Sources of Energy

Introduction

We need energy for doing work. There are many types of works and so there are different types of energy. Energy becomes an essential part of our everyday active life. We have leant about the various forms of energy and we know these different forms are intercom vertible. We shall now learn about different sources of energy and group them according to the manner in which they supply energy.

- **Characteristics (Factors Constituting a Source of Energy)**
  1. It should be capable of providing an adequate amount of energy.
  2. It should be convenient to use, easy to transport and store.
  3. It should be capable of delivering desired quantity of energy at a steady rate over a long period of time.

  Home requirement

  In homes, besides carrying life activities, we mostly use fuels and electricity for heating, lighting and operating machines and other appliances.

Conventional and Non-conventional Sources of Energy

Sources of energy are also classified as:

1. **Conventional sources of energy**

   The sources which are used extensively since ancient times and major portion of our energy requirement are met by them e.g., fossil fuels and hydro energy are known as conventional sources of energy. Biomass energy and wind energy also are conventional sources of energy.
2. **Non-Conventional sources of energy**

   The sources which are not used extensively i.e., are limited in use are called non-conventional sources. For example. Solar energy, sea energy, geothermal energy and nuclear energy. These are called as alternative sources of energy.

Fossil Fuels

The combustible substances formed from the dead remains of the animals and plants which were buried deep under the surface of the earth over millions of years are called fossil energy sources or fossil fuels. At present, a major part of our energy requirement is being supplied by fossil fuels. Example of Fossil Fuels: Coal, petroleum and natural gas.

- **Coal**
  1. **Description:** Coal is a naturally occurring black mineral. It is a mixture of free carbon and carbon compounds containing hydrogen, nitrogen, oxygen and sulphur. It is not only a good fuel but also source of many organic compound.
  2. **Formation:** Coal is believed to be formed from fossils of big trees which got buried inside the earth about 300 million years ago due to occurance of earthquakes and eruption of volcanoes.
  3. **Procurement (Mining):** The coal is procured from coal mines. Minerable coal is defined as 50% of all coal which is in a layer of at least 12 inches thick and within 4000 feet of the surface.
  4. **Varieties:** There are four varieties of coals classified on the basis of carbon contents.

Name	Carbon
(i) Peat	27%
(ii) Lignite	28-30%
(iii) Bituminous	78 — 87%
(iv) Anthracite	94 - 98%

     Coal with higher carbon content delivers more energy. It makes Anthracite as the best quality coal.
  5. Releases of Energy: When the coal is burnt, the carbon present in it reacts with oxygen to produce carbon dioxide. A lot of heat is also produced because the reaction is exothermic.

ILLUSTRATION

1. One gram of coal on complete combustion liberates 18 kj of heat. Calculate the amount of coal required to liberate the same amount of heat that an electric heater of 2kw provides in one hour.

Soln. $p = \frac{E}{t} \therefore E = p \times t = (2kw)(3600_s)$

$\therefore \quad E = 7200 KJ$

18 KJ of heat is liberated on burning 1g of coal

$\therefore$ 72000 KJ of heat is liberated by burning

$= \frac{7200 \times 1}{18} = 400$ g of coal

6. **Location of coal mines :** In India, places where coal is mainly found, are
   (i) Bihar and Jharkhand
   (ii) Madhya Pradesh and Chhattisgarh
   (iii) Orissa and (iv) West Bengal.

7. **Uses of coal:**
   (i) It is used as a fuel.
   (ii) It is used in the manufacture of coke.
   (iii) It is used in producing electricity in thermal plants.
   (iv) It is used in the manufacture of synthetic petrol and synthetic natural gas.
   (v) It is used in the manufacture of industrial fuel gases, (i.e., water gas and producer gas).
8. **Drawbacks**:
   (i) It is a dirty fuel.
   (ii) It is difficult to handle.
   (iii) Coal burning results in the loss of many valuable volatile compounds.
   (iv) It causes pollution by emission of sulphur.

Do You Know

India has about 6% share in the world reserves of coal estimated to be 790 billion tons. It is believed that the available coal reserves may last 250 years more at the present rate of consumption.

- **Petroleum**
1. **Description**: Petroleum is a naturally occurring dark coloured oily liquid which is found at various depths below the surface of the earth. The oil derived from oil wells is generally called natural oil or crude oil (it is also called rock oil).
   It is essentially a mixture of hydrocarbons and compounds containing oxygen and nitrogen. The exact composition of crude oil varies from one place to another and from one oil field to another.
2. **Formation:** According to modern view, the oil has been produced as a result of bacterial decomposition of plants and animals fossils got buried millions of years ago under the earth. The oil in the petroleum field is generally mixed with a gaseous mixture, known as natural gas.
3. **Procurement (Mining):** Petroleum is obtained by drilling holes in the earth's crust and sinking pipes into it. There are two government agencies which are active in exploration and production of petroleum oil in India. They are :
   (i) Oil and Natural Gas Corporation (ONGC) established in 1956. B
   (ii) Oil India Limited (OIL), established in 1981.
4. **Locations :** In India, places where petroleum oil is being extracted from oil wells are :
   (i) Assam: Rudra Sagar and Lakwa.
   (ii) Bombay: Bombay High off-shore areas.
   (iii) Godavari and Kaveri : Off shore deltas.
   (iv) Gujarat: Ankleswar and Kalol.
5. **Uses of Petroleum:** After refining (fractional distillation) many major fractions are obtained. They are given below along with their uses.
   (i) Petroleum gas: Gaseous fuel, LPG, production of carbon black, hydrogen and carbon monoxide.
   (ii) Gasoline: Motor fuel
   (iii) Kerosene: Domestic fuel, illuminant fuel, jet engine fuel.
   (iv) Diesel oil: Fuel for diesel engines.
   (v) Lubricating oil: Lubrication of machines.
   (vi) Paraffin wax: Candles, waterproofing. Vaseline, fabrics. •
   (vii) Petroleum coke (asphalt): Fuel, electrodes, artificial asphalt.
6. Use of Liquified Petroleum Gas (LPG): LPG is considered as a good fuel. The reasons are :
   (i) It has a high calorific value which is 50 kJ/g.
   (ii) It is very neat and clean domestic fuel.
   (iii) It bums with a smokeless flame and hence does not cause pollution.
   (iv) It does not produce any poisonous gases on combustion.
   (v) It is easy to handle and convenient to store.

- **Natural Gas**

  Natural gas is another source of heat energy. It is a fossil fuel.
1. **Compositions:** It mainly consists of methane (about 97%) and small quantities of ethane and propane.
2. **Compressed Natural Gas (CNG):** When natural gas in liquid form is subjected to high pressure, we get compressed natural gas (CNG).
3. **Use of Natural gas and CNG** :
   (i) Natural gas and compressed natural gas are used as fuel for scooters, buses and trucks.
   (ii) Natural gas is used for cooking food and heating water.
   (iii) Natural gas is used to produce electricity.
   (iv) Natural gas is used for manufacturing fertilizers.

ILLUSTRATION

2. Name place in India where fields of natural gas are found. Why is it called a clean fuel?

Soln. In India, natural gas is found in off shore areas of Mumbai, Krishna-Godavari basin, Jaisalmer, etc.

It is called a clean fuel because

(a) It does not leave residue.

(b) It does not produce smoke.

(c) It does not produce harmful gases,

Wind Energy

1. **Definition:** Flow of air is called wind. It possess enormous energy. As the energy is due to motion of air during flow, the energy is kinetic. Wind possesses kinetic energy.
2. **Source of wind energy:** Solar energy heats the entire earth but the heating is not uniform. The heating is more intense near the equator than in the polar region. This makes air in the equator region more hot and light. It rises up and its space is filled with the cooler air from polar region. In this way air flows from colder region at high pressure to hotter region at low pressure. The flow of air from one place to other constitutes wind.

   The smooth flow of air is disturbed continuously by rotation of the earth as well as local conditions. Due to these interacting factor the wind speed may vary from 5 km/h to about 10 km/h (gentle breeze) to very high speed of about 800 km/h of a storm (tornado).
3. **Traditional uses of wind energy:** Even the early man recognized the enormous energy possessed by wind and harnessed it for various purposes like :

   (a) Transportation and to propel the sail boat.

   (b) For grinding grain, pumping out water from wells and flooded areas, mines etc.

   (c) Drying clothes.

   (d) Winnowing

   In search of renewable energy sources, wind power is certainly one of the attractive solution. Now-a-days, wind energy is also used to generate electricity and in flying aeroplanes and gliders.

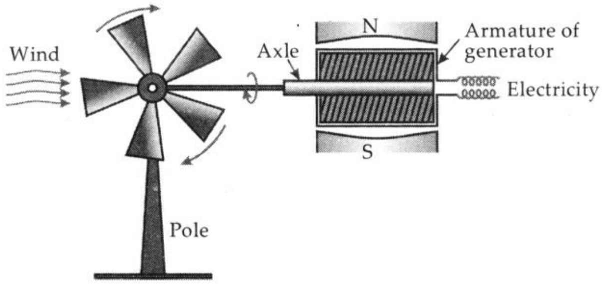
- **Wind Mill**

  A device used to convert wind energy into the mechanical energy is called wind mill.

1. **Construction:** It consists of a wheel with blades cut into its outer rim. The wheel rotates about anaxle mounted on a pole. The wind energy is used to rotate the wheel abc it its axle.
2. **Uses:** Wind mill is used for operating water pumps, grinders and is also used to produce electricity.

- **Wind Mill for producing electricity (wind generator)**

  Electricity is produced when an armature of a generator rotates between two poles (North and South poles) of a strong magnet. When wind falls on the wheel of a windmill, it rotates. The axle of the armature is connected to the shaft of the wind mill. So the armature of the generator rotates between two poles of a magnet along with the rotation of the wheel of the wind mill. Thus, electric current is produced. This is how, the kinetic energy of the wind is converted into electric energy.



It may be noted that electricity produced by a single wind mill is very small, which cannot be used for commercial purpose. To produce electricity on a region, large number of wind mills are installed. The region where large number of wind mills are erected to produce electricity is called wind energy farm. The small amount of electricity produced by each generator connected to each wind mill is combined to get electricity on a large scale.

Advantages of Wind energy

(a) Wind energy produces no smoke and no harmful gases. So this form of energy is pollution, free or environment-friendly.

(b) Wind energy is free of cost and hence devices operated by wind energy are economical.

(c) This source of energy is a renewable source of energy and is available for all times to come under favourable conditions.

Limitations of Wind energy

(a) We cannot depend upon wind energy as it is available only when air is in motion. The appliances or machines operating with wind energy stop working as soon as wind stops. The minimum speed of wind to operate generator to produce electricity is about 15 km/h. As soon as the speed of the wind becomes less than 15 km/h, the generator stops working.

(b) There are certain regions where wind is not available, so the use of wind energy is limited to certain places where wind is in plenty and blows most of the time.

(c) Wind energy is not sufficient to operate very heavy machines.

(d) Wind energy cannot be used to operate all types of machines.

(e) Wind mills are usually broken during storms and hence lot of money is spent for the maintenance of a wind energy farm.

Wind energy in India

The wind power potential of India is estimated to be 20 billion watt. (20,000 MW). Till the end of last century India has an installed capacity of more than 1025 MW for generating electrical energy from wind energy. This capacity is sure to increase with the commissioning of new power stations. At present, largest wind energy farm is established near Kanyakumari in Tamil Nadu. It can generate 380 MW electricity,

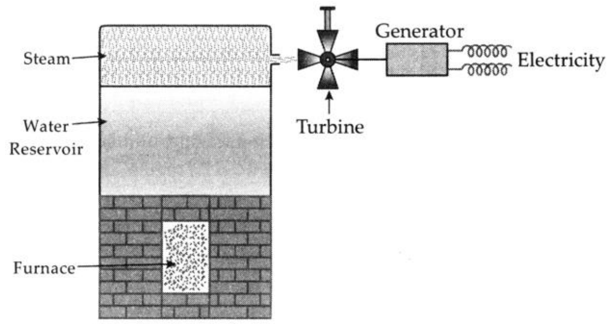
ILLUSTRATION

3. What causes the wind to blow?

Sol. Equatorial regions on the earth receive more solar radiation than other parts of the earth. As such, the air at equatorial regions is hotter and rises upwards into the atmosphere. The cooler air from other regions (especially Polar Regions) starts blowing to the equatorial regions to fill the space vacated by hot air. It is this moving air which is called wind

Thermal Power Plant

A thermal power plant produces electricity by burning the fossil fuels (i.e., coal or oil). A schematic diagram of a thermal power plant is shown in figure.



Thermal Power Plant

- **Working**

  Coal or oil is burnt in a furnace to produce heat energy. This heat energy is used to boil water in a reservoir. The steam produced in the water reservoir is allowed to fall on a turbine under high-pressure. The steam falling on the turbine through an axle rotates the turbine with high speed and produces electricity. In fact, the mechanical energy (kinetic energy of rotation) of the turbineis converted into electrical energy. The electricity, so produced is transmitted to distant places through transmission wires.

  Thermal power plants are usually set up near coal fields or oil fields. This is because the fuel like coal or oil used in a thermal power plant is easily available and there is no problem in transporting the fuel.

- **Disadvantage**

  The burning of coal or oil in a thermal power plant causes environmental pollution and global warming.

Biomass

The wood has been used as a fuel for a long time. If we can ensure that enough trees are planted, a continuous supply of fire-wood can be assured. You must also be familiar with the use of cow-dung cakes as a fuel. Given the large live-stock population in India, this can also-assure us a steady source of fuel. Since these fuels are plant and animal products, the source of these fuels is said to be bio-mass. These fuels, however, do not produce much heat on burning and a lot of smoke is given out when they are burnt. Therefore, technological inputs to improve the efficiency of these fuels are necessary. When wood is burnt in a limited supply of oxygen, water and volatile materials present in it get removed and charcoal is left behind as the residue. Charcoal bums without flames, is comparatively smokeless and has a higher heat generation efficiency Similarly, cow-dung, various plant materials like the residue after harvesting the crops, vegetable waste and sewage are decomposed in the absence of oxygen to give bio-gas. Since the starting material is mainly cow-dung, it is popularly known as 'gobar-gas'. Bio-gas is produced in a plant as shown in figure below.

Biogas Plant

The arrangement in which Biogas is obtained by the fermentation of biomass is called a biogas plant. The most common types of biogas plants used in India are:

1. Fixed dome type biogas plant
2. Floating gas holder type biogas plant.

Both the biogas plants require animal dung and plant waste as a raw material. Organic domestic and agriculture waste can also be added to it.

1. Fixed-Dome type Biogas Plant

Description: It has following sections:

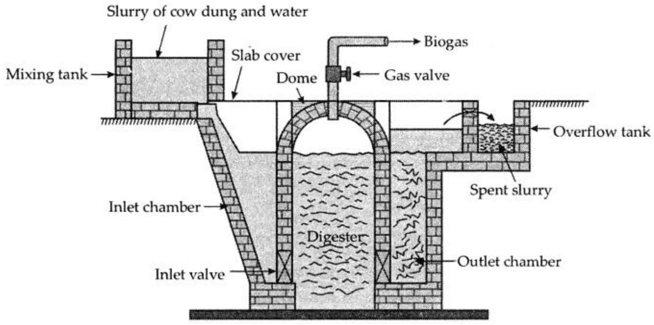
(i) Digester Tank: It is a well like structure made from bricks. Its roof is dome shaped which acts as a fixed strong tank (gas holder) for biogas. A tapped outlet for biogas is provided at the top of the dome.

(ii) Mixing Tank: It is a tank with a sloping floor made up of bricks on one side of the digester. It feeds the slurry to the digester tank. Slurry is a mixture of waste biomass and water mixed in equal proportion.

(iii) Inlet tank: It is made below the ground level under the mixing tank.

(iv) Over flow tank: It is made on other side of the digester as a level lower than mixing tank.

(v) Outlet tank: It is made below the ground level under the overflow tank.



Biogas Plants

- **Working**

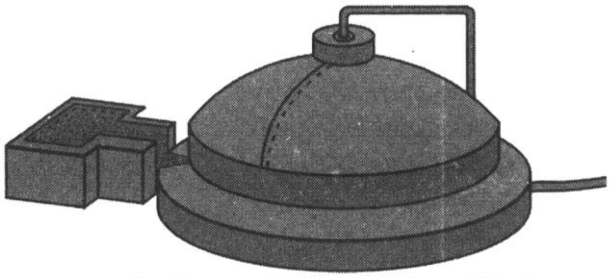
  Cow dung and water are mixed in equal proportional in mixing tank to form a slurry. The slurry goes into the inlet tank and the digester and fills about two-third of the digester. The top is left empty for the collection of the biogas. New gas plants take about two months to start functioning. The cow dung undergoes fermentation by anaerobic bacteria to form biogas which gets collected in the dome. As the amount of gas collected in dome increases, it exerts pressure over the slurry and forces the spent slurry in the digester to go out into the outlet tank and from there in overflow tank. The spent slurry is rich in nitrogen and phosphorus compounds and forms a good manure. The biogas collected in the dome is taken out through the tapped-oudet at the top, through a pipe provided with a gas control valve. It is then distributed as desired. Once the gas plant starts functioning, more cattle dung slurry is added to the digester. A continuous supply of biogas can be obtained.

Do You Know

It is cheap and easy to construct fixed dome type biogas plant because the material required is locally available in villages.

2. Floating Gas Holder Type Biogas Plant

The floating gas holder type plant is quite similar to the fixed dome type. Only difference is that it has a mobile dome made up of steel which floats over the slurry in the digester. As more and more gas is produced, the steel gas holder rises up, increasing the pressure inside the gas holder. This pushes the spent slurry towards overflow through outlet chamber for removal. The floating gas holder type biogas plant is expensive and has increased cost of maintenance because it has to be painted frequently to prevent it from corrosion and leakage of the gas).


Floating gas holder type Biogas Plant

Advantage of Biogas Plants

(a) We get clean fuel from bio waste.

(b) Animal dung and organic waste is disposed off usefully

(c) Spent slurry is used as manure in the fields.

Uses of Biogas

Biogas is used for cooking, lighting, pumping out underground water for irrigation and to generate electricity.

Advantages of Using Biogas as a Fuel

(a) Burning of biogas does not produce smoke. So it does not cause pollution

(b) Burning of biogas does not leave any ash (no residue is left).

(c) Biogas has higher calorific value than cow dung cakes, wood and charcoal etc.

(d) Use of biogas saves fossil fuels, hence help us in overcoming the energy crisis.

(e) It does not require any storage space in the house.

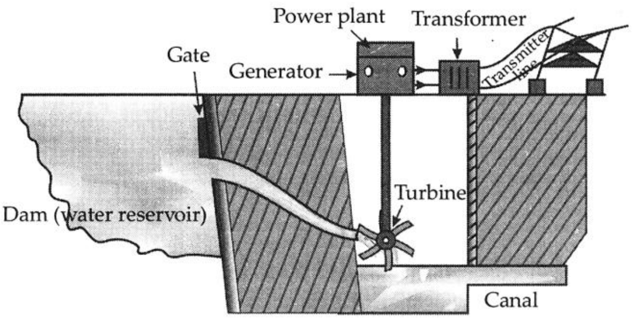
Limitation of using Biogas as a fuel

1. Biogas plants cannot be set up in the cities as quite a large space is required for its set up. Moreover getting dung to run the plant is not viable in cities.
2. Some families may not be able to afford the cost of construction of plant. To overcome the problem of cost and to ensure the availability of dung for the running of plant, it is advisable to set up community biogas plant in which cost of construction as well as the raw material (bio waste) is shared by several families.

Hydro power or Hydro Electric Power Plant

Flowing water is a major source of energy. The electricity produced by the flowing water is known as hydro-electric power. A plant used to produce hydroelectric power is known as hydro-electric power plant.

A dam or water reservoir is made over a river. The energy of stored water in the dam is potential energy. The water in a dam is allowed to fall on the water wheel or turbine. As a result of this, the turbine rotates whose axle is connected with the armature of the generator. The armature of the generator rotates within two poles of a strong magnet. The rotation of the armature of the generator between two poles of a strong magnet gives rise to electric current or electricity. This electricity is transmitted to the sub-stations through a transformer for further distribution to the houses and factories.



Hydro Power or Hydro Electric Power Plant

Principle of Generation of Hydroelectricity

Potential energy of water stored in a dam is converted into kinetic energy of the falling water. The water falls on the turbine, so kinetic energy of the flowing water is converted into the kinetic energy of the armature of the generator connected to the turbine. Then kinetic energy is converted into the electrical energy known as hydro-electricity.

- **Advantages of Hydroelectric power**
  (a) Hydroelectric power is pollution free.
  (b) Hydroelectricity is cheapest source of energy.
  (c) The energy of flowing water is renewable source of energy.
  (d) Lot of water is available in rivers, so the hydroelectric power is available free of cost. Money is spent only to construct dams and power stations.
- **Disadvantages of Hydroelectric Power**
  (a) Hydroelectric power is generated only near the rivers having water throughout the year. This electric power has to be carried to the sub-stations for distribution to the houses and factories situated far off from the sites of hydroelectric power stations. This is done through the transmission wires, so lot of money is to be spent on this process.
  (b) A large area of fertile land is submerged at the site of the dam constructed for tapping energy from the flowing water.
  (c) A large number of people residing near the site of a dam are dislocated. So, a lot of problems are to be faced in rehabilitating this population. That is why, there is a lot of opposition by the people around the site of dam for the construction of dam.
  (d) A large number of plants and wild life in the area of the dam is submerged in water. So, a large variety of flora (plants) and fauna (animals) is destroyed.
  (e) Hydroelectric dams cannot be constructed everywhere. They are constructed mostly in hilly areas.
- **Advantages of constructing Dams over rivers:**
  Dams are helpful to:
  (a) control floods over rivers.
  (b) generate hydro electricity.
  (c) irrigate agricultural land.
  (d) develop water sports for recreation
  (e) develop fishing zones.

Do You Know

The leading users of hydroelectric power include Norway and Brazil (where it account for more than 90% of the domestic electric generation), USA, Canada, China and Russia.

SOLAR ENERGY

(a) Source of solar energy: Nuclear fusion is the source of solar energy (energy from the sun). Sun is a huge spherical ball of fire. Its radius is 7 x 10^8 metre and mass 2 x 10^{30} kg. It is at a distance of 1.5 x 10^{11}metre from the earth. It contains 70% Hydrogen, 28% Helium and 2% Carbon and "other gases. Its inner core has a temperature of 10^7 degree.

At this high temperature, 4 atoms of hydrogen fuse to form one nucleus of helium and release a large amount of energy. This was explained by Hans Bethe in the year 1939.

The reaction is

$$4\,{}_1H^1 \rightarrow {}_2He^4 + 2\ \text{positron} + 26.7\,\text{MeV energy}$$

(b) How long will sun last: The sun radiates energy at the rate of 3.9 x 10^{26} W, since 5 billion years. Calculations have shown that the mass of the sun will exhaust in 5 billion years more. Hence solar energy will last till that large span of time. It is for this reason that we call solar energy as renewable (non-depletable). (Earth receives solar energy of about 1.4 kW/m^2).

Solar Cooker

A solar cooker is a solar heating device by which solar energy is directly harnessed. It works on the phenomenon of thermal conversion. It is used for cooking food.

There are two types of solar cookers namely:

(A) Box type solar cooker

(B) Concentrator type solar cooker

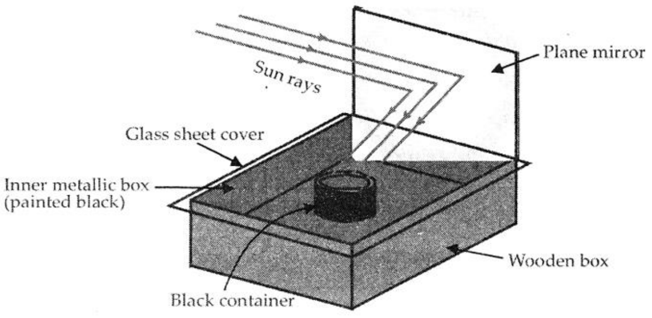
A. Box Type Solar Cooker

1. **Principle:** A box type solar cooker is based on the following facts :

   (i) Glass possesses the property of selective transmission of heat radiation.

   (ii) A black body is a good absorber of heat radiation.

   (iii) A mirror or a polished surface reflects heat radiation according to the laws of reflection.



Solar Cooker (Box type)

2. **Construction:** It consists of an insulated wooden or metallic box. Inside walls of the box are black painted. A plane mirror or reflector is attached to the box and its position is adjustable. It is provided with containers whose outer sides are black painted. A thick glass sheet covers the containers.
3. **Working:** The food to be cooked is taken in the containers which are then placed inside the box. The containers are covered with the glass sheet. The cooker is placed in sunlight and position of the reflector is so adjusted that a strong beam of sunlight is reflected on the top covered with glass sheet. Sunlight passes through transparent glass sheet and is absorbed by the black painted walls of the container and its box. The infrared radiations in the sunlight heat the box and the food inside the container. Inside the box the temperature may go up to 100°C to 140°C in 2 to 3 hours and the food gets cooked.
4. **Demerits:** Box solar cookers are not much popular because (i) it takes long time in cooking the food in them, (ii) they cannot be used for baking (making chapattis) and frying (dal).
5. **Function of thick glass sheet:** Glass sheet has a peculiar property. It allows shorter wavelength infrared (heat) rays at high temperature to pass through it but prevents longer wavelength infrared rays at low temperature.

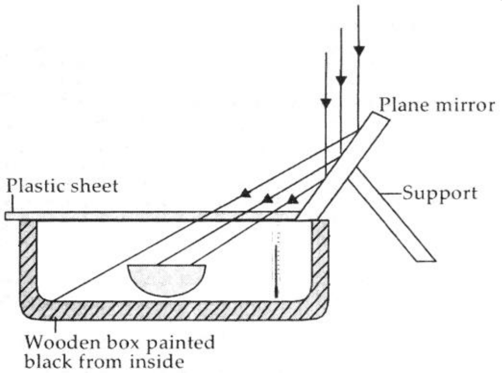
   The solar energy falling on the outer surface of the cooker glass cover contains short wavelength infrared rays due to high temperature. They all enter the cooker. Inside the cooker (the temperature is less) and longer infrared rays are emitted. They are not allowed to go out. The heat is not wasted and cooker has more efficiency.

   This function of glass sheet is called greenhouse effect.

ACTIVITY CORNER

To make a box type solar cooker

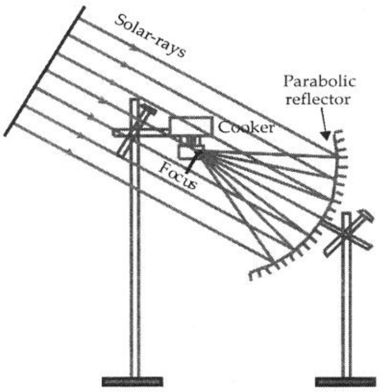
You are given, a wooden box, plane mirror, thermocole sheet, plastic sheet and thermometer. Take the wooden box, cover the inner wall and bottom surface with thermocole. To increase the efficiency of heat absorbtion you can paint the thermocole layer with back paint. Hing the plane mirror on the top of the solar cooker. Place the plastic sheet on the wooden box. The plane mirror is so adjusted that radiations falling on plane mirror after reflection should reach inside the wooden box. Keep the solar cooker in sunlight and the reflector is adjusted so that strong beam of sun rays may enter the wooden box. You may expect to get a temperature of 100^0C to 120^0C, when kept in sun for 2-3 hours you can measure the temperature using a thermometer. To get temperature up to 140^0C, you can replace plastic sheet by glass sheet.



B. Concentrator Type Solar Cooker

Such solar energy devices which reflect and concentrate solar energy from over a large area into a small area are called solar concentrators.

This type of solar cooker consists of a larger concave reflector or parabolic reflector. The sun rays are focused by this reflector at a point f. The intense beam of sun rays increases the temperature of point F to 200° C. The food to be cooked in a container is placed at point F. The concave reflector must be rotated so that it always face the sun for effective cooking of the food.

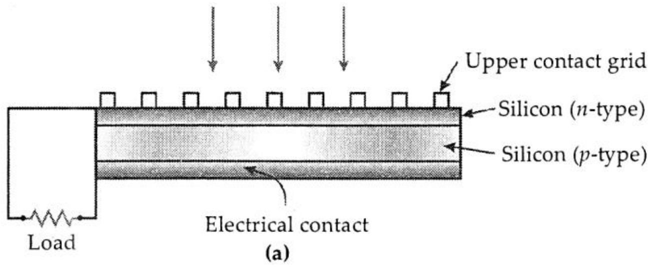


Concentrator type solar cooker

Solar cell

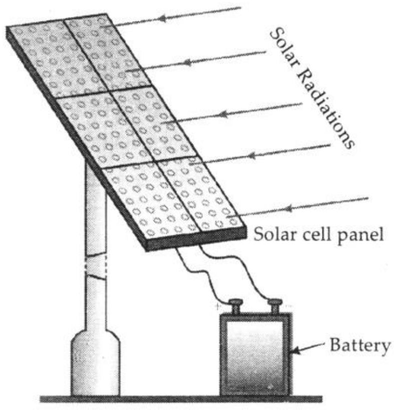
Solar cell is a solar electric device by which solar energy is directly harnessed. It works on the phenomenon of photovoltaic conversion.

1. **Construction:** These days solar cells are usually made from semi-conductor materials likes silicon and gallium (selenium with germanium are also used). Semi-conductors are made impure by adding to them some suitable impurities in suitable amount. These impure semi-conductors have more conductivity. Thin layers (wafers) of the two impure semi-conductors are arranged in such a way that when sun light falls on them, a potential difference is developed between the two regions (junction) of the wafers. This potential difference produces electric current A. 4 cm^2 (2 cm x 2cm) sized cell produces a potential difference of 0.4 volt to 0.5 volt and generates a current of 60 milli ampere (60 mA).
2. **Solar cell panel:** Solar cells usually arranged on large flat sheets constitute a solar cell panel. In a solar cell panel the output of each solar cell gets added and we get much higher power that can be put to various uses.



Solar Cell

The electricity produced by solar panels is stored by using it to charge storage batteries. These charged batteries later on provide direct current (D.C.) for operating appliances.



3. **Applications of solar cell panel:**
(i) These provide electrical power for space-crafts. Its electricity charges batteries inside the craft.
(ii) These provide energy to remote and isolated areas.
(iii) These supply power to domestic electronic appliances like TV., radio sets.
(iv)These provide electricity for street lightening and for operating water pumps.
(iv)These provide electricity to light houses situated in the sea and off-shore drilling platform.
(v))Solar cells are used to run calculator, Watches, pendulum clock and other small instruments.
4. **Advantages (Merits):**

(a) They directly utilize solar energy.
(b) They can work satisfactorily even in diffused radiations.
(c) They need no maintenance.
(d) They do not produce pollution.

5. **Disadvantages (Demerits)**:
(a) The energy stored in batteries, provide only direct current (D.C.). For devices which require alternating current (A.C.), D.C. is converted into A.C. Conversion reduces efficiency and increases its cost.
(b) They are very expensive because of use of expensive components like special grade silicon which is limited in nature.
(c) The efficiency of energy conversion is low as compared to other methods of generating electricity.

ILLUSTRATION

3. Why is energy of water flowing in river considered to be an indirect form of solar energy?

Sol. When sunrays fall on water bodies, water evaporates and forms clouds. These clouds produce rainfall and snowfall due to which we get flowing water. Thus, water flowing

Do You Know

Developing countries such as Dominican Republic, Sri Lanka Zimbabwe are leading users of solar cell panels.

ENERGY FROM THE SEA OR OCEAN

1. **Tidal Energy**
(i) Definition: Due to attraction of moon on sea water, water surface rises and falls and waves are formed. These waves are called tidal waves.
(ii) Sources of energy: Rise of ocean water is called high tide and the fall of ocean water is called low tide. These waves (jwar-bhata) in the oceans build up and recede (rise and fall) twice a day. Between the high tides and low tides, there is an enormous movement of water which generates large amount of energy. It occurs in the coastal areas
(iii) Harnessing energy: Tidal Energy can be harnessed by constructing a tidal barrage (or tidal dam). This barrage traps the water risen during the high tide. The trapped water is then allowed to fall down slowly on turbines (water wheels) to start them rotating. The rotating turbines generate electricity.
(iv) Locations chosen: (a) Gujrat-Gulf of Kutch Lamba, (b) West Bengal-Sundervans.
(v) Limitations: The rise and fall of water during tides is not high enough to generate electrical energy on a large scale. There are very few places suitable for building dams. It is for these reason that the tidal energy is not likely to be a major source of energy.

2. **Energy of Ocean Waves**
(i) Definition: Due to blowing of wind on the surface ocean, waves are produced on the water surface. These waves are called ocean waves (sea waves or water waves).
(ii) Source of energy: Ocean (sea) waves move very fast with the blowing wind. This gives kinetic energy to the ocean (sea) waves.
(iii) Harnessing energy: Turbines (water wheels) are so arranged that they are rotated by the moving waves. The rotating turbines generate electricity.
(iv) Commonly utilized devices:
(a) Surface followers: These are a series of floating objects pivoted about a rigid shaft along a coast line. The mechanical linkage between fixed and floating objects produces mechanical power. This mechanical power is converted into electrical energy. Surface followers can trap about 80% of the energy of the waves.
(b) Oscillating water columns (OWC): These are similar to navigational buoys. When waves arrive, they compress air in the vertical pipe of an anchored buoy. This compressed air derives a turbine generator to produce electrical energy.
(c) Focussing devices: These are barriers who channelize water and concentrate a large waves into small area. This focusing action increases the height of waves and water fills an elevated reservoir. When this stored water is released to the sea level, it operates hydroelectric turbines. Electrical energy becomes available.

ILLUSTRATION

4. Mention shortcomings of the energy we get from sea waves

Sol. Short coming of energy from sea wave:

(i) A minimum energy density of 400 MW/km is required to explore energy from sea-waves profitly.

(ii) Initial cost of establishing the plant is hight.

5. List some disadvantages of tidal energy.

Son. Disadvantages of tidal energy:

(i) The range of rise and fall of water during tide is enough to produce electricity on a small scale only.

(ii) Tidal dam cannot be built anywhere on sea-shore.

(iii) It is not a potential source of energy.

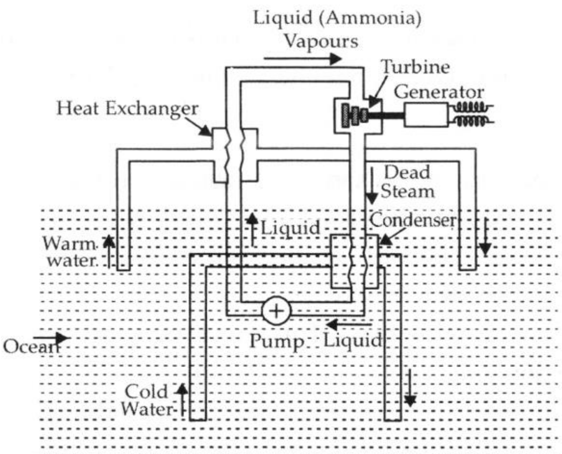
3. Ocean Thermal Energy (OTE)

Heat energy of the sun is absorbed by the surface water of the sea or ocean which increases the temperature of upper layers while the temperature of the deeper layers of water is relatively low. The energy extracted due to difference in the temperature of water at the surface of sea and deep below the sea is called ocean thermal energy.

Harnessing the ocean thermal energy: There is a temperature difference between the water at the surface of the sea and deep below the sea. The difference in temperature at many places is of the order of 20°C. This difference in temperature can be exploited to produce electric energy in ocean thermal energy conversion plant (OTEC).

Ocean thermal energy conversion plant (OTEC)

OTEC is a power plant device used to harness ocean thermal energy and to produce electricity.



Ocean Thermal Energy conversion (OTEC) Power Plant

In one of the methods a low melting point liquid or fluid such as ammonia (volatile liquid) or chlorofluorocarbon (CFC) is used to run the turbine of a generator. The warm surface water is used to boil the liquid like ammonia or CFC in a heat exchanger and vapours thus formed are used to drive the turbine of the generator. In another exchanger cold water from the depth of the ocean is pumped up to condense the vapours of the ammonia again to liquid. This ammonia is reused and the cycle repeats.

Advantages:

1. OTEC system can be operated for 24 hours throughout the year.
2. Unlike the other ocean energy generating system one does not have to wait for tides or waves.

Do You Know

Tides are formed due to attraction of Moon for the ocean water. It is not an indirect form of solar energy.

Geothermal Energy

(a) Definition: Energy harnessed from the heat of the earth, is called geothermal energy (This energy does not come directly or indirectly from solar energy).

(b) Explanation: We know that the deeper regions of the earth's crust are very hot. The heat melts the rocks. The molten rocks called magma formed in deeper hot regions of earth's core get pushed upward and trapped in certain regions (called hot spots) due to geological changes. The magma gets collected at some depth below the earth's surface. These places, called hot spots, become source of geothermal energy.

(c) Procurement: Underground water in contact with the hot spots turns into steam which gets compressed to very high pressure. Thus steam is extracted by linking pipes through holes drilled upto hot spots. The out coming steam rotates the turbine of an electric generator and produces electrical energy.

(d) Locations: In India there are only few places where geothermal energy can be exploited on commercial lines. One such place is located in Madhya Pradesh.

Advantages of Geothermal energy

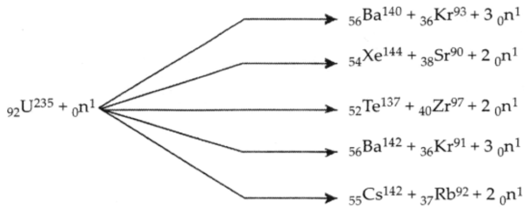
1. Geothermal energy can be converted continuously into electricity for 24 hours throughout the year.
2. Geothermal energy causes no pollution, so it is environment friendly.
3. The cost of converting geothermal energy into electricity is very less.

Nuclear Energy

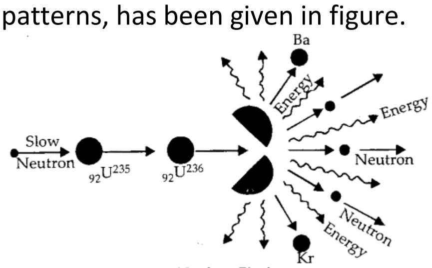
A physical reaction which involves changes in the nucleus of an atom is called a nuclear reaction. The energy released during a nuclear reaction is called nuclear energy (because it comes from the nucleus of an atom). Nuclear energy can be obtained by two types of nuclear reactions:
(i) Nuclear fission and (ii) Nuclear fusion
The source of nuclear energy is the mass of nucleus. A small amount of mass of nucleus is destroyed during a nuclear reaction which gets converted into a tremendous amount of energy. The nuclear energy is released mainly in the form of heat (and some light). The nuclear energy is also known as atomic energy because it can be considered to be coming from the atoms. We will now describe the nuclear reactions of fission and fusion in detail, one by one. Let us start with nuclear fission.

- **Nuclear Fission**

  The phenomenon of splitting up of a heavy nucleus, on bombardment with slow speed neutrons, into two fragments of comparable mass, with the release of two or more fast moving neutrons and a large amount of energy is known as nuclear fission. The first nuclear fission to be discovered was that of Uranium-235. This nucleus as well as those of uranium-233 and plutonium-239 undergo fission when struck by slow moving neutrons. There are other heavy nuclei that can be induced to undergo fission. However these three are the only ones of practical importance. Few different ways in which the Uranium-235 nucleus splits are shown below:



  Over 200 different isotopes of 35 different elements have been found among the fission products of Uranium-235. Most of them are radioactive. The schematic representation of the fission of Uranium-235, showing one of its many fission patterns, has been given in figure.



Nuclear Fission

On the average, 2, 3 neutrons are produced by every fission of U-235. If one fission produces 2 neutrons, these two neutrons can cause two fission on hitting another U-235 nucleus. The 4 neutrons thereby released can produce four fission and so on.
In this way, the secondary neutrons (formed during fission) further cause fission and thus set up chain reaction releasing huge amount of energy.
The tremendous amount of energy released during fission is due to mass defect. The sum of the mass of fragments produced and neutrons released during fission is less than the sum of target U-235 nucleus and bombarding neutrons. For example, the loss in mass during fission can be derived as:

In amu $\;{}_{92}U^{235} + {}_0n^1 \quad {}_{56}Ba^{140} + {}_{36}Kr^{93} + 3{}_0n^1$

$\underbrace{235.118 \quad 1.009}_{236.127} \quad \underbrace{143.881 \quad 89.947 \quad 2.018}_{235.846}$

Thus, mass defect, $\Delta m = 236.127 - 235.846 = 0.281\,\text{amu}$

$\because 1\,\text{amu} = 931.478\,\text{MeV}$

$\therefore \Delta E = \Delta m \times 931.4780$

[from Einstein equation, $\Delta E = \Delta mc^2$

$= 931.478 \times 0.281 = 261.75\,\text{MeV}$

Thus, for the fission of each nucleus of Uranium-235, about 261.75 MeV energy is released which corresponds to about 8 x 10^7 kJ per g of uranium. It is also evident that about 0.1% (0.281 amu out of 236 amu) of the total mass undergoes decay and produces energy. Note that most of the energy is released out in the form of kinetic energy.
The pressure and temperature increases tremendously during fission.
For a fission chain reaction to occur, the fissionable material must have a minimum mass. Otherwise, neutrons will escape from the sample before they have the opportunity to strike another nucleus and cause additional fission. The chain stops if enough neutrons are lost. The amount of material is then said to be a subcritical mass. The amount of fissionable material large enough to maintain the chain reaction with a constant rate of fission is called the critical mass. When a critical mass of material is present, only one neutron from each fission is subsequently effective in producing another fission. The critical mass of uranium-235 is about 1 kg. The chain reaction multiplies the number of fission reactions

showing very few secondary neutrons to escape if more than a critical mass of fissionable material is present. A mass in excess to critical mass is referred as supercritical mass and this leads to a violent nuclear explosion.

Nuclear fission is an uncontrolled reaction in atom bomb whereas in nuclear reactors, it is controlled by using control rods of boron, steel or cadmium which capture some of the neutrons so that chain reaction does not become violent, slowing down the speed of neutrons by moderators e.g., D^2O, graphite so that neutrons can be captured more readily by the fuel. A circulating coolant (water, molten Na) is employed to remove the heat from the reactor to outside where it is used for power production. The coolant liquid can also serve as the neutron moderator.

U^{238} does not show fission by slow speed neutrons and that is why refining of Uranium is necessary before its use as nuclear fuel in nuclear reactors. Natural uranium consists of 99.3% U^{238} + 0.7% U^{238}. Elements upto ygTa have been found to undergo fission. $_{94}Pu$ was used in the first atom bomb explosion at Hiroshima in Japan.

- **Nuclear Power Plant**

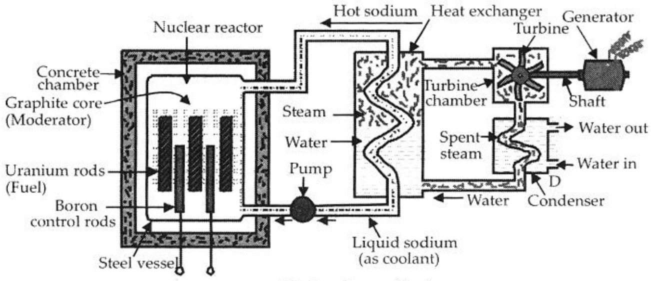
If only one of the neutrons produced in each fission is able to cause further fission, then the process is slow and the energy is released steadily. Such a chain reaction is called as controlled chain reaction. The energy released in this process can be utilized for peaceful purposes. This is actually what happens in nuclear reactors.

Nuclear fission produces the energy generated by nuclear power plants using nuclear reactors. The energy liberated in a controlled manner is used to produce steam which can run turbines and produce electricity. In nuclear reactors, the nuclear fission is controlled by controlling the number of neutrons released during the fission. Controlling of neutrons is based upon the fact that cadmium and boron can absorb neutrons to form the corresponding isotopes which are not radioactive.

$$_{43}Cd^{113} + _0n^1 \rightarrow _{43}Cd^{114} + y - ray$$

$$_5B^{10} + _0n^1 \rightarrow _5B^{11} + y - ray$$

The design of a nuclear power plant is basically the same as that of a power plant that burns fossil fuel except that the burners are replaced by a reactor core. In both instances, steam is used to drive a turbine connected to an electrical generator.



Nuclear Power Plant

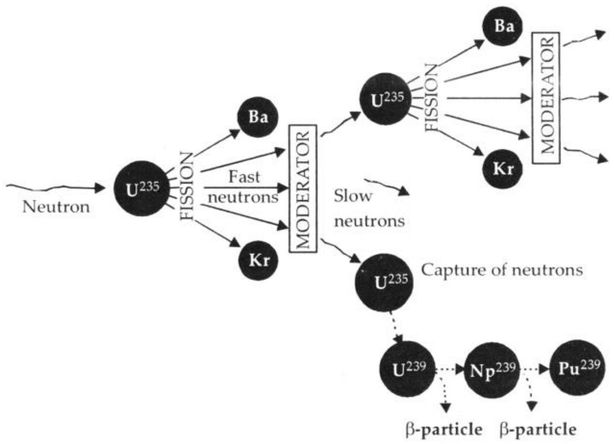
(a) Fuel rods: The fuel of the nuclear reactor is a fissionable substance such as U235, Typically, uranium is enriched to about 3% U235 and then used in the form of rods or pallets. These enriched uranium rods are encased in zirconium or stainless steel vessel.

(b) Control rods: Rods made up of material such as cadmium or boron suspended between the fuel rods control the fission process by absorbing neutrons. These control rods regulate the flow of neutrons by lowering or rising up to keep the reaction chain self-sustaining, while preventing the reactor core from overheating.

(c) Moderator: The reaction is started up by a neutron emitting source. The reactor core also contains a moderator, which acts to slow down the speed of neutrons so that they can be captured more readily by the fuel and the fission process can take place more efficiently. Heavy water (D_2O) and graphite acts as good moderators. The moderator is arranged so that it surrounds the fuel rod to give more efficient action.

(d) Coolant: A coolant liquid (molten Na or heavy water) circulates through the reactor core to carry off the heat generated by the nuclear fission. The liquid enters the base of the reactor core and come out at the top. The heat carried by the circulating liquid coming out from top is used for producing steam. As a result the liquid cools down and is pumped back to the base of the reactor. The cooling liquid also serves as the neutrons moderator.

(e) Shield: The entire reactor core is enclosed in a heavy steel or concrete dome (the shield) to prevent the loss of heat and to protect the persons operating the reactor from radiation.



Nuclear fission in a nuclear reactor using enriched uranium

The nuclear power plants convert huge amount of energy produced during controlled fission into electrical energy. Four nuclear power plants have been set up in India at Tarapur, Kota, Narora Kalpakkam Kaiga and Kakrapar. The reactors in which energy is produced by the fission of U235 by slow speed neutrons are called thermal reactors.

Nuclear Bomb (or Atom Bomb)

The highly destructive nuclear bomb (or atom bomb) is based on the nuclear fission reactions of uranium-235. In the nuclear bomb, the fission reaction of uranium-235 (or plutonium-239) is deliberately allowed to go out of control so as to produce an enormous amount of energy in a very short time. This energy causes destruction all around. The atom bombs based on the fission of Uranium-235 and Plutonium-239 were dropped on the Japanese cities of Hiroshima and Nagasaki, respectively in 1945 during the Second World War. Both these atom bombs caused a reat loss of human life and property. About 1.54 lakh people were killed in these two atom bomb attacks.

ILLUSTRATION

6. In one fission of uranium, $3\times10^{-11}J$ of energy is made available. Calculate the total number of fissions necessary per second to generate power of 15 kw.

Sol. Energy released per fission $3\times10^{-11}J$

Total energy required per s =15kw

=15kw=15000 W=15000 J/S.

Number of fissions per s = $\dfrac{totlenergy/s}{energy/\ fission}$

$$=\frac{15000}{3\times10^{11}}=5\times10^{14}$$

Nuclear Fusion

The process of combination of two light nuclei to form a heavy nucleus is known as nuclear fusion. Obviously, the process of fusion is just the reverse of fission. An important feature of fusion is that there is a release of huge amount of energy in the process. This can be easily understood. When two light nuclei combine to form a heavy nucleus, there occurs a small mass defect. In other words, the mass of the heavy nucleus turns out to be less than the sum of the masses of two light nuclei. This small mass defect results in the release of a huge amount of energy according to Einstein mass-energy relation

$$\Delta E=\Delta m\times c^2$$

For example, by the fusion of two nuclei of heavy hydrogen or deuterium ($_1H^2$), the following reaction is possible:

$$_1H^2+_1H^2\rightarrow_1H^3+_1H^1+4.0\ \text{Mev}$$

The nucleus of tritium ($_1H^3$) so formed can again fuse with a deuterium nucleus:

$$_1H^3+_1H^2\rightarrow_2He^4+_0n^1+17.6\ \text{Mev}$$

The net result of these two reactions is that three deuterium nuclei fuse together to form a helium nucleus and release 21.6 MeV energy which is obtained in the form of kinetic energy of proton ($_1H^1$) and neutron $_0n^1$),

Alternatively, following reactions are also possible for the fusion of three deuterium nuclei:

$$_1H^2+_1H^2\rightarrow_2He^3+_0n^1+3.3\ \text{Mev}$$

$$_2He^3+_1H^2\rightarrow_2He^4+_1H^1+18.3\ \text{MeV}$$

The energy output in the process of nuclear fusion (21.6 MeV) is quite less than the energy liberated in the fission of a U^{235} nucleus (200 MeV). But this does not imply that fusion is a weaker source of energy than fission. The number of hydrogen nuclei in 1 gram of heavy hydrogen is much more than the number of U^{235} nuclei in 1 gram uranium. Therefore, the energy by the fusion of a certain mass of heavy hydrogen is much more than the energy released by the fission of equal mass of uranium. It may alternatively be explained as:

	Fusion reaction	Mass defect	Energy released
	$_1H^2+_1H^2\longrightarrow{}_1H^3+_1H^1$	4.3×10^{-3} amu	4.0 MeV
	$_1H^3+_1H^2\longrightarrow{}_2He^4+_0n^1$	18.9×10^{-3} amu	17.6 MeV
Net	$3\ _1H^2\longrightarrow{}_2He^4+_1H^1+_0n^1$	23.3×10^{-3} amu	21.6 MeV

Thus, a mass defect of 23.2 x 10^{-3} amu is noticed out of 6 amu or about 0.386% mass decay is responsible

for release of energy (In nuclear fission it was 0.1%). Huge amount of energy is required to overpower the Coulombic forces of repulsion between two nuclei which is obtained by triggering nuclear fission. The temperature corresponding to nuclear fusion is about 1.2×10^7 K. The requisite condition for fusion reaction exists in stars and in the sun. Though the sun's surface temperature is only about 6000 K, its internal temperature is as high as 1.5×10^7 K. Under these conditions, H nuclei undergoes fusion to form Helium nuclei and in the process a continuous emission of solar energy occurs. Therefore, fusion is also referred to as thermonuclear reaction.
It is an uncontrolled reaction and the principle is used in the formation of Hydrogen bomb.

Hydrogen Bomb (A Fusion Bomb)

1. **Principle:** It works on principle of nuclear fusion (which is an uncontrolled nuclear reaction).

2. **Construction:** It consists of an arrangement for nuclear fission at the centre of a mixture of deuterium ($_1H^2$) and lithium ($_3Li^6$).

3. **Working:** The nuclear fission provides heat and neutrons.
Fission (in the centre) $\rightarrow$ Heat + Neutrons
Neutrons are used in converting lithium into tritium ($_3H^1$) and heat is liberated.
$$\underset{\text{Neutron}}{_0n^1} + {_3Li^6} \rightarrow \underset{\text{Tritium}}{_1H^3} + Heat\ energy$$
Heat liberated starts fusion between $_1H^2$ and $_1H^3$ and liberates large amount of energy
$$\underset{\text{Deuterium}}{_1H^2} + {_1H^3} \rightarrow {_2He^4} + {_0n^1} + Energy$$
$$_1H^3 + {_1H^3} \rightarrow {_2He^4} + 2{_0n^1} + Energy$$
$$_1H^2 + {_1H^2} \rightarrow {_2He^4} + Energy$$
Tritium has to be produced within the hydrogen bomb because it is not stable.

4. **Enormousity of the energy produced:** In formation of a single Helium nucleus four nudeons (2_1H^2) take part and 26.7 MeV of energy is produced.
Hence, energy released per nucleon = $\frac{26.7}{4} = 6.675 MeV$
It is about 8 times more than in fission. This fact makes hydrogen bomb 8 times more dangerous than atom bomb which is a fission bomb.

Source of Energy of the sun-nuclear fusion

Hans Bethe in 1939 suggested that the source of energy of the Sun and other stars is thermo- nuclear or nuclear fusion reactions.

ILLUSTRATION

7. 48 KJ of energy is produced per minute in a nuclear reactor. Calculate the number of fission which would be taking place in a reactor per second, if the energy released per fission is $3.2 \times 10^{-11} J$

Sol. In 60 second, the energy produced
=48 KJ
In 1 second, the energy produced

Advantages of Nuclear Energy

The advantages of nuclear energy are that:
(a) it produces a large amount of useful energy from a very small amount of a nuclear fuel (like uranium-235).
(b) once the nuclear fuel (like uranium-235) is loaded into the reactor, the nuclear power plant can go on producing electricity for two to three years at a stretch. There is no need for putting in nuclear fuel again and again.
(c) it does not produce gases like carbon dioxide which contributes to greenhouse effect or sulphur dioxide which causes acid rain.

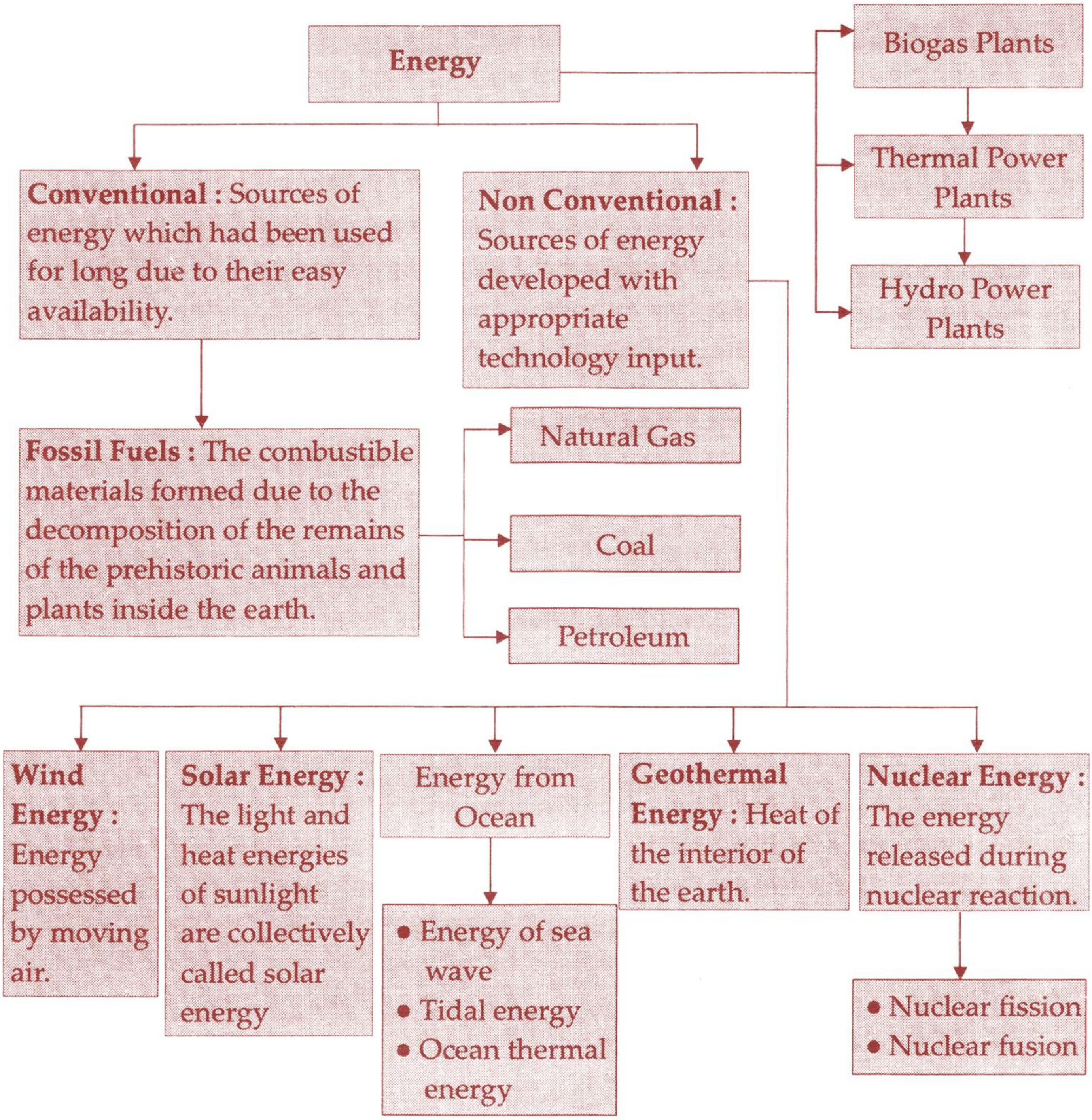
Disadvantages of Nuclear Energy

The disadvantage of nuclear energy are that:
(a) the waste products of nuclear reactions (produced at nuclear power plants) are radioactive which keep on emitting harmful nuclear radiations for thousands of years. So, it is very difficult to store or dispose of nuclear wastes safely. Improper nuclear waste storage or disposal can pollute the environment.
(b) there is the risk of accidents in nuclear reactors (especially the old nuclear reactors). Such accidents lead to the leakage of radioactive materials which can cause serious damage to the plants, animals (including human beings) and the environment.
(c) the high cost of installation of nuclear power plants and the limited availability of uranium fuel make the large scale use of nuclear energy prohibitive.

ESSENTIAL POINTS For COMPETITIVE EXAMS

- The various sources of energy are the sun, the wind, water, fossil fuels etc.
- A good source of energy is one which supplies large amount of useful energy, easily available, economical and cause minimum environmental pollution.
- Electricity produced by flowing water is known as hydro-electric power.
- Biomass is a material which contains carbon and other combustible material.
- Plants, wood, animals and plants waste are the examples of biomass.
- Gobar gas or bio-gas is the example of a bio-mass energy source.
- Main constituent of a biogas or gobar gas is methane gas.
- Biogas plant is an arrangement of producing biogas from animal dung, human excreta, industrial and domestic wastes.
- Biogas plant is of two types : (a) Fixed-dome type, (b) Floating gas holder type
- Constant and rapid use of conventional sources of energy would ultimately exhaust these sources and hence a need for tapping energy from alternate or non-conventional sources of energy is seriously felt.
- Solar constant is defined as the energy received from the sun in one second by a unit square metre area of the outer edge of earth's atmosphere exposed perpendicular to the radiation of the sun at an average distance between the sun and the earth.
- Value of solar constant =1.4 kW/m^2
- Water due to its high specific heat capacity (4200 $J\ kg^{-10}C^{-1}$) is a store house of heat energy,
- Energy from sea or ocean water is available in the form of (i) Energy of sea waves (ii) Tidal energy and (iii) Ocean thermal energy (OTE).
- The heat energy stored in the hot spots of earth's crust is called geo-thermal energy.
- The energy obtained from the conversion of nuclear mass is known as nuclear energy.
- Nuclear energy is obtained by two processes known as nuclear fission and nuclear fusion,
- Nuclear energy is expressed in electron-volt (eV)
  $1\ eV = 1.6 \times 10^{-19}\ J$
  $1\ MeV = 10^6\ eV = 1.6 \times 10^{-13}\ J$
- Nuclear fission is the process of splitting a heavy nucleus (say Uranium) into two comparatively higher nuclei along with the release of large amount of energy when bombarded with thermal neutron.
- Energy released per fission of $_{92}U^{235}$ is about 200 MeV.
- Nuclear reactor is a device used to carry out controlled chain reaction.
- Nuclear fusion is the process of fusing or combining together two small nuclei to form a comparatively big nucleus with the release of large energy.
- Nuclear fusion reactions occur at very high temperature (10^7 K).
- Source of energy are classified in to two categories (i) conventional or non-renewable sources of energy and (ii) Non-conventional or renewable sources of energy.

CONCEPT MAP


Energy
Conventional : Sources of energy which had been used for long due to their easy availability.
Non Conventional : Sources of energy developed with appropriate technology input.
Biogas Plants
Thermal Power Plants
Hydro Power Plants
Fossil Fuels : The combustible materials formed due to the decomposition of the remains of the prehistoric animals and plants inside the earth.
Natural Gas
Coal
Petroleum
Wind Energy : Energy possessed by moving air.
Solar Energy : The light and heat energies of sunlight are collectively called solar energy
Energy from Ocean
• Energy of sea wave
• Tidal energy
• Ocean thermal energy
Geothermal Energy : Heat of the interior of the earth.
Nuclear Energy : The energy released during nuclear reaction.
• Nuclear fission
• Nuclear fusion