Chapter 12

NON-CONVENTIONAL ENERGY SOURCES

12.1 Introduction

Every activity for survival and subsistence requires energy; cooking food, driving a vehicle, running industries, producing electricity and even performing day to day activities like walking and talking need energy. This energy requirement is fulfilled by a variety of resources. Human beings derive energy from the food they eat. The energy needs of vehicles and industries are met by coal, petrol, diesel, etc. These sources are obtained from the earth's interior where they were produced by the fossilization of plants and animals that got buried under the earth millions of years ago. These energy resources also termed as fossil fuels are the *conventional sources of energy.*

Rising living standards has increased the energy demand drastically and with the current pace of fuel consumption, scientists predict that the conventional sources of energy will soon be depleted. It is therefore mandatory to harness natural sources like sun, water and air to meet the growing energy demands of the present century. These energy sources are termed as the *non-conventional (or alternate) sources of energy.* These are abundantly available in nature and will never come to an end. All that is required is technology that can enable us to use these resources economically. This chapter deals with the various non-conventional energy sources and the technologies to convert them economically into usable form.

12.2 Non-Conventional (or Alternate) Sources of Energy

These energy resources are inexhaustible natural resources and are replenished at a rate greater than their rate of consumption. Hence they are also termed as the *renewable energy sources.* The common examples are as follows:

1. Solar Energy
2. Wind Energy
3. Energy from water/Hydroenergy
4. Tidal Energy
5. Wave Energy
6. Energy from Biomass

7. Ocean Thermal Energy Conversion
8. Geothermal Energy
9. Hydrogen Energy

12.3 Solar Energy

Sun is the major source of energy on earth. It gives 1000 times more energy than we require. If this energy is trapped economically the energy crisis of the world would be solved. Solar energy can be used either

(i) Directly as thermal energy like in solar cookers, solar water heater, solar dryers, desalination of sea water, etc.

(ii) Indirectly using photovoltaic cells to convert solar energy to electricity. This is carried out by using silicon solar cells. The electricity so generated can be used for street lighting, lightning homes and buildings, running motors, pumps, electric appliances, etc.

Although the initial installation cost of a solar plant is high, it is clean energy, does not discharge harmful products in air and once installed the running cost is less and hence it is cheap.

Applications of Solar Energy

1. *Solar Water Heating* These use sunlight to heat water. A solar water heating unit comprises a blackened flat plate metal collector with an associated metal tubing facing the sun. The plate collector has a transparent cover and a layer of thermal insulation beneath it.

   The metal tubing of the collector is connected by a pipe to an insulated storage tank. The collector absorbs solar radiations and transfers heat to water circulating through the tubing. This hot water is supplied to storage tank via the metal tubing.

   This water heating system is used in hotels, guesthouses, tourist bungalows, hospitals, canteens as well as domestic and industrial units.

2. *Solar Cooker* Here solar energy is utilized for cooking food. A simple solar cooker is a type of a flat box which is blackened from the inner side. The solar radiations enter the box through two glass covers. These are absorbed by pots blackened from outside. The collector area is increased by providing a plane reflector mirror.

3. *Solar Lightning* Electricity is produced directly from solar energy by means of photovoltaic cells. A photovoltaic cell is an energy conversion device used to convert photons of sunlight directly into electricity. These can be used to operate irrigation pumps, rail road crossing signals, to run calculators, watches, etc. These can also be used for providing electricity in rural areas i.e., for lighting street lights. A detailed description of the principle and working of photovoltaic cells is discussed in the forthcoming sections.

4. *Solar Ponds* A solar pond is a natural or artificial body of water utilized for collecting and absorbing solar radiation and storing it as heat. It is very shallow (5-10 cm deep) and has a radiation absorbing bottom made of black plastic. It has a curved glass fiber cover over it to permit the entry of solar radiation and reduce loss of energy by radiation and convection. Loss of heat to the ground is minimized by providing a bed of insulating material under the pond.

Solar ponds utilize water for collecting and storing the solar energy which is used for many applications such as space heating, for industrial process to generate electricity by driving a turbine powered by evaporating an organic fluid with low boiling point.

5. *Solar Green Houses* These are big houses made of glass to store solar energy. They utilize the principle of greenhouse effect and are used for growing plants in cold countries or in cold climatic conditions.
6. *Solar Distillation* Solar energy is used for converting saline water into potable water in arid, semi arid and coastal areas.
7. *Solar Pumping* The power generated by solar energy is utilized for pumping water for irrigation purposes.
8. *Solar Drying of Agricultural and Animal Products* Agricultural products, fruits, etc are dried by keeping them in big cabinets made of glass.

Solar Photovoltaic Cell

A photovoltaic cell is a device that converts solar energy directly into electrical energy. When solar radiations fall on these devices they are converted directly into dc electricity.

A solar cell is made up of light sensitive *p-n* junction photodiode. The photodiode is made of semiconductor materials like silicon, cadmium telluride, gallium arsenide, etc which are capable of absorbing the photons of sunlight. However silicon solar cells are the most commonly used ones. The silicon solar cells are thin wafers of about 250 μm in thickness. A *p-n* junction diode is formed by doping a portion of this wafer with a trivalent impurity (for *p*-type) and another portion with a pentavalent impurity (for *n* -type) (For more details on *p-n* junction and semiconductors refer chapter 9 – Solid State). Metal contacts are attached on the front and back side of the cell. The front contact is in the form of metal grid to permit sunlight to pass through it and the contact on the back side completely covers the surface. The *n*-type silicon is on the front side and the *p*-type silicon is on the back side. An antireflection coating of silicon nitride or titanium oxide of about 0.1 μm thickness is applied on the top surface (fig 12.1).

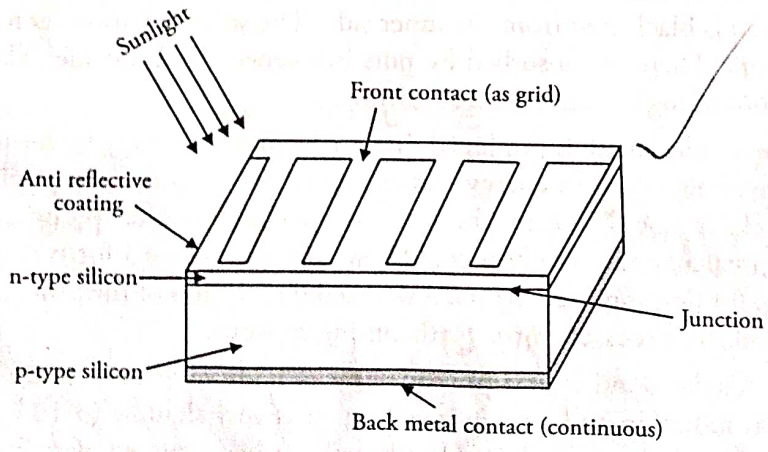

Figure 12.1 *Schematic diagram of a solar cell*

When this cell is irradiated with solar radiation on the front side (n – type silicon) electrons are knocked out from the valence band to the conduction band. These electrons flow from n-type semiconductor to p-type semiconductor thereby completing the circuit and the current flows from p-type to n-type region.

In actual practice a large number of solar cells are arranged in definite patterns to form the solar panel that helps to achieve the desired voltage.

12.4 Wind Energy

Wind energy is the energy generated by harnessing the energy of winds, usually by windmills.

Winds are caused by the uneven heating and cooling of the earth's surface and by earth's rotation. Heating and cooling of atmosphere generates convection current and thus generates winds. Winds are also caused due to the natural movement of air across land and sea.

Basic Technology

The linear kinetic energy of the wind is transformed into rotational movement needed to turn an electrical turbine. A rotor having one, two or three blades is used to bring about this transformation. The rotors of the wind turbine rotate generating power. This energy generated can be harnessed in various ways:

(a) *In Batteries* The power generated from wind turbines can be used to charge batteries which can store energy in the form of chemical energy for later use.

(b) *Heating* The power generated can be used to heat water either by passing power through a resistance or by churning water.

(c) *Fuel cells* The generated power can be used to produce hydrogen and oxygen by the electrolysis of water. These gases can then be used to generate electricity using fuel cells.

(d) *Wind pumps* Wind turbines can be used for producing mechanical power for pumping water. These are called wind pumps and the pumped water can be used for irrigation, domestic water supply or can be stored in large overhead tanks for later use.

(e) *Integration with the grid* The power output of wind turbine can be integrated with the electric grid to be utilized later during the no wind periods.

Advantages and Disadvantages of Wind Energy

Wind energy, like solar energy is clean energy. The operation and maintenance cost of windmill is low. However, the initial installation cost is high.

The demerits include the uncertainity of the strength of wind, high noise created by the moving windmill; moreover it also affects scenic beauty of the natural landscape adversely. Sometimes birds are killed by flying into the rotors.

12.5 Energy from Water/Hydroenergy

It is the energy generated from flowing and falling water. Water is stored in dams built across flowing rivers. This raises the water level thereby increasing its potential energy or hydraulic head. The water falls on hydraulic turbines which convert pressure and kinetic energy of water into rotational kinetic energy. The rotating shaft of the turbine drives the generator which transforms mechanical energy into electrical energy. Electrical energy is then transmitted using transmission lines (Fig 12.2).

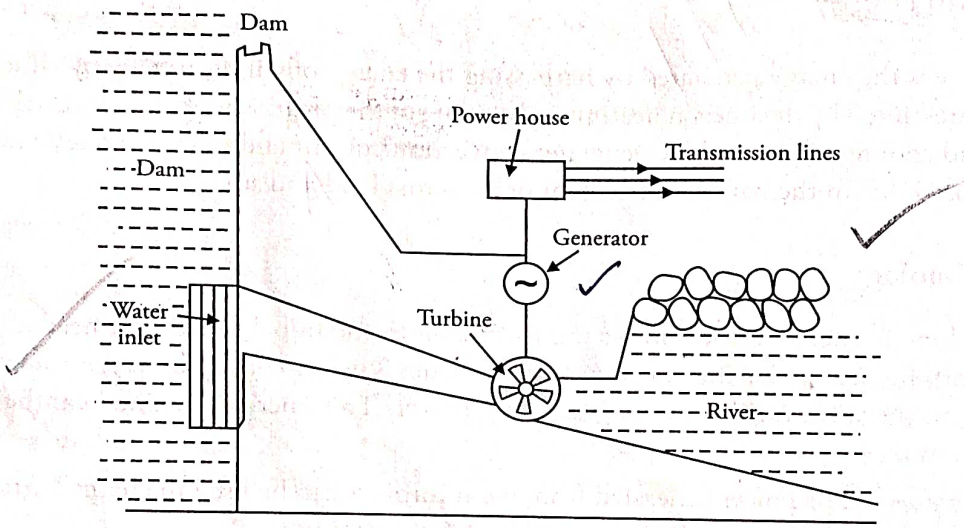

Figure 12.2 *Schematic diag of Hydroelectric power plant*

Advantages and disadvantages of hydroelectricity

At present hydroelectricity is the only renewable energy resource used to generate electricity on large scale. It does not cause pollution and is more reliable than wind or solar or wave energy. However it involves building of dams which is very expensive and leads to submerging of low lying areas, loss of forest and agricultural land and the need to rehabilitate people living in the submerged zones. Moreover the impounded water also increases the seismicity of the region.

12.6 Tidal Energy

All celestial bodies in the universe attract each other. The sun and the moon exert gravitational pull on the earth. This causes the surface water on the earth to rise up and bulge towards the moon leading to the formation of tides. Tides are formed periodically in the oceans due to various positions of the rotating moon and sun. Tide formation brings about a water level difference in the oceans. The highest level of tidal water is known as the high tide or the flood tide and the lowest

level is known as the low tide or ebb. This difference in water level of high tide and low tide is called the tidal range and it contains large amount of potential energy. Tidal ranges of about 5 m and above can be used to drive turbines coupled with generator to generate electricity.

Basic Technology

A tidal power plant consists of a reservoir or basin to hold water during high tides. A dam or dyke acts as a barrier between the sea and the reservoir /basin. The dam is provided with a series of sluice gates to permit the entry of water into the basin during high tides (Fig 12.3).

When there is high tide the water level rises and the water enters the reservoir/basin through the sluice gates. The impounded water is held there till the tide recedes creating a suitable head. The water is then released through turbines thus generating electricity. The water is released till the head falls to the minimum operating point. As the water rises again during high tide the basin is filled again thus repeating the cycle.

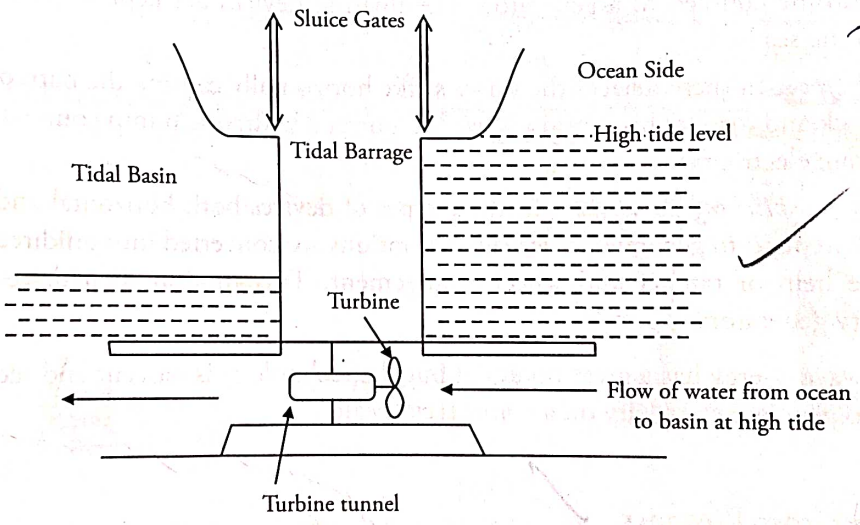

Figure 12.3 *Schematic diagram of a tidal power plant*

Advantages and Disadvantages

Tidal energy like any other renewable energy source does not cause pollution and is inexhaustible. However it is generated in regions far away from the load centres thereby increasing the cost of transmission.

12.7 Wave Energy

Waves originate due to the transfer of wind energy to the surface of sea water. The height and strength of waves depend upon the speed of the wind and the distance over which it interacts with

water. The waves possess both kinetic and potential energy ⇒ the former due to the movement of waves and the latter due to the lifting of water mass above the sea level. Waves can rise from a height of 10m to 100m above the sea level. The power of waves can be harnessed to generate electricity.

Basic technology

The technology for harnessing energy from waves is different from that of tides because tides provide a much larger water head than waves do and the tides are periodic whereas waves are fluctuating. The common devices used to convert wave energy to electric energy are described below:

(1) *Heaving float type* This device floats on the water surface and moves up and down with the vertical motion of the waves. This vertical motion is used to operate a piston of an air pump which stores energy as compressed air. The compressed air is used to generate electricity using an air turbine coupled to a generator. The floating devices are kept in place by anchoring them to the sea bed.

(2) *Pitching type* In these devices the waves strike horizontally causing the flaps of the device to swing back and forth. This motion is used to power a hydraulic pump coupled to a generator to generate electricity.

(3) *Heaving and pitching float type* In these types of devices both horizontal and vertical wave motions are used to generate power. These motions are converted into unidirectional motion with the help of ratchet and wheel arrangement. This motion then drives floating and stationary generators.

Although wave energy has a great potential but the technology is nascent and requires research to enable us to generate electricity on a commercial scale.

12.8 Energy from Biomass

Biomass is one of the oldest sources of energy. Wood has been used to generate energy from times immemorial. Today many sources of biomass like plants, agricultural waste, organic waste from industries and cities, municipal solid waste, forest residues are used to generate energy. Dedicated energy crops such as fast growing trees and grasses can be used as sustainable long term source of biomass. Oil obtained from petro plants is also used as source of bioenergy.

Biomass can be converted into energy by three basic technologies:
(1) Incineration (2) Thermochemical process (3) Biochemical process

(1) *Incineration* Incineration means the direct combustion of biomass in furnaces called incinerators. Biomass such as waste wood, agricultural waste products, waste from food industry, municipal solid waste is burnt and the heat thus produced can be used either for space heating or cooking or to generate steam in boiler to run turbine coupled to a generator to produce electricity. A schematic diagram of generating electricity from biomass by incineration is shown in fig 12.4.

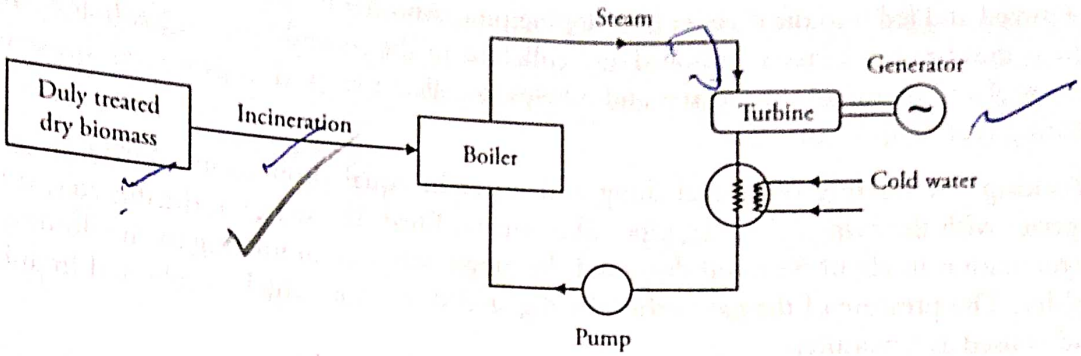

Figure 12.4 *Schematic diagram of generating electricity from biomass by incineration*

(2) *Thermochemical* Thermochemical process involves the conversion of solid biomass in either absence of air or limited supply of air. The process is called *pyrolysis* or *gasification* and can be used to process solid fuels like rubber and plastic which cannot be processed by other methods. Gasification is carried out in a gasifier and it converts the biomass either into a mixture of gases such as H_2, CO, CO_2, CH_4 and N_2 (mainly producer gas) or liquid in the form of oil. The end product depends upon the feedstock and the temperature and pressure conditions employed. Gaseous products are generally formed when pyrolysis is carried out above 1000°C and liquid products are formed at low temperature (250 -450°C) and high pressure (270 atm). Fig 12.5 gives a schematic diagram of gasification/pyrolysis process for generation of electricity.

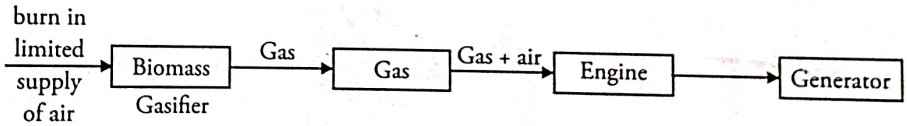

Figure 12.5 *Schematic diagram of generating electricity by pyrolysis (Thermochemical process)*

(3) *Biochemical* This method involves the anaerobic digestion of biological matter. Organic matter, animal dung, poultry waste, vegetable matter, human excreta, plant waste, etc are subjected to the action of microorganisms in closed tank in the absence of oxygen (anaerobic conditions). The organic matter undergoes degradation and a gas rich in methane is evolved. This gas is collected and can be used in kitchens as fuel. It is highly inflammable and is called biogas or *gobar* gas. Its approximate composition is:

CH_4 = 55%; H_2 = 7.4 %; CO_2 = 35%; N_2 = 2.6 % and H_2O = traces.

Its average gross calorific value is 5300 Kcal/m^3

Manufacture A biogas plant consists of an underground tank called the digester and a gas holder above the ground. The digester is made up of bricks masonary wall in cement mortar. Two small tanks are constructed on the ground on either sides of the digester. In one tank the dung and water

are mixed and fed into the digester by a sloping pipe. Another pipe serves as an outlet pipe through which the digested slurry is removed and collected in the second tank. A gas holder made up of steel is placed on top of the digester and it helps to collect the gas thus produced. It can be fixed or floating type (Fig. 12.6).

Working A mixture of animal dung and water in equal proportion (slurry) is fed into the digester with the help of the inlet pipe. The slurry is filled till the top of the digester. It undergoes fermentation in about 50 to 60 days, and the biogas starts accumulating in the dome-shaped gas holder. The pressure of the gas pushes the digested slurry out, which is collected in another tank and is used as a manure.

Uses Biogas is a clean fuel and is used for cooking and as an illuminant in rural areas. The spent slurry is a very useful fertilizer and has 43% more strength than dung used directly as manure.

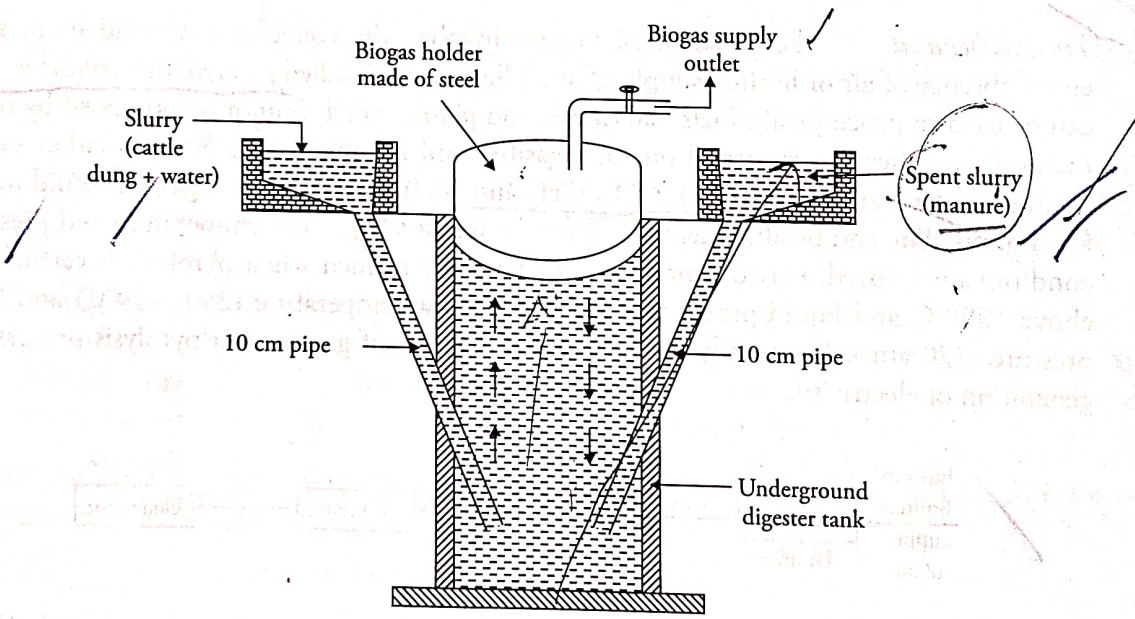

Figure 12.6 *Floating gas holder type biogas plant*

12.9 Geothermal Energy

Geothermal energy is the energy which lies embedded within the earth's crust. The temperature of earth increases with depth below the surface. All the heat stored in the earth's crust as thermal energy constitutes an inexhaustible source of energy termed as geothermal energy.

Hot molten rock called 'magma' is present at a depth of 25–40 Km below the earth's surface. This molten magma is sometimes pushed up towards the surface resulting in volcanic eruption. When ground water comes in contact with magma it gets heated. In some places, the steam or hot water comes out of ground naturally through cracks in the form of natural geysers. This hot geothermal water or steam is used to operate turbines to generate electricity.

Geothermal energy is large enough to meet the energy requirement for nearly 3,50,000 years but the limitation is the technology to harness it economically. Although unlike solar and wind

energy, geothermal energy is available all the time and does not depend on the weather conditions; however there are certain disadvantages as well. Continuous extraction of heated water from the ground can lead to subsidence of land in that area. Moreover geothermal water is accompanied by dissolved gases that lead to air pollution.