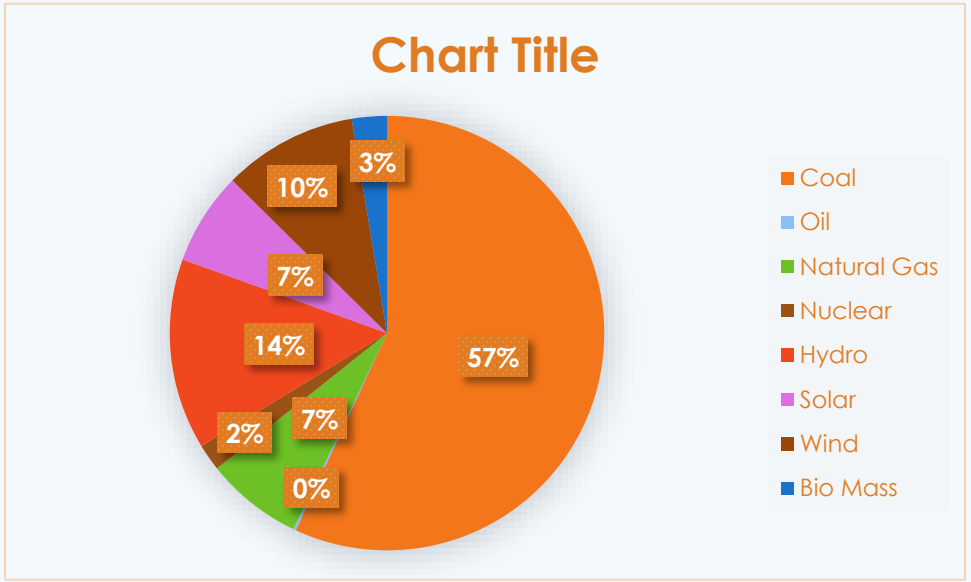
Energy Sources

- From above table we see that the non-commercial sources contributes a huge 8% of total energy demand.
- This is 4 times the energy produced by Hydro and 60 times more than that of Nuclear energy.
- In developing nations the non-commercial sources play a significant role in energy supply, and this dependence is likely to grow continuously unless some alternate sources are adopted.

Energy Sources

- Table below gives the % usage of various energy sources (India)

Coal	56.9%	66.3% Non-Renewable
Oil	0.2%	
Natural Gas	7.2%	
Nuclear	2.0%	
Hydro	14.2%	33.7% Renewable
Solar	6.9%	
Wind	10.0%	
Bio Mass	2.6%	



(source: Wikipedia)

Conventional Energy Sources

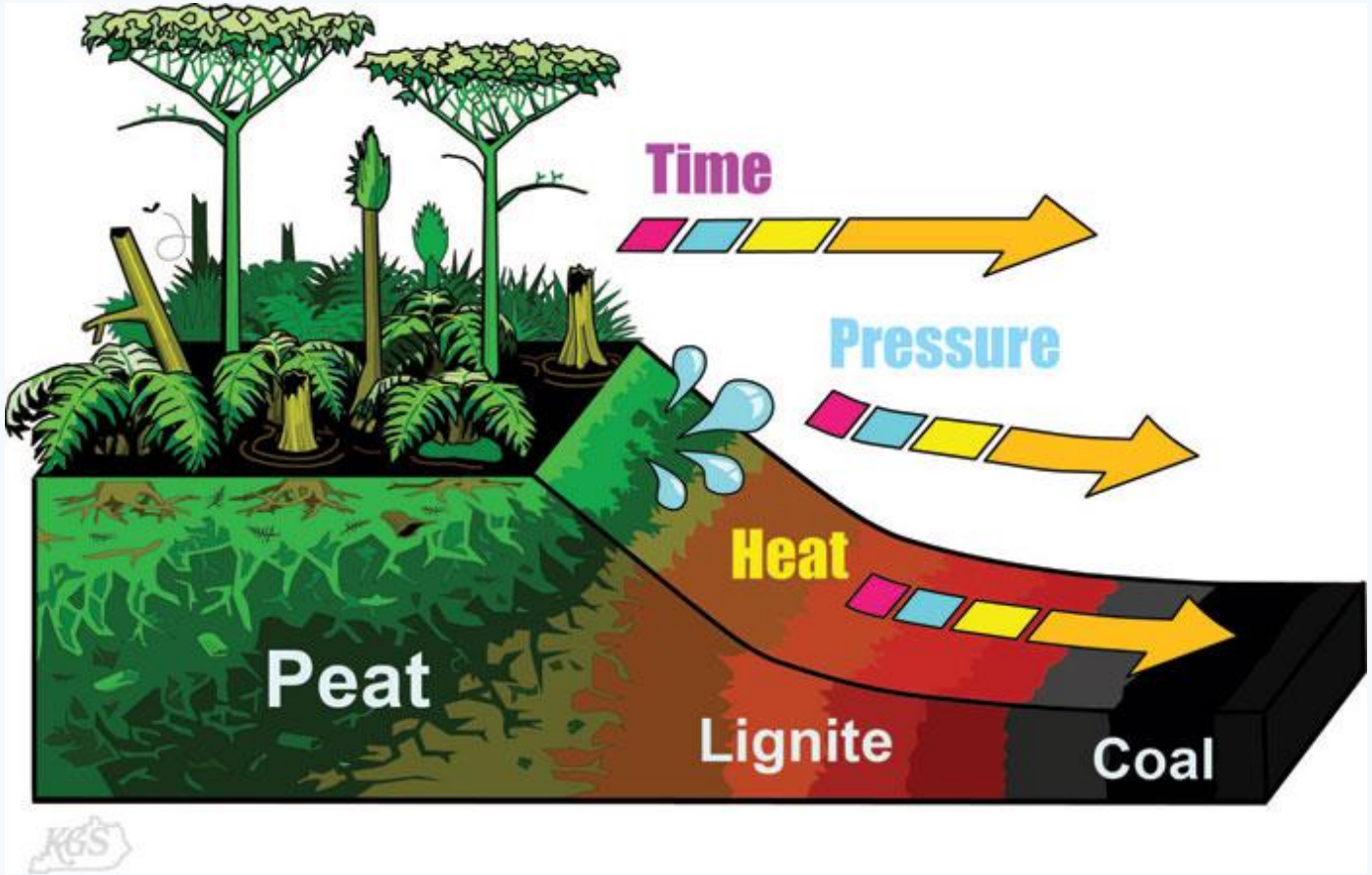
1. Coal

- Coal is a **non-renewable energy source** because it takes millions of years to form. That means what is in the ground now is all there is and we can't realistically make more.
- Since the advent of industrialization, the Coal has been the most common source of energy.
- To generate energy from coal, mainly it is burnt in Boilers and Heat energy is produced, which in turn is used to generate other forms of energy such as Electricity.

How Coal is formed

- The energy in coal comes from energy that was stored in giant plants that lived hundreds of millions of years ago in swamp forests, even before the dinosaurs!
- When these giant plants and ferns died, they formed layers at the bottom of the swamps. Water and dirt began to pile up on top of the dead plant remains.
- Over thousands of years pressure and heat would build up on top of the plant remains, undergoing chemical and physical changes and pushing out the oxygen, turning these remains into what we call **coal.**

How Coal is formed



Types of coal

- The geological process of changing something under the effect of temperature and pressure is called metamorphism.

1. **Peat** is generally considered a precursor of coal, but it has been used as a fuel in some areas — most notably in Ireland and Finland. In its dehydrated form, it can help soak up oil spills.
2. **Lignite** is the lowest quality and the first to be formed.
3. **Sub-Bituminous Coal** is most often used as fuel for steam-electric power generation.

Types of coal

4. **Bituminous Coal** is a dense sedimentary rock, generally of a high-quality.
5. **Steam coal** is a transition type between bituminous and anthracite.
6. **Anthracite** is the highest rank of coal. It's a hard, glossy rock and highly valued for its properties.
7. **Graphite** is not generally considered a type of coal because it cannot be used for heating. It is most often used in pencils or as a lubricant (when powdered).

The Adverse Effects Of Coal

- Coal is one of the main contributors to global warming, and coal mining and its fueling of power stations cause major environmental damage.
- Coal mining had been very dangerous. The list of coal mine accidents is long, and even today, accidents are still surprisingly common.
- Many miners also suffer from **Coal-worker's Pneumoconiosis**, also known as **"Black Lung"**.

The Adverse Effects Of Coal

- In 2008 the World Health Organization (WHO) calculated that coal pollution alone is responsible for one million deaths annually across the world; other organizations have come up with similar figures. According to a US report published in 2004, coal-fired power plants shorten nearly 24,000 lives each year in the US (2,800 from lung cancer).
- Burning coal releases great quantities of carbon dioxide into the air and also releases methane — a much more potent greenhouse gas. Methane accounts for 10.5% of greenhouse gas emissions created through human activity.

Thermal Power in India

- India's electricity sector is dominated by fossil fuels, and in particular coal, which in 2017-18 produced about three fourths of all electricity.
- However, the government is pushing for an increased investment in renewable energy. The National Electricity Plan of 2018 prepared by the Government of India states that the **country does not need additional non-renewable power plants in the utility sector until 2027**, with the commissioning of 50,025 MW coal-based power plants under construction and achieving 275,000 MW total installed renewable power capacity after retirement of nearly 48,000 MW old coal fired plants.

Wikipedia

2. Oil

- Almost 40% of the total energy needs of the world is fed by Oil.
- The rising prices of Oil has brought a considerable strain to the world economy.
- With today's rate of consumption of oil and what we have in reserve, the oil will last for about 100 years, unless more oil source is discovered.

3. Gas

- Natural Gas is an incompletely utilised resource available at the bottom of earth.
- Its huge quantity is burnt off in the oil production process.
- It is not fully utilised due to non availability of ready market and due to it's high transportation cost.
- Gaseous fuels can be classified as:
  1. Gases of fixed composition such as Acetylete, Ethylene, Methane etc.
  2. Composite industrial gases such as coke oven gas, blast furnace gas etc.

4. Agricultural & Organic Waste

- This includes waste produced from various agricultural operations such as manure, corn-stem, paddy husk, harvest waste, saw dust, animal dung, left overs from various crops.
- All these wastes are generally burnt or are left in open environment, which causes serious environmental issues.
- Following steps can be taken to reduce environmental problems:

4. Agricultural & Organic Waste

1. The Waste should be utilised near the source so that transportation cost is reduced.
2. The people in the rural area should be properly educated about the proper utilization of agricultural wastes.
3. These wastes should be used to generate energy, which can in turn be used to fulfil local/rural energy needs.
4. Other non energy uses should be considered.

5. Water

- The energy form water is generated by allowing the water to fall under the force of gravity.
- It is used almost exclusively for Electricity generation.
- The Potential energy of the water is converted into Mechanical energy through Hydraulic Turbines, which in turn moves the Generator which generates Electricity.
- In rivers the water is available in abundance but the capital cost of Hydro Electric Plant is very high as compared to other kinds of power plants. The operating cost of these plants is low as no fuel is required.

5. Water

- The water energy is the only renewable, non-depleting source at present which is being used as commercial source of energy.
- In addition it does not create any pollution problem

6. Nuclear

- Nuclear power is the use of nuclear reactions that releases nuclear energy to generate heat, which most commonly is then used in steam turbines to produce electricity in a Nuclear Power Plant.
- Nuclear power can be obtained from nuclear fission, nuclear decay and nuclear fusion reactions.
- At present majority of electricity is produced by Nuclear fission of Uranium and Plutonium.

Non-Conventional Energy Sources

NCES

- The NCES are Solar, Wind, Sea/Ocean, Geothermal, Biomass etc.
- Many people are continuously trying to find more NCES.
- The other terms used to describe the non-conventional energy are ‘Alternative’, ‘Appropriate’, ‘Natural’, ‘New’, and ‘Renewable’.
- Various NCES are:

1. Solar Energy:

- Energy produced through the sunlight is called solar energy.
- Sun's energy comes to earth in form of Light and Heat. This energy keeps the temperature of earth's atmosphere at normal level, so that living things can survive, the heat causes currents in atmosphere (wind) and ocean (tide), causes the water cycle and generates photosynthesis in plants.
- Solar energy can be utilized in two ways, either Thermally or by Photovoltaics.

1. Solar Energy:

- The solar photovoltaic cells are exposed to sunlight and in turn the electricity is produced. Photovoltaic cells converts the sun light energy into electricity.
- The Solar energy's potential is about 178 Billion MW, which is around 20000 times more than the world's total energy demand.
- Various applications of Solar energy are:
  1. Solar Water Heating
  2. Solar Cookers

1. Solar Energy:

3. Solar engine for water pumping.
4. Street Lights
5. Solar drying of agricultural and animal products.
6. Salt production by sea water evaporation.
7. Heating and Cooling of Residential buildings.
8. Solar Furnace.
9. Solar distillation.
10. Electric power generation by Solar Ponds, Steam Generators heated by rotating reflectors and Photovoltaic cells.

2. Wind Energy:

- Energy can be produced by harnessing the wind power.
- Wind is caused by mainly two reasons:
  1. Heating & Cooling of the atmosphere which generates convection current.
  2. The Rotation of Earth with respect to its atmosphere and its motion around the Sun.
- The potential of wind energy is very large which is estimated to be about 1.6×10^7 MW.

2. Wind Energy:

- **Wind Energy is an indirect source of Solar Energy. Why?**
- In India generally the wind speed is low. Therefore attempts are being made for development of low speed, low cost wind mills.
- Special focus is on development of mill for water pumping which can operate at low wind speed of 8-36 km/hr. Which can be utilised for providing drinking water in small rural area, irrigation of small farms.
- In India high speed winds are available in coastal areas of Saurashtra, Rajasthan and some parts of central India.

2. Wind Energy:

- In these area we can use high speed wind mills, to generate Electricity and feeding the same to the grid.
- **Wind Mill Types:**

1. Multi-blade type Wind Mill
2. Sail type
3. Propeller type

Horizontal Axis

4. Savonius type
5. Darrieus type

Vertical Axis

2. Wind Energy:

- **Characteristics of Wind Energy:**
  1. It is a renewable source of energy.
  2. Wind power systems are non-polluting and has no adverse effects of the environment.
  3. Wind energy systems avoids fuel provision and transport.
  4. On small scale of upto few kilowatts, it is less costly. On large scale the costs are comparable with the costs of conventional energy sources, but low cost can be achieved by mass production.

2. Wind Energy:

- **Problems with Wind Energy:**
  1. Availability of wind is fluctuating or irregular in nature.
  2. Unlike water energy, it requires storage means because of irregular nature.
  3. Wind energy systems are noisy in operation; a large unit can be heard many km away.
  4. Large area is needed for installation of Wind Farms, for Electricity generation.

2. Wind Energy:

- It is used for operating water pumps for irrigation purposes. Approximately 2756 wind pumps were set up for this purpose.
- In seven states, wind power operated power houses were installed and their installed capacity is 1000 MW.
- India has second position in wind power energy generation.

3. Bio Mass and Bio Gas

- Bio Mass means Organic Matter.
- The Bio-mass is produced in nature through Photosynthesis achieved by solar energy conversion.
- In simplest form the reactions in the Photosynthesis can be represented as:

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

- In this reaction, the water and carbon dioxide are converted into organic material $C_6H_{12}O_6$ which is basic molecule of stable carbohydrate at low temperature.

3. Bio Mass and Bio Gas

- At high temperature, it breaks and releases Heat of amount equal to 112 kcal/mole or 469 kJ/mole.

$$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O + 112\ \text{kcal/mole}$$

- So the absorbed energy of photons is converted into carbohydrate which can then be used as source of energy.
- It is possible to produce large amount of carbohydrate by growing Algae (say) under suitable conditions, in plastic tubes or in ponds.

3. Bio Mass and Bio Gas

- Then the Algae, which is our Bio-Mass in this example, could be harvested, dried and burned for production of heat that could be converted into Electricity.
- The energy from Bio-Mass is taken by burning it directly or by further processing it to produce more convenient liquid and gas forms.

3. Bio Mass and Bio Gas

- The Bio-Mass resources falls into three categories:

1. Bio-Mass in its traditional solid form. (e.g. Wood, agri waste etc.) This form is directly burned to get energy.
2. Bio-Mass in its non-traditional form (converted into liquid form) In this category the Bio-Mass is converted into liquid from such as Ethanol & Methanol, which can be used as liquid fuel in engines
3. Bio-Mass in Fermented form. In this category Bio-mass is fermented to obtain its Gaseous fuel called Bio-Gas. Bio-gas has 55-65% Methane, 30-40% CO_2 and rest impurities containing H_2, H_2S and some N_2.

3. Bio Mass and Bio Gas

- **Energy Plantation:** For large scale production of electricity, use of fire wood as a fuel for the boiler of a conventional power plant is called Energy Plantation scheme. In this some selected species of trees are planted and harvested over regular time period, on land near a power plant.
- This requires a large area near power plant for plantation purpose.
- The trees which are suggested for India are Eucalyptus, Casuarina and Babool.

3. Bio Mass and Bio Gas

- **Bio-Gas:** The main source for production of bio-gas is wet cow dung (gobar) or wet livestock waste (or even Human waste).
- The bio-gas has a particular significance in India because of large cattle population, which is about 250 million.
- Some other sources of bio-gas are: Sewage, Crop residue, vegetable waste, poultry waste, algae etc.

4. Ocean Thermal Energy Conversion (OTEC)

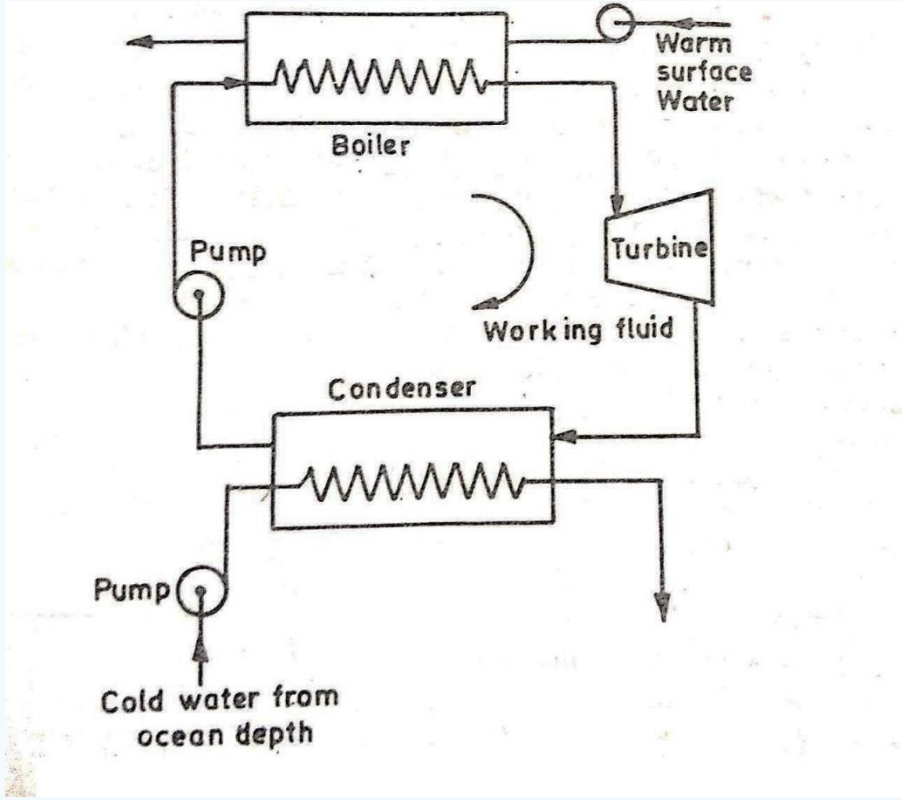
- This is also as indirect source of Solar Energy.
- The tropical oceans absorb a large amount of solar energy. The surface of ocean acts as collector of heat, while the temperature in the depths is 20-25 °c lower.
- This difference in temperature is used to obtain energy.
- The surface water, which is heated, is used to heat some low boiling organic fluid such as ammonia, propane, R-12, R-22, etc.
- Then the vapour produced will run the heat engine.

4. Ocean Thermal Energy Conversion (OTEC)

- The exit vapour is condensed using cold ocean water of deeper regions.
- Several such plants were build in France with capacity upto 7.5 MW.
- The OTEC works in Closed Rankine Cycle.
- In India the Department of Non-Conventional Energy Sources (DNES) has proposed to set up a 1 MW OTEC plant in Lakshadweep Islnd.

4. Ocean Thermal Energy Conversion (OTEC)

- Rankine Cycle OTEC

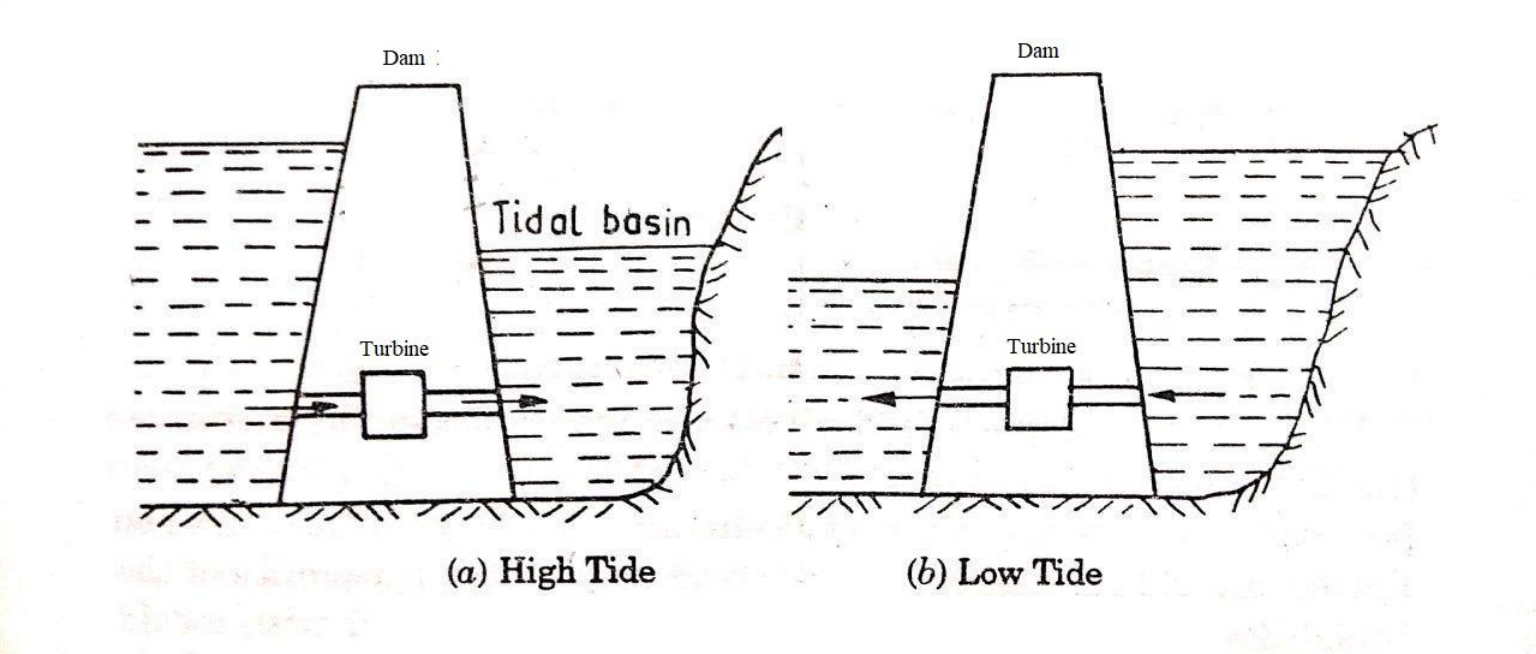


5. Tidal Energy

- The Tides in the sea are result of the universal gravitational effects of the Sun and Moon on the Earth.
- This causes a periodic rise and fall of the sea water level with daily rising and setting of the Sun and Moon.
- These tides can be used to produce electricity which is known as Tidal power.
- When the water is above the mean sea level it is called *flood tide*, and when it is below it's called *ebb tide*.

5. Tidal Energy

- To harness the power of tides, a dam is built near the coastal area. The dam has large gates to let the water in and out. A low head hydraulic reversible Turbine is used which in turn generates electricity.



5. Tidal Energy

- A tidal basin is formed, which is separated from the sea by the dam. With every tide, a difference in water levels of the sea and the basin is obtained.
- The basin is filled with water with high tide and emptied with low tide, with the water passing through the Turbine.
- The turbine is reversible type which can operate in both directions of rotation.
- The turbine is coupled with a Generator, which generates Electricity.

5. Tidal Energy

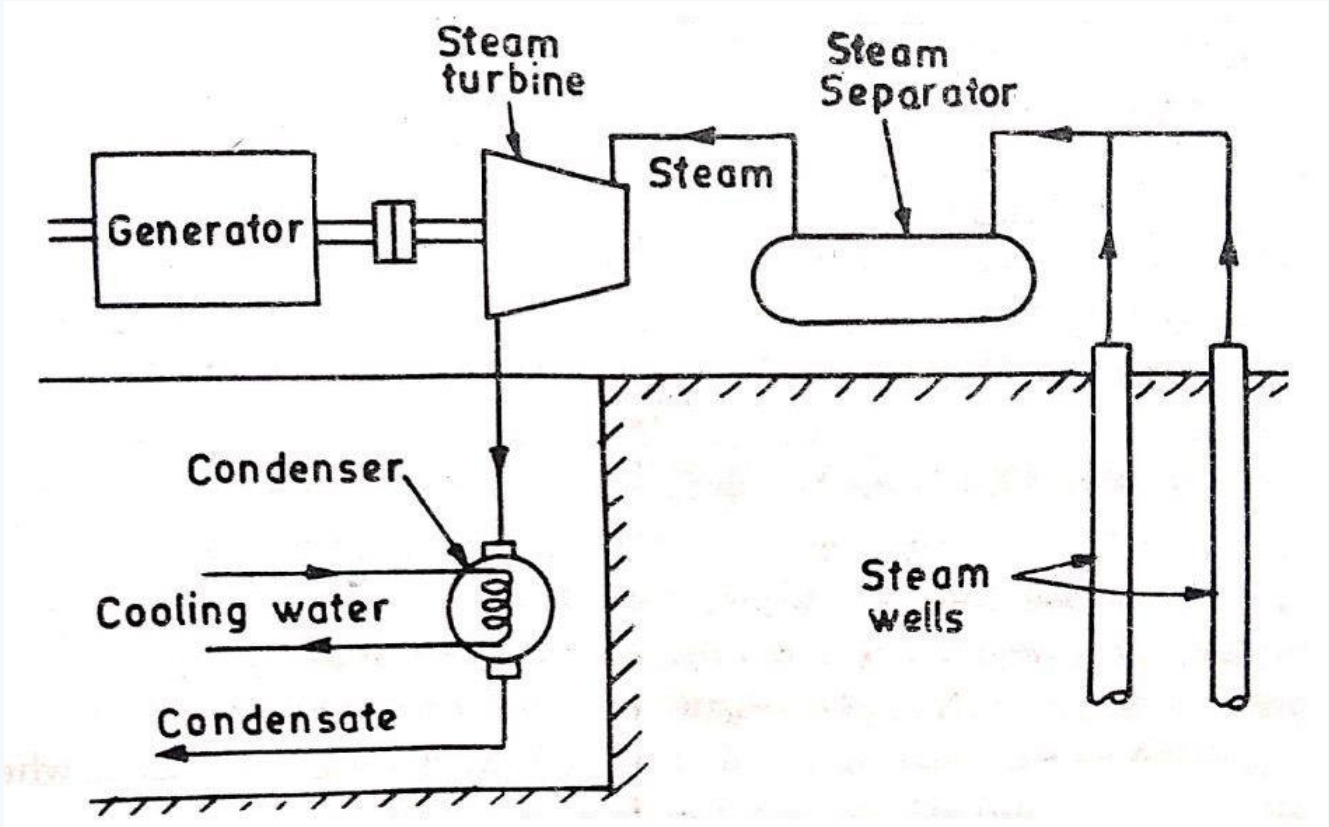
- The tidal plant shown in figure is called as Single Basin Plant. The problem with such plants is that it can not generate electricity continuously.
- To overcome this drawback, two basin plants can be used.
- Due to the absence of cost effective technology, and unavailability of continuous tides, this source of energy is not fully utilized.

6. Geothermal Energy

- This energy is embedded within the Earth. The Earth has molten core and various volcanic activities occurs in many places.
- Due to the heat, the ground water is converted into steam and sometimes the hot water and steam comes out naturally due to high pressure.
- For large scale use, we can bore holes (Steam Wells) for upto 1000m, which will release the steam & hot water with temperature upto 200-300 °c.
- These steam can be used to operate steam turbine which will generate electricity.

6. Geothermal Energy

- Geothermal power plant



6. Geothermal Energy

- The water coming out of steam wells contains high amount of dissolved minerals, and the steam contains these water molecules.
- So the moisture and solid particles needs to be separated out from the steam before being fed to the steam turbine.

7. Hydrogen Energy

- The Hydrogen can play an important role as an alternative source of energy.
- Its burning process is non-polluting and it can be used in the fuel cells too.
- Hydrogen has highest energy content per unit of mass as compared to any other chemical fuels.
- One of the most attractive feature of Hydrogen is that, it can be produced from water which is easily & abundantly available in nature.

7. Hydrogen Energy

- The problems with Hydrogen Energy are:

1. Hydrogen is not freely available in nature, it has to be produced.
2. technical problems in production of Hydrogen, its storage and transportation.

8. Fuel Cells

- It is defined as an electro-chemical device which continuously converts the fuel into electrical energy.
- The difference between a fuel cell and a battery is that, the battery generates electricity from the energy which is stored in it. While, the fuel cell generates electricity from fuel which is stored in an external tank.
- So, a battery may become dead, while a fuel cell will run until the fuel supplied to it.

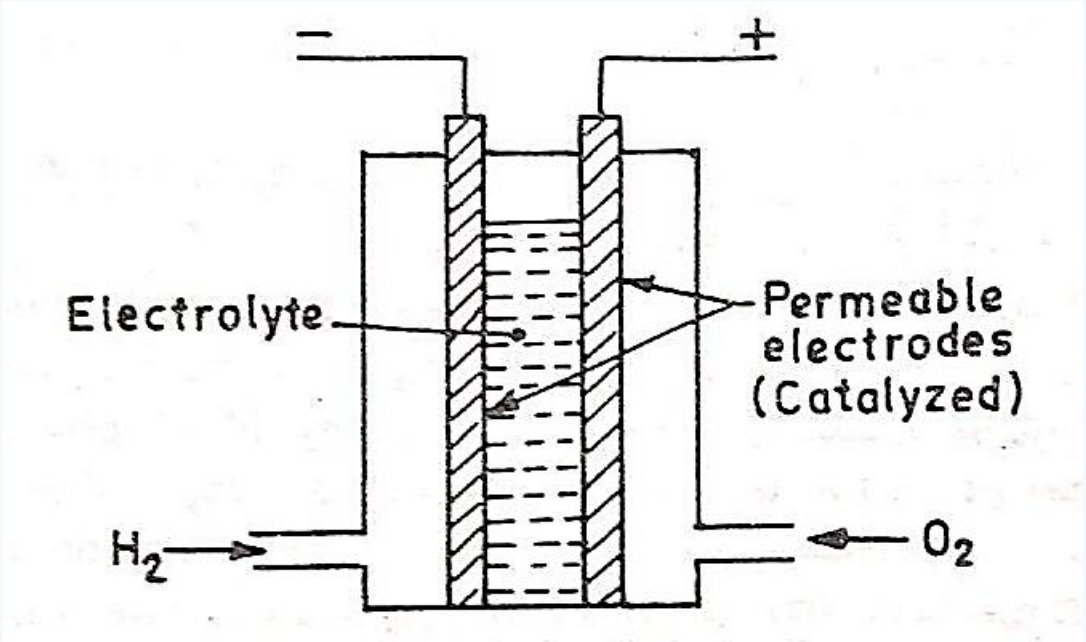
Qu. Write difference between Fuel Cell and Battery.

8. Fuel Cells

- Some types of fuel cell are: Hydrogen-Oxygen (H_2, O_2), Hydrazine-Oxygen (N_2H_4, O_2), Carbon/Coal-Oxygen (C, O_2), Methane-Oxygen (CH_4, O_2).
- Hydrogen-Oxygen fuel cells (Hydrox) are most efficient and highly developed cell among all.
- In this two porous carbon or nickel electrodes are immersed in an electrolyte. The electrolyte is usually 30% KOH due to its high electrical conductivity and low corrosiveness.
- In the fuel cells the prime requirement of electrolyte is that, it should not change as the cell operates.

8. Fuel Cells

- The H_2 fed at one end, is absorbed by electrode, which gives free electrons and it also reacts with Hydroxyl ions (OH^-) of electrolyte to form H_2O.



8. Fuel Cells

- The free electrons travel from one electrode to another through external circuit, causing current.
- These electrons reacts with the H_2O and the O_2 being fed from another side, and forms Hydroxyl ions (OH^-).
- The OH^- ions generated are consumed in the electrolyte and thus the electrolyte remains unaffected.

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

$$2H^+ + 2OH^- \longrightarrow 2H_2O$$

$$O_2 \longrightarrow 2O$$

$$O + H_2O + 2e^- \longrightarrow 2OH^-$$

8. Fuel Cells

- These type of cells operate at (or slightly above) the atmospheric pressure and at temperature of about 90 °c. These cells are also called as Low Pressure and Low temperature cells.
- In high pressure cells the pressure may go upto 45 atmospheric and temperature may go upto 300 °c.
- A single Hydrogen-Oxygen fuel cell produces an emf of 1.23 volts. By connecting more cells in proper arrangement we can get higher values of voltage and power.

8. Fuel Cells

- Advantages of fuel cells:

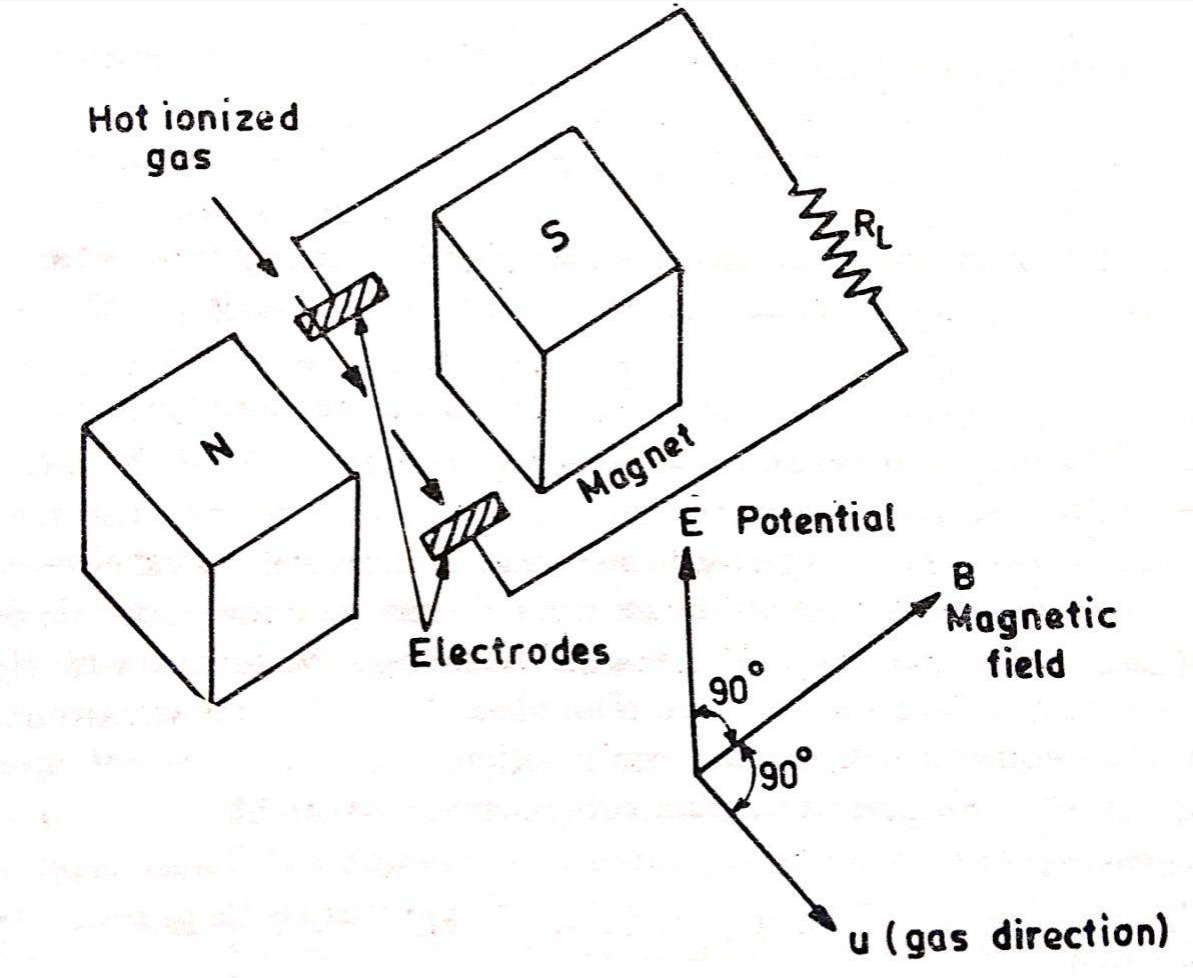
1. It is a direct conversion process and does not involve a thermal process, so it has high efficiency (38% - 60%).
2. The cell unit is small, light weight and requires low maintenance.
3. Fuel cells use may reduce the transmission losses.
4. Very low pollution and noise, it can easily be used in residential areas.

- Drawbacks includes low voltage output, high initial costs and low service life.

9. MHD (Magneto Hydro-Dynamic) Power

- The principle of MHD power generation is based on direct conversion of Thermal Energy into Electrical Energy.
- It is based on the Faraday's principle: "When an electric conductor is moved across a magnetic field, a voltage is induced in it which produces electric current."
- In MHD generation solid conductor is replaced by electrically conducting fluid, which may be either an ionised gas or liquid metal.

9. MHD (Magneto Hydro-Dynamic) Power



9. MHD (Magneto Hydro-Dynamic) Power

- As shown, Hot, partially ionised and compressed gas is passed through a strong magnetic field in a duct, which causes generation of electrical potential in the gas.
- Electrodes placed at the two ends of the duct, pick up the potential generated in the gas.
- In this manner the Direct Current (DC) is obtained, which can be later converted into AC using an inverter.
- An experimental MHD plant of 5 MW is set up in Tiruchirapalli.

Suggested Study

- Advantages & Disadvantages (Merits & Demerits)of Non-conventional / Renewable energy sources.
- Obstacles in implementation of NCES.
- Prepare answers of previous year's questions and questions given in the book.

- Note: Energy Storage (of Solar, Wind etc.) will be studied in upcoming units.

End of Unit - 1