1. Role of energy in Economic and Social development

The word 'Energy' is derived from the Greek word 'en-ergon' means 'in-work' or 'Work content'. The capability to do work depends on the amount of energy available. S.I unit of energy is Joule.

Energy resources are classified into two types basing on their long term availability.

1. **Non-Renewable energy resources**: Energy resources which are finite and cannot be replenished after consumption are known as non-renewable energy resources.
   Examples: Coal, Oil, Natural Gas, Nuclear Energy etc
2. **Renewable energy resources**: Energy resources which are infinite and can be replenished after consumption are known as renewable energy resources.
   Examples: Solar energy, Wind energy, geo thermal energy, hydro energy.
   - Presently, 80 % of the global energy consumption is from non-renewable energy resources.

Historically, energy is the driving force behind the economic and social development of mankind. Energy requirement of man increased drastically from the times of primitive man to the present industrial era. Before the industrial revolution, wood was the main source of energy. The discovery of steam engine in 1785 which works with the burning of coal lead to industrial revolution. The industrial revolution is the most important step in the economic and social development. Later, the discovery of internal combustion engine in the late nineteenth century lead to the use of petrol, diesel and natural gas to fulfil our increasing energy needs. The discovery of induction motor to generate electrical power by Tesla in 1888 started the electrical age. Hence Energy has been the driving force behind the social and economic development of mankind.

The availability of sufficient amount of energy is fundamental to the economic growth and social development of a country. It is clear that countries having higher per capita energy consumption have higher literacy rates, while countries having lower per capita energy consumption have lower literacy rates. Hence energy consumption is directly linked to the social development of a country. For example, per capita energy consumption in the America is 12000 kWh/year while it is 600 kWh/year in India.

The economic development of a country is also linked to the availability of energy resources and their consumption. The economic development of a country mainly depends on the following sectors.

- Commercial
- Industrial
- Residential
- Transportation

Energy is the driving force in all these sectors. Hence availability of sufficient amount of energy for these sectors leads to the economic growth. Access to modern energy services are necessary for improved health, education, Industrial and agricultural productivity. Hence per capita energy consumption is a measure of prosperity of a country.

One of the major challenges of global economy is that approximately 1.2 billion people don't have access to the modern energy resources leading to poverty. Moreover, the conventional energy resources like Coal, Petroleum and Natural gas Poverty can be eradicated only if the modern energy resources are accessible even to the common man. The discovery of eco friendly new renewable energy resources like wind energy, solar energy etc. helps to overcome this problem.

1.2 Environmental degradation due to energy production and utilization

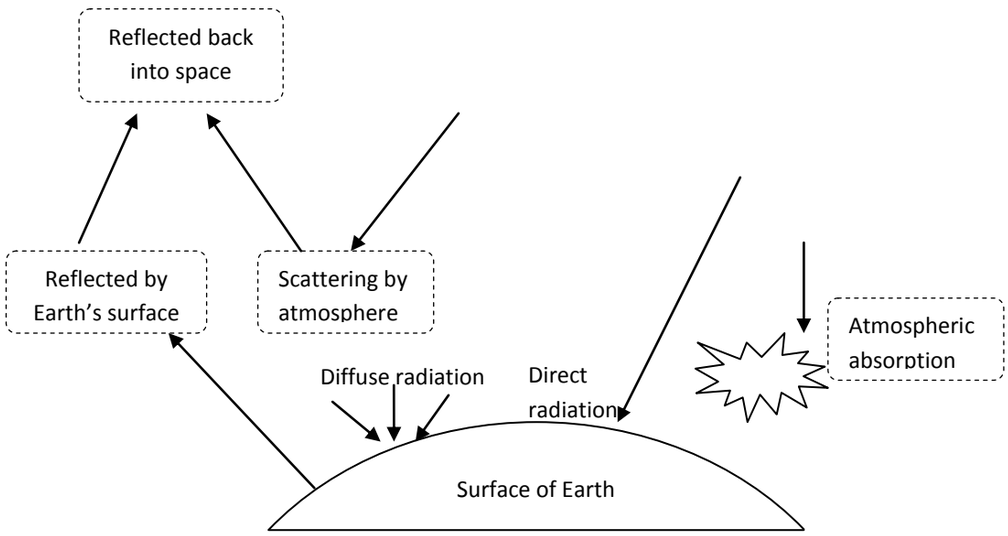
Use of energy in any form affects the environment. We know that, approximately 70 % of the world's energy is produced from fossil fuels. But as fossil fuels contain large quantity of carbon, burning of fossil fuels produces carbon dioxide which leads to environmental degradation. Since the energy requirement of man increased drastically from the times of primitive man to the present industrial era, use of fossil fuels also increased. This excessive use of fossil fuels is causing environmental pollution which is hazardous to the survival of mankind. Major environmental problems due to the energy production and utilization are global warming and ozone depletion.

We know that green houses gases like CO_2, methane, nitrous oxide etc. trap heat and thereby keep the temperature of the Earth warm around 30^0C by absorbing infrared radiation from the Sun. In the absence of green house gases, the temperature of the Earth would have been -18^0c which is not conducive for existence of life on planet Earth. But, due to excessive use of fossil fuels, the concentration of CO_2 in the atmosphere gradually increased to dangerous level. Hence the balance of heat is disturbed and too much heat is trapped. As a result the average temperature of the Earth increased above the acceptable level. This is known as global warming or global climate change. This global warming is due to the excessive use of fossil fuels like coal, oil, natural gas etc which increase CO_2 levels in the atmosphere. The concentration CO_2 in the atmosphere increased drastically from 280 ppm in 1850 to the present level of 400 ppm. Since plants absorb CO_2 and release oxygen, deforestation also contributed to increased levels of CO_2 and thereby global warming also. The use of eco friendly new renewable energy resources like wind energy, solar energy, hydro energy etc. in place of fossil fuels helps to overcome this problem.

Ozone layer depletion is also an important environmental concern due to excessive energy production. Ozone layer is located in stratosphere at a height of 12 to 25 km. It protects us from harmful ultraviolet radiation emitted from the Sun. The ozone molecule absorbs ultraviolet radiation and decomposes in to oxygen and monatomic oxygen and thereby blocks the ultraviolet radiation from reaching the Earth's surface. The gases produced due to the burning of fossil fuels and the use of chloro-fluoro carbons in air conditioning and refrigerating machines are responsible for the depletion of ozone layer. Approximately 5 % of ozone layer is already damaged. The depletion of ozone layer is highest in south pole. Owing to the depletion of ozone layer, ultraviolet radiation reaches the earth's surface and produce harmful effects on human life.

1.3 Energy flow diagram to the Earth

Earth receives energy from Sun in the form of electromagnetic radiation. The reflection, scattering and absorption of the solar radiation by the Earth's surface and atmosphere are shown in figure. This is known as energy flow diagram to the Earth.



- It is clear from the diagram that, a part of the solar radiation is reflected back in to space by the Earth's atmosphere.
- The radiation which enters the atmosphere is partly absorbed by the molecules in the air. For example, Oxygen and Ozone molecules absorb ultraviolet radiation while CO_2 molecules absorb infrared radiation.
- A part of the solar radiation which enters the atmosphere is scattered by the clouds and dust particles in the atmosphere.
- The radiation which is not absorbed or scattered by the atmosphere falls the Earth's surface directly from the Sun. This radiation is known as direct radiation or beam radiation.
- In addition to the direct radiation, a part of the radiation reflected and scattered by the atmosphere reaches the earth's surface. This radiation is known as diffused radiation. Diffused radiation comes from all directions unlike the direct radiation which comes directly from the sun.
- Hence the solar radiation received by earth's surface at any place is the sum of direct radiation and diffuse radiation.

2.1 Global Energy Resources (OR) Energy Resources in India

The word 'Energy' is derived from the Greek word 'en-ergon' means 'in-work' or 'Work content'. The capability to do work depends on the amount of energy available. S.I unit of energy is Joule.

Energy is the most important factor of economic and social development of a country. It is observed that per capita energy consumption is a measure of the economic prosperity of the country. Energy is used mainly in four sectors.

- Commercial
- Industrial
- Residential
- Transportation

The energy consumption is maximum in the industrial sector.

Energy resources are classified into two types basing on their long term availability.

1. **Non-Renewable energy resources**: Energy resources which are finite and cannot be replenished after consumption are known as non-renewable energy resources.
   Examples: Coal, Oil, Natural Gas, Nuclear Energy etc
   - Non- renewable energy resources cause environmental pollution and global warming. Hence their use should be minimised in future.
2. **Renewable energy resources**: Energy resources which are infinite and can be replenished after consumption are known as renewable energy resources.
   Examples: Solar energy, Wind energy, geo thermal energy, hydro energy.
   - Renewable energy resources do not cause environmental pollution. They produce clean energy. Hence their use should be increased in future.

Presently, 80 % of the global energy consumption is from non-renewable energy resources.

Important energy resources:

1. **Coal:**
   - Coal is a non renewable energy resource.

- It is a fossil fuel. It is formed due to the decomposition of vegetable matter buried inside the earth and formed as a solid layer due to the heat and pressure of the earth.
- Coal mainly contains carbon and hydrocarbons.
- Basing on the carbon content, coal is classified into peet, lignite, bituminous, anthracite in the increasing order of carbon content..
- Coal is mainly used to produce electricity through thermal power stations.
- Total coal reserves in the world are estimated to be 22.4×10^6 Million tonnes.
- USA has the largest coal reserves in the world.
- In India, largest coal reserves are in Jharkand, UP,MP,Bihar etc.
- With the present rate of consumption, coal lasts only for 205 years.
- Since coal is a fossil fuel, burning of coal produces Co2 which causes global warming. Hence the use of coal should be decreased in future.

2. **Oil:**
   - Oil is a non-renewable energy resource.
   - It is a fossil fuel. It is formed due to the decomposition small animals and plants that died at the bottom of oceans and formed as a liquid layer due to the heat and pressure of the Earth.
   - Oil mainly contains complex mixture of hydrocarbons and some inorganic elements like sulphur, oxygen and nitrogen.
   - Crude oil is refined to obtain Petroleum, Diesel and Kerosene.
   - Oil is mainly used in transportation sector.
   - Total oil reserves in the world are estimated to be 3100 billion barrels.
   - Venezuela has largest oil reserves in the world.
   - In India, Oil reserves are found in Assam, Krishna-Godavari basin etc.
   - With the present rate of consumption, oil lasts only for 40 years
   - Since oil is a fossil, burning of oil produces Co2 which causes global warming. Hence the use of coal should be decreased in future.
3. **Natural gas:**
   - Natural gas is a non-renewable energy resource. It is the cleanest fossil fuel.
   - It is found along with crude oil.
   - Natural gas mainly contains methane, ethane, propane etc.
   - Natural gas is used in thermal plants for electricity generation and as fuel for transportation.
   - Total natural gas reserves in the world are estimated to be 5500 trillion cubic feet.
   - Russia has largest natural gas reserves in the world.
   - In India, Bombay high basin and Gujarat has largest natural gas reserves.
   - With the present rate of consumption, natural gas lasts only for 53 years.
4. **Nuclear energy:**
   - Nuclear energy is a non-renewable energy resource.
   - It is produced in nuclear fission reaction when a heavy nucleus splits in to two smaller nuclei.
   - Einstein's mass energy equivalence principle is the basis for this energy.
   - Nuclear energy of the atoms is converted into electrical energy using a breeder reactor in nuclear plant.
   - Isotopes of Uranium and Plutonium are used as nuclear fuel.
   - USA is the leading producer of nuclear power in the world.

5. **Hydro-electric power:**
   - Hydro-electric power is a renewable energy resource.
   - It is produced when the potential energy of water is converted into mechanical energy using hydraulic turbines.
   - It is mainly used for electric power generation.
   - 16.5 % of world' electricity produced using hydro power.
   - World' largest hydro plant is located in China with a capacity of 22.5 GW.
   - It is also an indirect form of solar energy.
   - It does not cause any environmental pollution. It is a clean energy.

2.2 Need for the use of renewable energy sources

The word 'Energy' is derived from the Greek word 'en-ergon' means 'in-work' or 'Work content'. The capability to do work depends on the amount of energy available. S.I unit of energy is Joule.

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Presently, 80 % of the global energy consumption is from non-renewable energy resources as they are cheaper and convenient to use .But non-renewable energy resources have number of disadvantages.

Major disadvantages of non-renewable energy resources:

- Burning of fossil fuels produces CO_2 and other pollutants like CO, NO_2, SO_2 etc which cause environmental pollution and health hazards. Excess CO_2 also produces global warming.
- Since the rate of energy consumption is increased, the reserves of non-renewable energy resources are decreasing rapidly and create problems for energy security.
- Coal is valuable petro-chemical and is used as raw material for various chemical, pharmaceutical and paints. Hence coal must be reserved for future needs instead of using for energy production through combustion.
- Nuclear energy also causes environmental problems due to radioactivity and nuclear waste.
- Large hydro-electric plants cause ecological imbalances and earthquakes.

Hence due to these disadvantages, there is a great need for the use of eco-friendly renewable energy resources in place of non-renewable energy resources. Moreover, renewable energy resources have number of advantages.

Major advantages of renewable energy resources:

- ✓ Renewable energy resources are available in nature free of cost.
- ✓ They are continuously replenished over a short period of time. Hence they are inexhaustible.
- ✓ Renewable energy resources does not environmental pollution. Hence they are eco-friendly.
- ✓ They have small gestation period.
- ✓ Renewable energy resources can help save foreign exchange and generate local employment.

Hence the use of renewable energy resources should be increased to avoid environmental degradation and energy security problems.

3.1 Principle of wind energy conversion

Wind means "Air in motion". We know that a moving object has kinetic energy. Hence wind has kinetic energy. The kinetic energy of the wind can be converted in to electrical energy by using wind turbines.

Wind energy is an important renewable energy resource. Winds are formed due to pressure differences which are created due to the uneven heating of the earth's surface by the sun. Hence wind energy is an indirect form of solar energy. Approximately, 2% of the solar energy is converted to wind energy.

Advantages and disadvantages of Wind energy:

Advantages:

- ✓ Wind energy is a renewable energy.
- ✓ Wind energy is a clean energy. It does not cause environmental pollution.
- ✓ Wind energy can be produced even in remote areas where other forms of energy may not be available.

Disadvantages:

- Wind turbine design is complex.
- Since the speed of wind is not always constant, Wind energy is irregular and unsteady.

Principle of wind energy conversion:

Wind energy is the kinetic energy of the moving air. The basic principle of wind energy conversion is

"Converting the kinetic energy of the wind to mechanical energy using a wind turbine. This mechanical energy is converted to Electrical energy using an aero-generator".

Let V be the velocity of the wind, ρ be the density of air and A be the area through which the air flows per unit time. Then the mass of the air passing through the wind turbine per unit time is given by

$$m = \rho AV$$

$$\text{Kinetic energy} = \frac{1}{2}mV^2 = \frac{1}{2}\rho AV.V^2 = \frac{1}{2}\rho AV^3$$

$$\text{Total power} = \frac{1}{2}\rho AV^3$$

Let D be the diameter of the wind turbine, then

$$A = \pi\frac{D^2}{4}$$

$$\text{Total power} = \frac{1}{2}\rho AV^3 = \frac{1}{2}\rho\left(\pi\frac{D^2}{4}\right)V^3 = \frac{1}{8}\rho\pi D^2V^3$$

Wind power $P = \frac{1}{8}\rho\pi D^2V^3$

The above equation gives the maximum theoretical power that can be obtained from wind. But experimentally, all this power cannot be extracted. Approximately a fraction $\frac{16}{27} = 59.3\ \%$ of the power in the wind can be extracted. This limit is called Gilbert's limit or Betz coefficient.
It is clear from the above equation that wind power depends on the following factors

1. **Air density (ρ):**
   Wind power is directly proportional to the air density (ρ).
2. **Wind speed (V):**

Wind power is directly proportional to the cube of wind speed (V). Hence wind turbine should be established in areas where wind speed is high. Optimal wind speed range is 5 m/s to 25 m/s.

3. **Diameter of the rotor (D):**
   Wind power is directly proportional to the square of the diameter of the wind turbine rotor. Hence wind turbine should have large rotors.

Hence principles of wind energy conversion are

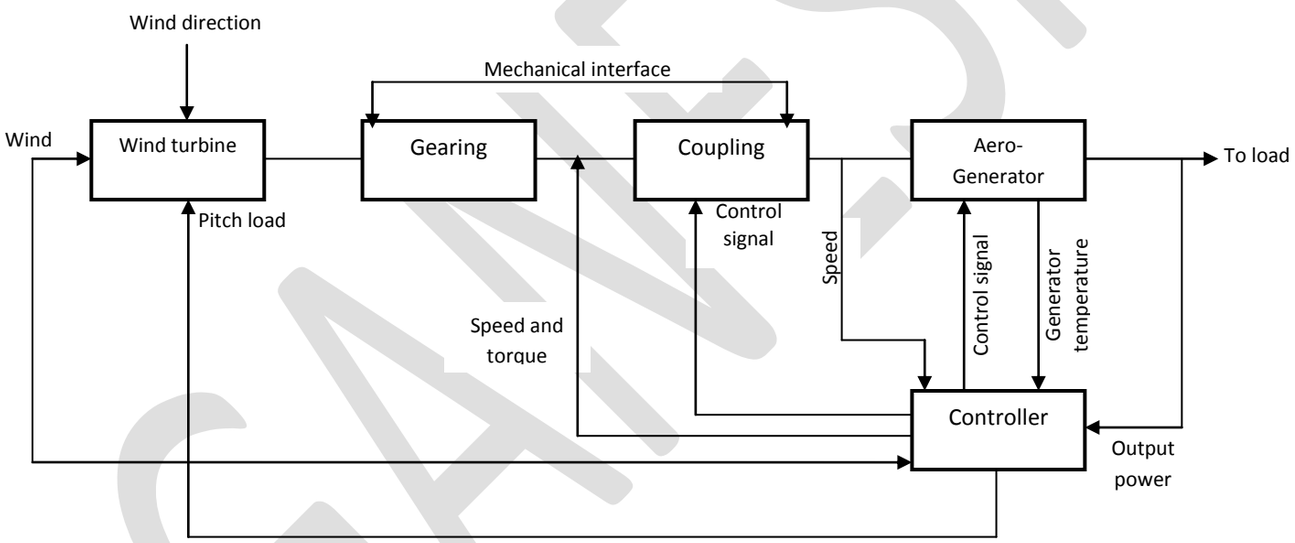
- ✓ Wind should be high
- ✓ The rotors of the wind turbine should be large.

3.2 Components of a Wind turbine (or) Operation and characteristics of wind turbine or (wind energy conversion system)

Wind energy is the kinetic energy of the moving air. The basic principle of wind energy conversion is

"Converting the kinetic energy of the wind into mechanical energy using a wind turbine".

This mechanical energy is converted to Electrical energy using an aero-generator.
Basic components and functioning of a wind energy conversion system are shown in the block diagram.



Wind turbines are mainly classified in to two types basing on the axis of rotation.

- **Horizontal Axis Wind Turbine**: When the axis of rotation is parallel to the direction of wind, the turbine is called Horizontal Axis Wind Turbine.
- **Vertical Axis Wind Turbine**: When the axis of rotation is perpendicular to the direction of wind, the turbine is called Vertical Axis Wind Turbine.

Presently, Horizontal Axis Wind Turbines are used more than the Vertical Axis Wind Turbine for wind power generation.
The main components of wind turbine are given below.

1. **Turbine Blades**: A wind turbine has two or three rotating blades to convert the kinetic energy of the wind in to rotational energy. These blades are made of high density wood or glass fibre. The blades are designed basing on the laws of aerodynamics to efficiently convert the kinetic energy of the wind into rotational energy. When wind passes through the turbine, two forces lift and drag act on the blades and rotate them. These two forces are responsible for the wind energy conversion. The blades are designed such that lift is maximum and drag is minimum. Generally diameter of a blade is of the order of 100 m.

2. **Hub:** The central portion of rotor wheel is known as hub. The blades are connected to the hub.
3. **Nacelle:** The hub is attached to nacelle which is mounted at the top of a tower. Nacelle contains gearbox, brakes, generator and control block.
   - Gearbox increases the rotation speed of the shaft.
   - Brakes are used to stop the rotor when power is not required.
   - Generator converts the rotational energy of the shaft into electrical energy. This generator is known as aero-generator. This aero-generator contains a step up gear box and suitable coupling. The output of the generator is connected to the load.
   - Control block measures the wind speed, wind direction, output power and generator temperature and send control signals to protect the system from very strong winds and electrical faults.
4. **Yaw control mechanism**: The extract maximum wind energy, wind turbine must always directly face the wind. Hence Yaw control mechanism is used to change the orientation of the turbine depending on the wind direction such that it always faces directly into the wind.
5. **Tower**: Tower supports nacelle and rotor. Since the wind speed increases with height, height of the tower is large so that maximum wind power can be extracted.

3.3 Applications of wind energy

I. Mechanical applications:

- Wind turbines are used to pump water in remote areas. These are called wind pumps. The wind pumps are used to supply water for livestock, small scale irrigation and domestic water supply.
- Wind power is used to produce heat with 100 percent efficiency using paddlewheel and other turbines.

II. Electrical applications:

- Low power wind turbines are used to generate electricity for space heating and cooling of homes, water heating, battery charging and for operating domestic appliances such as fan, light and small tools.
- Medium power wind turbines are used to produce electrical power for navigation signal, remote communication, weather stations.
- Wind turbines of capacity 100 to 250 kW are used to supply electrical power to isolated population, commercial refrigeration and small industries.
- Large wind turbines with a capacity of few MW are used to supply power to grid.

4.1 Hydrogen Energy-Production of Hydrogen using Electrolysis of water

As we know, approximately 70 % of the world's energy is produced from fossil fuels. But as fossil fuels contain large quantity of carbon, burning of fossil fuels produces carbon dioxide which leads to global warming. Hence Hydrogen energy system is an alternative to fossil fuels. Hydrogen gas was discovered by Henry Cavendish in 1766.

The basic principle involved in the production of energy from Hydrogen is given below.

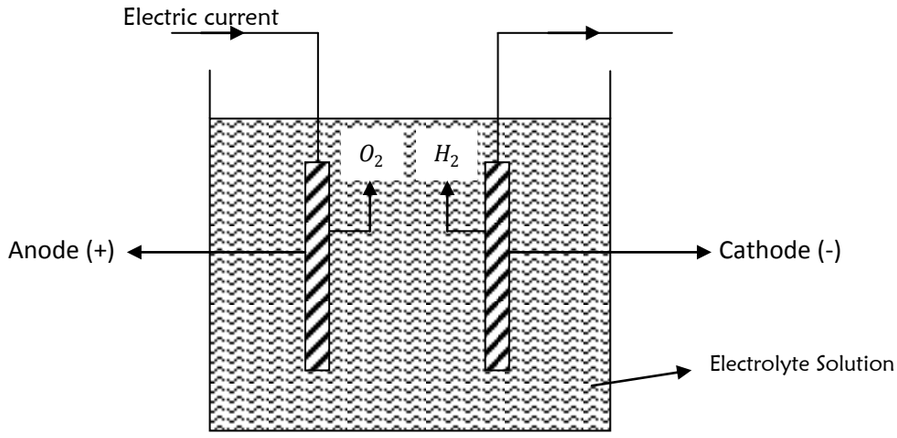
Combination of Hydrogen gas with oxygen in the air liberates chemical energy with water as the only product. This chemical energy can be converted into electrical energy.

$$2H_2 + O_2 \longrightarrow 2H_2O\ (Water) + (Heat)$$

Even though, Hydrogen is the most abundant element in the universe, it is not available in free state on planet Earth. Hydrogen easily forms bonds with other elements and hence found in large quantities in compounds like water, fossil fuels and biological materials due to its high chemical reactivity. Energy must be supplied to break the chemical bonds and produce hydrogen gas from these materials. Hence production of hydrogen gas is the first step in the extraction of hydrogen energy.

Electrolysis of water:

Hydrogen gas can be produced from water which is abundantly available on Earth using electrolysis. **The process of splitting water into hydrogen and oxygen using direct electric current is known as electrolysis.**



Electrolysis cell consists of two electrodes, anode and cathode immersed in a conducting solution called electrolyte. A battery is connected to the electrodes. When electric current passes through the electrolyte, water is decomposed into hydrogen gas and oxygen gas. Hydrogen gas is released at cathode and oxygen gas is released at anode. The rate of hydrogen production is directly proportional to the current. Hence high current density is required to produce large quantity of hydrogen gas.

The reaction of electrolysis is given below.

$$2H_2O\ (Liquid) \longrightarrow 2H_2\ (Gas)\ (At\ cathode) + O_2(Gas)(At\ Anode) + (Heat)$$

The reactions at cathode and anode are given by

Cathode:

$$4H_2O + 4e^- \longrightarrow 2H_2 \uparrow + 4\ OH^-$$

Anode:

$$4\ OH^- \longrightarrow O_2 \uparrow + 2H_2O + 4e^-$$

The efficiency of electrolysis is given by

$$E = \frac{\text{Hydrogen produced (In m}^3\text{)} \times \text{K}}{\text{Power input(In kWh)}} \times 100$$

Experimentally, the value of K is found to be 3.3 kWh/m^3

Generally the efficiency of electrolysis is approximately 60 to 70%. The electrolysis efficiency can be increased by decreasing the decomposition voltage. Due to this reason, nickel plated steel electrodes are used in electrolysis. Diaphragms prevent electronic contact between electrodes and passage of dissolved gas from one electrode to another electrode. Asbestos is the most common material used for cell diaphragms.

The energy required to produce hydrogen is 3.5 kWh/m^3

The available electrolysis processes are

- Alkaline electrolysis
- Membrane electrolysis
- High temperature steam electrolysis.

4.2 Use of Hydrogen as fuel

As we know, approximately 70 % of the world's energy is produced from fossil fuels. But as fossil fuels contain large quantity of carbon, burning of fossil fuels produces carbon dioxide which leads to global warming. Hence Hydrogen energy system is an alternative to fossil fuels. Hydrogen gas was discovered by Henry Cavendish in 1766.

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Combination of Hydrogen gas with oxygen in the air liberates chemical energy with water as the only product. This chemical energy can be converted into electrical energy.

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Advantages of hydrogen as fuel:

- ✓ Hydrogen has very high energy content.
- ✓ Hydrogen energy is a clean energy. It does not cause environmental pollution.
- ✓ Hydrogen can easily be transported and distributed through pipelines.
- ✓ Since water is abundantly available on earth, large quantity of hydrogen can be produced from sea water.

Applications of hydrogen energy:

- ➢ Hydrogen is used for H2-O2 fuel cell for production of electrical energy.
- ➢ Hydrogen is used as fuel in aircrafts and rockets in liquid form
- ➢ Hydrogen energy is used in cooking, water heaters and air conditioning.
- ➢ Hydrogen energy is used in petroleum refining.
- ➢ It is used in manufacture of vanaspati, fertilizers and alcohols.
- ➢ Hydrogen is also used in generators.

Problems with hydrogen as fuel:

- Commercial production of hydrogen is costly.
- Difficulty in storage since it is highly explosive.

Biomass

Biomass is the organic material derived from plants and animals on land and water. The energy obtained from biomass is known as biomass energy. Earth's biomass is an enormous store of energy.

Examples: Residues of agriculture and forestry, animal waste etc.

- ✓ We know that animals feed on plants and plants grow through photosynthesis process using solar energy. Hence biomass is also a form of solar energy.

  Solar energy → Photosynthesis → Biomass → Energy generation
- ✓ Biomass is a renewable energy resource because it is renewed naturally in a short span of time unlike fossil fuels which take millions of years to form.
- ✓ Biomass is a clean energy. It releases the same amount of carbon which it absorbs during its life time when burnt. Hence there is no net addition of carbon to the atmosphere. Hence biomass energy is considered as 'carbon cycle neutral'

5.1 Biomass Resources

Biomass is the organic material derived from plants and animals on land and water. The energy obtained from biomass is known as biomass energy.

Examples: Residues of agriculture and forestry, animal waste etc.

Earth's biomass is an enormous store of energy. It is estimated that one just one eighth of the total biomass produced annually would provide all of humanity's current demand for energy.

Some important biomass resources are given below.

1. **Forests:**
   - Forests are good resources of biomass.
   - Forests provide timber, fuel wood, charcoal and raw material for paper mills and other industries.
   - Fast growing trees like Eucalyptus, Neem, Kikar are specially cultivated for energy.
   - Some plants of forests produce vegetable oil which is used as bio-diesel.
   - Forests also provide foliage and logging residues.
   - The calorific value of forest residue is 3888 to 5219 Kcal/Kg for hard wood species.
2. **Agricultural residues:**
   - Agricultural residues such as straw, rice husk, coconut shell, groundnut shell, sugarcane are used for production of biomass energy.

- These agricultural are converted into briquettes or pellets to be used as clean fuels. These are called bio-fuels.
- The agricultural residues can also be gasified to obtain producer gas which can be used as biofuel.

3. **Energy crops:**
   - Certain plants are cultivated to provide raw material for bio-fuels. This is known as energy farming and the crops are called energy crops.
   - Energy crops are mainly divided into three types. Sugar plants, Starch plants and Oil producing plants
   - In sugar plants, crops like sugarcane, sweet sorghum, sugar beet are cultivated to provide raw material for the production of bio-ethanol.
   - In starch plants, plants like Jerusalem artichoke, Cassava, grains such as maize, barley, rice and wheat provide raw material for production of bio-ethanol.
   - In oil producing plants, plants like sunflower, groundnut and cottonseed are grown to provide vegetable oil whichnis used as bio-fuel.
4. **Aquatic plants:**
   - Plants grown in water to provide raw material for producing biogas or ethanol are known as aquatic plants.
   - Examples of aquatic plants are hyacinth, kelp, seaweed and algae.
5. **Urban waste:**
   - Urban waste can be used as biomass.
   - Urban waste is of two types, municipal solid waste and sewage.
   - Municipal solid waste can be used to produce biomass energy through combustion.
   - Sewage can be used to produce biogas.

5.2 Aerobic and anaerobic bio-conversion

The process of extracting energy from biomass is known as biomass conversion. Biomass conversion technologies are divided into four types.

1. Densification
2. Combustion and incineration
3. Thermo-chemical conversion
4. Bio-chemical conversion

Biochemical conversion (or) Bio-conversion

Biochemical conversion is the decomposition of biomass into liquid and gaseous fuel using the metabolic action of micro organisms like bacteria and yeasts. Biochemical conversion is divided in to two types.

- Aerobic bio-conversion
- Anaerobic bioconversion

1. Anaerobic bioconversion:

The process of decomposition of biomass using bacteria in the absence of oxygen is known as anaerobic bio-conversion. This process is also called anaerobic fermentation. In this process, wet biomass and animal waste with high moisture content are decomposed by bacteria for several days in a sealed tank called digester. As a result, the biomass is converted into biogas due to the metabolic activity of the bacteria.

This process takes place in two stages by two different groups of micro organisms. In the first stage, the organic material is hydrolyzed into fatty acids, alcohol, sugars, H_2 and CO_2. In the second stage, methane forming organism converts the products of the first stage to methane and CO_2 in the temperature range 30-55^0 C. Hence this process generates mostly methane and CO_2 gas with small impurities such as hydrogen sulphide. The biogas obtained from

anaerobic bio-conversion can be directly burnt or upgraded to superior fuel gas by removal of CO_2 and other impurities. This process takes place in a sealed tank called 'digester' where the protein rich sludge left behind is used as animal feed or fertilizer. The most useful biomass materials for this process are manure, algae, plant residues and other organic waste materials with high moisture content.

Wet biomass $\longrightarrow$ Biogas (Largely CH_4 and CO_2)

2. <u>Aerobic bio-conversion:</u>

The process of decomposition of biomass using bacteria in restricted oxygen supply is known as aerobic bio-conversion. This process is used to convert food waste into organic fertilizer using restricted air supply, stirring, pH and temperature at 55-65°C. To maintain neutral pH at the beginning of the process, 5% $CaCO_3$ is added to the solid biomass. This process produces CO_2, NH_3 along with other gases in small quantities and large quantity of heat. The final by-product of this process is used as fertilizer.