Topic 2: Energy Resources

Introduction

The production of electricity and its per capita consumption is regarded as the indication of the standard of living of people in a nation. Energy is a key input in the economic growth. The growth of a nation largely depends on the availability of energy. The energy consumption in the world has been increasing at an alarming rate for the past few decades. The conventional energy resources such as coal, wood, diesel, petrol, natural gas, etc. are depleting. It has been estimated that the conventional fuels may last for 5-6 decades only. To meet the major part of energy demand in future, every nation is making efforts to find non-conventional energy sources such as solar, wind, tidal and geothermal. Energy resources are the main sources of energy from which the energy can be extracted and utilized for mankind.

Learning Outcomes of Topic 2

Upon completion of this study unit, you should be able to:

1. classify energy resources
2. discuss the different types of energy resources: thermal energy, hydel energy, nuclear energy, solar energy, wind energy, tidal energy, geothermal energy, ocean energy
3. explain energy parameters: energy intensity, energy elasticity
4. discuss global energy resources
5. give a report on the world energy status
6. discuss the environment aspects of energy: pollution, greenhouse effects, energy chain

1.2 ENERGY RESOURCES

- **What do you understand by energy resources?**

Energy resources are the main sources of energy from which the energy can be extracted and utilised for mankind. Energy is a key input in economic growth. The growth of a nation largely depends on the availability of energy resources.

1.2.1 Classification of Energy Resources

- **How can energy resources be classified?**

or

- **Discuss the primary and secondary energy resources. Also, describe the future of non-conventional energy sources**

or

- **What are the conventional and non-conventional energy sources? Describe the fossil fuels as the conventional energy resources.**

The energy resources can be classified on the basis of usability of energy resources, traditional usage of energy resources, long-term availability of energy resources, commercial application of resources and origin of resources.

Primary and secondary energy resources

(i) **Primary resources.** Resources available in the nature in the raw form are called primary resources. Fossil fuels (coal, oil and gas), uranium and hydropower are primary energy resources. These energy resources cannot be used in raw form. Primary energy resources have to be located, extracted, processed and converted into a suitable form before use.

(ii) **Secondary resources.** Secondary energy resources are obtained form primary energy resources by processing. Processing helps in transformation of primary resources into the secondary or usable energy form so that it can be utilized by consumers. Electricity, steam, hot water, petrol, diesel, LNG and CNG are secondary energy resources.

Conventional and non-conventional energy resources

(i) **Conventional.** Conventional energy resources are energy resources which have been traditionally used from many years. These resources are also widely used at present and likely to be depleted.

(ii) **Non-conventional.** These are alternate energy resources to the conventional energy resources which are being considered to be used on large scale. The conventional energy resource are likely to be depleted in about 50–60 years and non-conventional energy resources should be fully developed by then to meet the energy requirement.

The comparison of conventional and non-conventional energy resources is given in Table 1.1.

TABLE 1.1 Comparison of conventional and non-conventional energy resources

Conventional resources	*Non-conventional resources*
Traditional	Non-traditional
These have been in use for many years	These are not in routine use at present
These resources can be easily converted into mechanical energy	These resources require some costly method to be converted into mechanical energy
These are likely to be depleted, that is, these have limited availability	These are non-depletable or may be available in vast quantities
Coal, petrol, diesel, nuclear fuels CNG and LPG are conventional energy resources	Solar, wind, tidal geothermal and biogas are non-conventional energy resources

Renewable and non-renewable energy resources

(i) **Renewable.** Resources which can be renewed by nature again and again so that their supply is not adversely affected by the rate of their consumption are called renewable resources.

(ii) **Non-renewable.** Resources which are available in certain finite quantity and cannot be replenished are called non-renewable.

The comparison between renewable and non-renewable resources is given in Table 1.2.

TABLE 1.2 Renewable and non-renewable resources

Renewable resources	*Non-renewable resources*
These are inexhaustable resources	These are exhaustable resources
These are non-traditional in use	These are traditional in use
New methods are being developed to use these resources	Widely used used as energy resources
Efforts are taken to make vast use of these resources	Efforts are taken to conserve these resources
Hydel, solar, wind, tidal and geothermal resources are renewable energy resources	Fossil fuels, nuclear fuels and natural gases are non-renewable resources

Commercial and non-commercial energy resources

(i) **Commercial energy resources.** The secondary usable energy resources such as electricity, CNG, LPG, petrol and diesel are essential for commercial activities. The economy of a nation highly depends on its ability to process and transform the natural raw energy sources into usable commercial energy sources.

(ii) **Non-commercial energy.** The energy which can be derived directly from nature so as to be used without passing through any commercial outlet is known as the non-commercial energy. Wood, animal dung cake and crop residues are non-commercial energy sources.

Energy resources of different origins

The energy resources based on their origin can be nuclear, fossil fuel, hydro, solar, biomass, wind, tidal, geothermal, ocean thermal and ocean tidal resources.

1.3 TYPES OF ENERGY RESOURCES

The energy resources can be thermal, hydel, nuclear, solar, wind, tidal, geothermal and ocean resources.

1.3.1 Thermal Energy

- **What is thermal energy? How are fossil fuels classified?**

Thermal energy is the energy which is stored as the heat energy in the fossil fuels. Fossil fuels are the fuels obtainable from the earth that have been accumulated over thousands and thousands of years by the decaying of plants. These fuels produce heat energy when they are burnt. Heat energy is mainly used for transportation and electric power generation in thermal power plants. The fossil fuels can be classified as shown in the Figure 1.1.

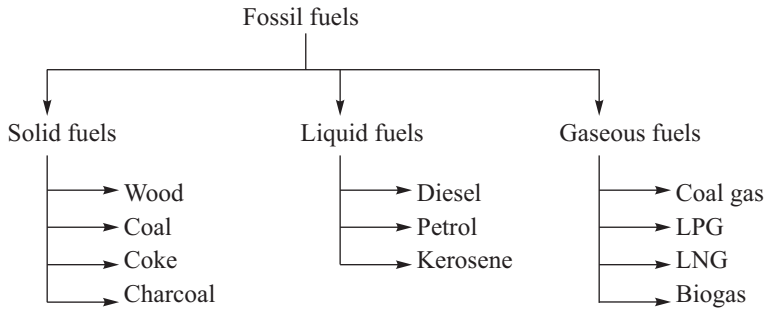

Figure 1.1 Types of fossil fuels.

1.3.2 Hydel Energy

- **What is hydel energy? Describe briefly a hydroelectrical power plant.**

Hydel energy is the potential energy of water created due to the storage of water at a higher level. A dam is built across the river to store water at a higher level. When this stored water in dam at the higher level flows under pressure to the lower level, it can run the turbine to generate electrical power. A hydroelectric power plant is shown in Figure 1.2. It consists of (i) reservoir, (ii) penstock to carry water from reservoir to turbine, (iii) turbine to convert water energy into mechanical work, (iv) generator to convert mechanical work into electrical energy and (v) power transmission system.

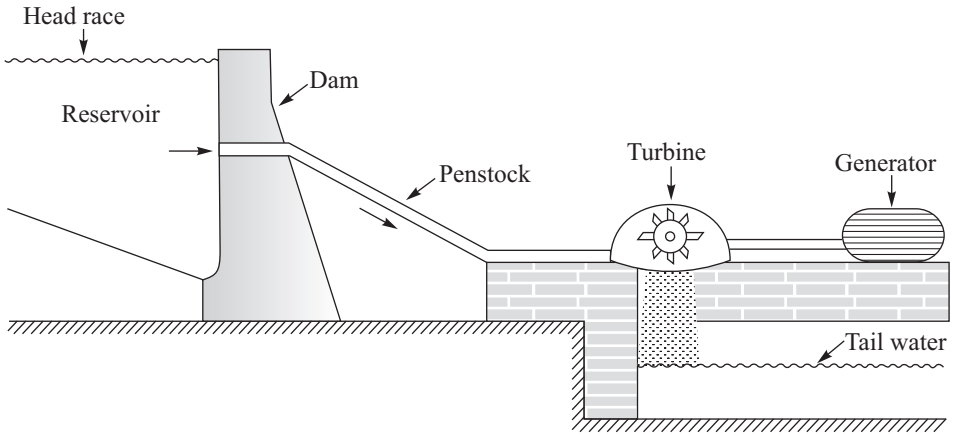

Figure 1.2 A hydroelectrical power station.

1.3.3 Nuclear Energy

- **What is nuclear energy? Explain the process of nuclear fission.**

The nuclear energy is released when atoms of certain unstable material split in the process of fission. A small mass of nuclear fuel such as uranium can release an enormous amount of heat energy when it undergoes fission process. One kilogram of uranium-235 can give heat energy on fission process which is equal to the heat which can be obtained by burning 4000 tons of high-grade petroleum. The uranium can be made to undergo fission process inside a nuclear reactor. The nuclear fission is a chain reaction as shown in Figure 1.3.

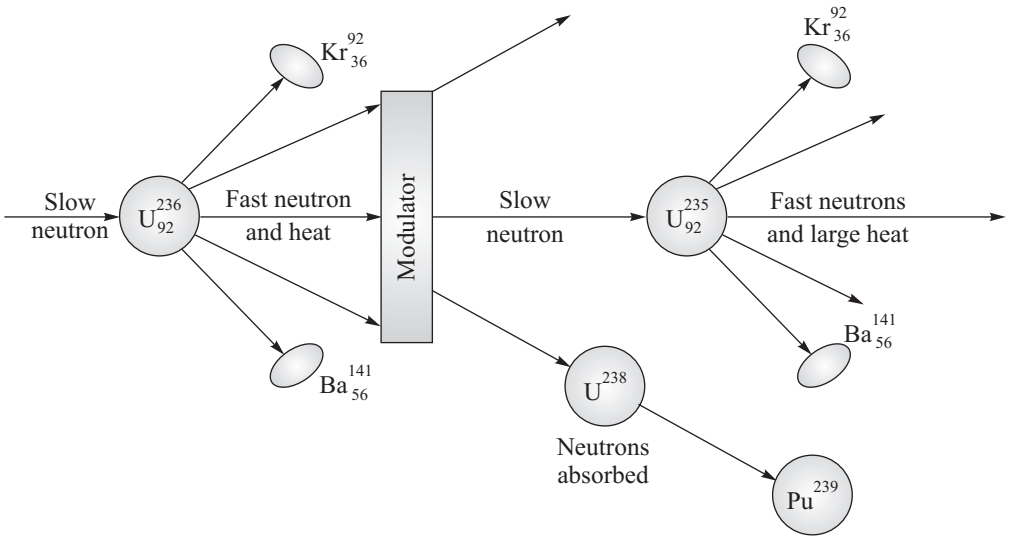

Figure 1.3 Fission process in the nuclear fuel.

1.3.4 Solar Energy

- **What is solar energy? Describe with the help of a neat sketch the working of a solar plant.**

or

- **What do you understand by photovoltaic conversion? What are the advantages and disadvantages of solar energy?**

The sun is a continuous fusion reactor in which hydrogen combines to form helium and liberates large amounts of heat in the process. The sun rays contain a large amount of energy in the form of electromagnetic radiation due to the continuous nuclear fusion reaction taking place in the sun. The energy is released at the rate of 3.7×10^{20} MW. This heat energy contained in the sun rays can be utilised to generate electrical power. The sun rays are focused on solar collector to heat butane water to generate butane gas in the butane boiler. The butane gas under high pressure from the boiler is taken to butane turbine to perform

mechanical work. A generator is coupled to the turbine to generate electrical power as shown in Figure 1.4. The potential of power generation by solar energy can be in the order of 1.75×10^{11} MW. The mechanical devices which help to collect the solar radiations so as to convert them into heat energy are called solar collectors.

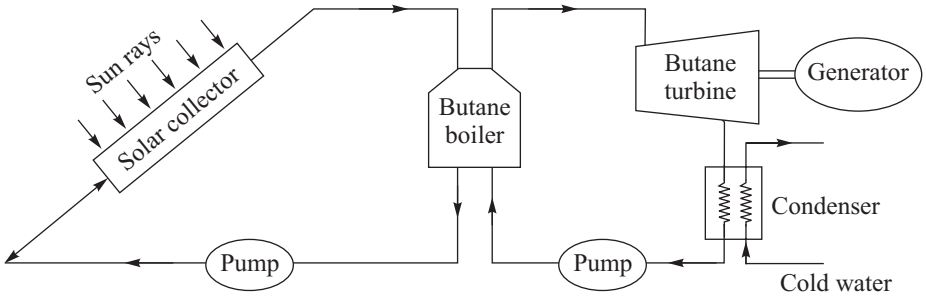

Figure 1.4 The power generation by the solar cell.

Photovaltaic conversion is a direct electricity generation method in which sunlight is converted into electricity using solar cells. The most common solar cells are manufactured from a highly refined silicon material. A single solar cell can produce electric power of 1 W at voltage of 0.5 V. Several solar cells can be connected in series or parallel to produce power of required voltage and current. Solar cells are an intermittent energy source and generally used with batteries to store generated electricity, thereby providing a more economical power generation system.

Advantages of solar energy are as follows:

(i) Solar energy is available freely in nature.
(ii) It is a renewable energy resource.
(iii) It does not pollute the environment.
(iv) It can be directly converted into electricity by employing photovoltaic cells.

Disadvantages of solar energy are as follows:

(i) It is available only during daytimes and clear days.
(ii) Solar energy obtainable also depends on seasonal variations.
(iii) It requires a large area to entrap appreciable solar energy for the generation of an economical amount of electricity.

1.3.5 Wind Energy

- **What is wind energy? How are windmills classified? What are the advantages and disadvantages of wind energy? Why are blades made of fibre-reinforced plastic (FRP)?**

Wind is induced in atmosphere by uneven heating of earth's surface by the sun. The wind energy is associated with the movement of large masses of air from cold to hot regions. The motion results from uneven heating of atmosphere by sun, thereby creating, temperature, density and pressure differences. The wind energy can be used to run windmill, which in turn

will drive a generator to produce electric power or run water pumps. The energy available in the wind is about 1.5×10^7 MW.

Windmill is a device which converts the kinetic energy of the moving mass of air or wind into mechanical work. The windmills can be classified depending on the orientation of axis of rotation as horizontal axis windmill as shown in Figure 1.5a and vertical axis windmills as shown in Figure 1.5b. The windmills can also be classified based on the number of blades as single bladed windmill, double bladed windmill, three bladed windmill and multibladed windmill as shown in Figure 1.6.

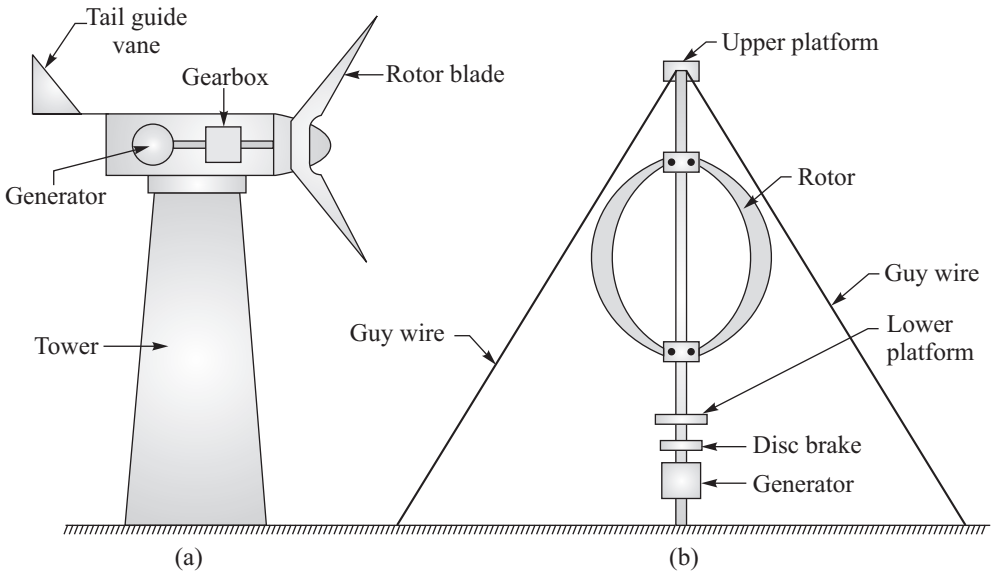

Figure 1.5 Horizontal and vertical axis windmills. (a) Horizontal axis windmill and (b) vertical axis windmill.

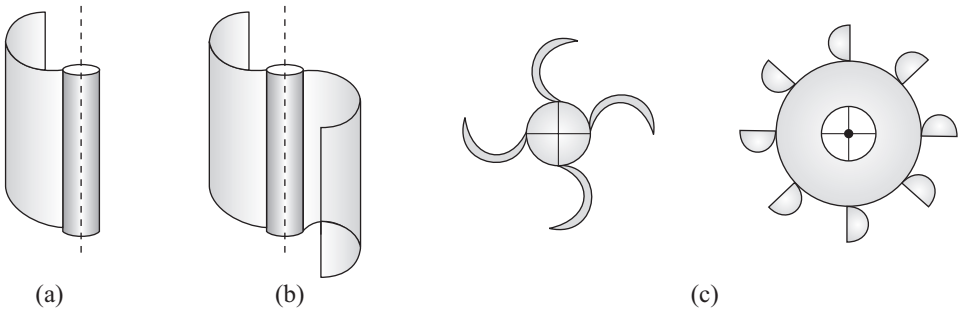

Figure 1.6 Windmills with different number of blades. (a) Single bladed rotor, (b) double bladed rotor and (c) multibladed rotor.

The blades of the windmills are generally made of composite materials such as fibre-reinforced plastic because this material is less costly, easy to use for manufacturing and possesses high strength to weight ratio.

Advantages of wind energy are as follows:

(i) It is freely and abundantly available in nature.
(ii) It is a renewable energy source.
(iii) It does not cause pollution to environment.
(iv) Windmills require minimal maintenance and operating cost.

Disadvantages of wind energy are as follows:

(i) It cannot produce steady and consistent power.
(ii) It can generate only low power.

1.3.6 Tidal Energy

- **What is tidal energy? Explain with a neat sketch the working of a tidal power plant.**

Ocean waves and tides contain a large amount of both potential and kinetic energy which can be utilised for power generation. A tide is the periodical rise and fall of sea water caused principally by the interaction of the gravitational fields of the sun and the moon. The highest level of tidal water is called flood or high tide and the lowest level is called low or ebb tide. The level difference between the high and the low tide is called tidal range. The up and down movement of the tide is used for filling and emptying the tidal basin of the plant. The typical tidal plant is shown in Figure 1.7. The tidal basin is filled up during high tide and it is emptied out during low tide. The flowing in and flowing out water between sea and tidal basin is used to run a turbine and generate electricity.

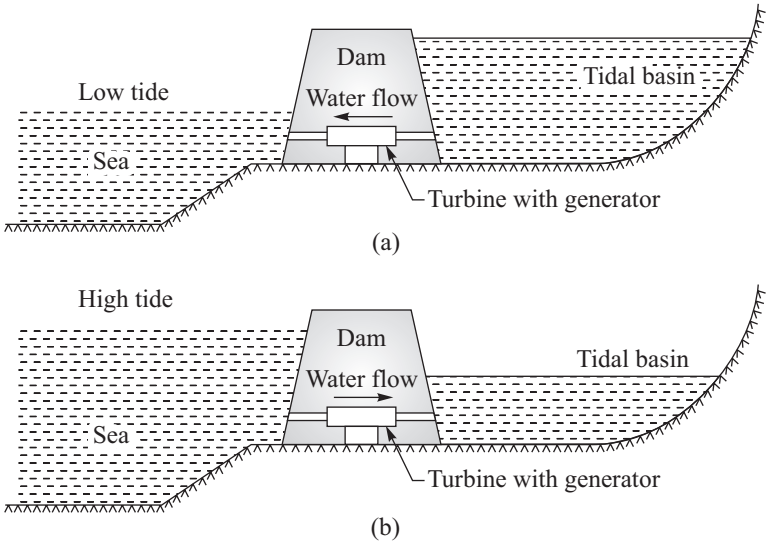

Figure 1.7 High and low tide and working of a tidal plant.
(a) Low tide and water flows out from tidal basin, thereby running turbine.
(b) High tide and water flows in from sea to tidal basin, thereby running turbine.

Advantages of tidal energy are as follows:

(i) It is free from pollution.
(ii) It is superior to hydel energy as it does not depend on rains.
(iii) The tidal basin can also be used for fish farming.
(iv) It is best suited to meet peak power demands.

Disadvantages of tidal energy are as follows:

(i) Tidal power plant is costly compared to thermal and hydel power plants.
(ii) Limited locations are available for the construction of tidal power stations.
(iii) Power generation is not continuous and depends on the capacity of tidal basin.

1.3.7 Geothermal Energy

- **What is geothermal energy? Explain the working principle of a geothermal power plant with the help of a neat sketch.**

The word geothermal is a Greek word meaning the heat of the earth. The temperature at earth's core is on the order of 4000°C. The internal heat energy available at a considerable depth below the surface of the earth is called geothermal energy. It is the heat source in the form of molten rock within the earth which is called magma and it has the temperature of about 3000°C.

A geothermal power plant is shown in Figure 1.8. The water is made to flow down through a porous layer to magma heat source where the water is converted into steam by the heat available at magma. The steam comes out through the vents of the earth surface. This steam is used to vapourise certain low boiling refrigerant. This high pressure refrigerant steam is used to run the turbine. The turbine runs a generator to produce electric power.

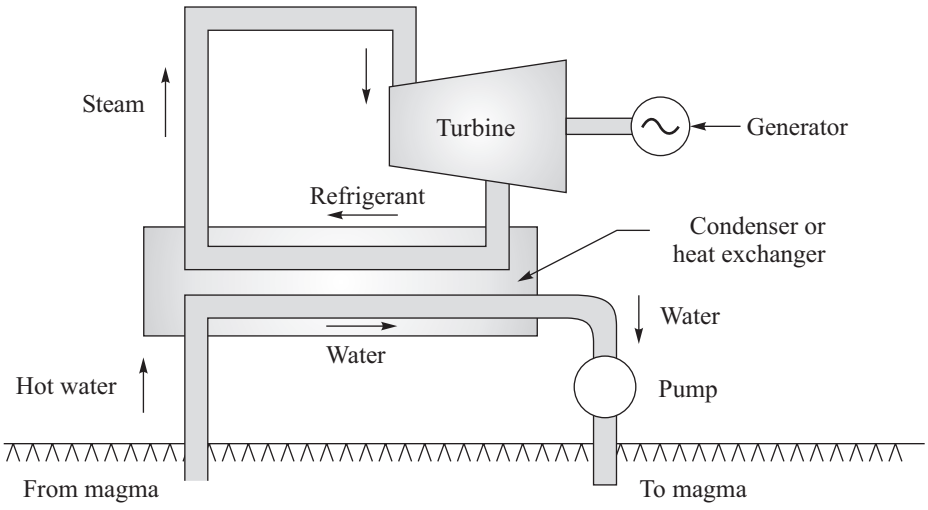

Figure 1.8 Geothermal power plant.

Advantages of geothermal energy as follows:

(i) Energy is continuously available. It is more reliable.
(ii) It has a good potential to meet the power requirement.
(iii) Capital cost is low in comparison to nuclear and thermal power plants.

Disadvantages of geothermal energy are as follows:

(i) Components of the plants are liable to be corroded.
(ii) Gaseous effluent creates nuisance at the site for the workers.
(iii) Gaseous effluent also creates thermal pollution to the environment.
(iv) Groundwater is likely to be polluted from gaseous effluents.

1.3.8 Ocean Energy

- **What are the various types of energy which ocean can provide? Explain Ocean Temperature Energy Conversion (OTEC) and working of an OTEC power plant with the help of a sketch.**

The various types of energy resources which ocean can provide are as follows:

(i) The tides of the ocean can be used to generate electricity.
(ii) The wind produces large waves in the ocean having high kinetic energy which can be converted into electric power.
(iii) The temperature gradient from the surface of ocean to the great depth inside the ocean can be used to provide thermal energy to generate electricity.

The water at the ocean surface is around 25°C, while it is about 5°C at a depth of 100–200 m. Hence, these is a temperature gradient of about 20°C between these two levels and this can be used for generation of electricity by Ocean Thermal Energy Conversion (OTEC). A low boiling point liquid such as ammonia, propane or freon can be vapourised into high pressure vapour using the heat of warm water available at the ocean surface into a boiler as shown in Figure 1.9. The liquid vapour is then used to run a turbine coupled with a

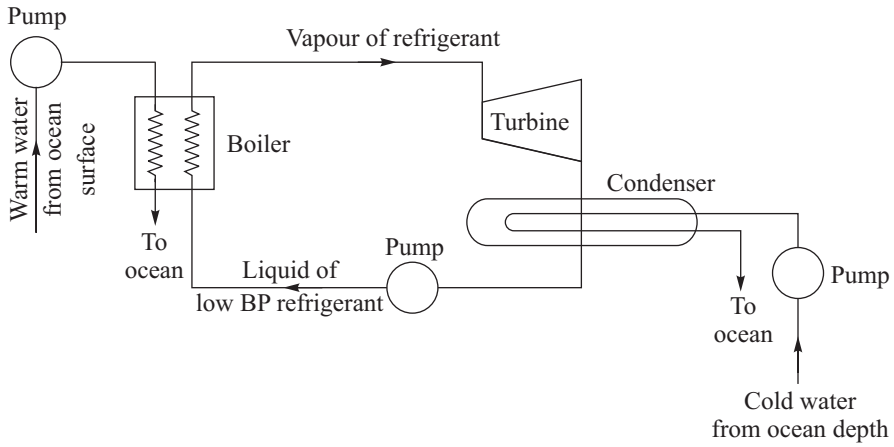

Figure 1.9 OTEC power plant.

generator to produce electricity. After expansion in the turbine, the liquid vapour is condensed into liquid in the condenser using cold water from the deep ocean at a temperature of about 5°C. The condensed liquid is pumped back to the boiler so as to be heated by warm water from the ocean surface. This cycle is repeated.

Advantages of OTEC are as follows:

(i) Power generation is continuous throughout the year.
(ii) Energy is available from nature at no cost.

Disadvantages of OTEC are as follows:

(i) It has a small temperature gradient which gives a small thermodynamic efficiency.
(ii) Capital cost is high due to necessity of heat exchanger, boiler and condenser.

1.4 ENERGY PARAMETERS

The consumption of energy as well as the growth of energy requirement has to be monitored by every nation. To conserve energy resources, it is necessary for every nation to adopt measures to maximise economic development with minimum energy consumption. The energy parameters are measured using the yardstick of gross domestic product (GDP). The GDP is the value of all finished goods and services produced in a given period.

1.4.1 Energy Intensity

- **What do you understand by energy intensity? What are the factors affecting the energy intensity?**

The energy intensity is defined as the ratio of energy consumption and GDP.

$$\text{Energy intensity} = \frac{\text{Energy consumption}}{\text{GDP}}.$$

The energy ratio is a measure of the efficiency in utilising energy in developing national economy. High value of energy intensity indicates that higher amounts of energy resources are used in converting these resources to national GDP or economy. Lower energy intensity indicates that a lower price or cost is made in converting energy resources into national GDP. Factors affecting energy intensity are as follows:

(i) Energy efficiency of the appliances and buildings by proper design and provision of insulation
(ii) Fuel economy of vehicles
(iii) Frequency of travel and larger geographical distances, resulting in greater travelling and energy consumption
(iv) Economical means and pattern of transportation
(v) Availability of mass transit system and its capacity and utilisation
(vi) Efforts to conserve energy
(vii) Weather with mild temperature not requiring heating or cooling

Developed countries such as the USA and Japan have reduced energy intensity compared to underdeveloped countries.

1.4.2 Energy Elasticity

- **What is energy elasticity?**

It is defined as the growth in energy requirement per GDP.

$$\text{Energy elasticity} = \frac{\text{Growth in energy requirement}}{\text{GDP}}$$

The energy should contribute in increasing the GDP. The lower is the value of energy elasticity the more is the growth of GDP. The value of energy elasticity for the developed countries ranges from 0.8 to 1.0.

1.5 GLOBAL ENERGY RESOURCES

The average percentage consumption of various primary energy resources in the world is shown is Figure 1.10. There is currently heavy dependence on fossil fuels. Nearly 87% of the world's energy supply primarily comes from fossil fuels.

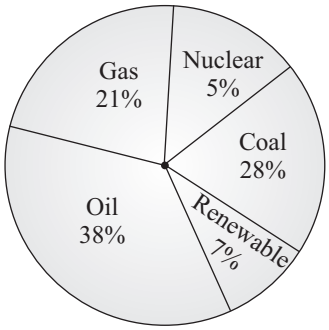

Figure 1.10 Percentage consumption of primary energy resources in the world.

1.5.3 World Energy Status

- **Describe briefly the world energy status.**

The present availability of energy resources in world is discussed next.

Conventional resources

(i) **Fossil fuels.** The fossil fuels have been a major source of energy. These include coal, oil and gas. These fuels are formed by slow decomposition of organic matters under pressure, heat and bacterial action at a considerable within the depth earth. Fossil fuels are expected to last for few decades.

(ii) **Hydro resources.** These are renewable and non-polluting. These require huge capital investment. So far 20% potential has been harnessed. The global installed generating capacity is about 627,000 MW, thereby generating 23% of total electricity produced in the world.

(iii) **Nuclear resources.** Uranium reserves are scarce in the world and they are expected to last for 5 decades. There are about 440 nuclear power plants in the world, generating about 1/6th of the world's electricity. Fast breeder reactors (FBRs) utilise fast neutrons and these generate more fissile materials than they consume.

Non-conventional sources

(i) **Solar energy.** Solar energy can be a major source of power which can be used in thermal and photovoltaic conversion systems. The earth continuously intercepts solar energy of 178 billion MW, which is 10,000 times more than the world's requirement. However, solar PV power cells are an expensive source of power.

(ii) **Wind energy.** The power estimated to be harnessed from wind energy turbines is about 1.6×10^5 MW. It is the most economical energy resource. The worldwide installed wind energy generation capacity is 47,317 MW.

(iii) **Biomass energy.** Biomass energy resources consist of (i) wood, leave and forest industry waste, (ii) algae and other vegetation from ocean and lake, (iii) municipal and industrial waste and (iv) rural waste. Biomass materials can be transformed by biological processes to produce biofuels such as methane, producer gas, ethanol and charcoal. Biomass can supply energy which is estimated to be about 2×10^{21} J in a year.

(iv) **Geothermal energy.** The present installed electrical power generating capacity from geothermal resources is about 7704 MW in the world while the direct thermal use installed capacity is about 16,649 MW.

(v) **Ocean tidal energy.** There is a potential of about 550 billion kW/year energy, which is possible from ocean tidal energy resources. Currently, very few tidal power plants are installed worldwide.

(vi) **Ocean wave energy.** The estimated potential of this resource is 20×10^5 MW. However, no major development work has been carried out to utilise this resource.

(vii) **Ocean thermal energy conversion.** It has more potential than that of tidal or wave energy resources. No commercial installation has been done so far to utilise this resource.

1.6 ENVIRONMENT ASPECTS OF ENERGY

1.6.1 Pollution

- **What are the pollutants produced during energy conversion? What do you understand by indoor and outdoor pollution? What are the remedial actions?**

During every energy conversion process, some energy is released into the atmosphere in the form of heat. Some pollutants in the form of gases are also produced during conversion and these gases are also emitted into the surroundings. Both heat and gases can cause degradation of the environment. The emitted gases are as follows:

(i) **Carbon dioxide (CO_2).** Excess emission of CO_2 in the atmosphere causes global warming.
(ii) **Carbon monoxide (CO).** It severely impairs the oxygen-dependent tissues in the human body.
(iii) **Sulphur oxide (SO_x).** It causes respiratory diseases, acid rains and corrosion of metals and building stones.
(iv) **Nitrogen oxide (NO_x).** It can cause respiratory and cardiovascular diseases, deprive body tissues of oxygen and form acid in lungs.

The pollution can be of following types:

(i) **Indoor pollution.** Indoor pollution occurs by the use of conventional chullahs in rural areas. Nearly 5 lakh children and women die every year from diseases caused by indoor air pollution. Indoor pollution can be avoided by the use of improved household stove.
(ii) **Outdoor pollution.** This is mainly caused by the use of fossil fuels (coal and oil) in industry and transports.

The remedial actions are as follows:

(i) Lesser use of fossil fuels and use of more gasified coal.
(ii) Alternative fuels such as hydrogen which are non-polluting should be used.
(iii) Vehicles running on electricity or battery to be used instead of IC engines.

1.6.2 Greenhouse Effects

- **What do you understand by greenhouse effect?**

A greenhouse made of transparent glass sheets behaves differently to incoming shortwave radition and outgoing longwave radiation. It allows the entry of sunlight but prevents the exit of heat (reflected infrared radiation). The greenhouse can maintain a controlled and warm environment inside for growth of plants. The earth has an envelope of carbon dioxide (CO_2) which behaves similar to greenhouse. The envelope allows heat from sun to enter but prevent heat to escape from earth by stopping reflected infrared radiation. This phenomenon of greenhouse effect by CO_2 envelope helps the earth to maintain the surface temperature to 15°C (hospitable to life), otherwise the earth would become a frozen planet. Normal concentration of CO_2 is about 0.03% and any increase in the concentration of CO_2 will upset the temperature

balance, resulting in further warming of the globe. The carbon dioxide emission is more from developed countries, accounting for 82% of total greenhouse gas emission of the world.

1.7 ENERGY CHAIN

- **What do you understand by energy chain?**

The primary energy sources in the raw form cannot be used directly. It is impossible to drive a vehicle or electric motor using coal, petroleum or uranium. The energy available in primary energy sources is called raw energy. The primary energy sources have to be transformed into useful forms of energy resources which are then called secondary energy resources fuels.

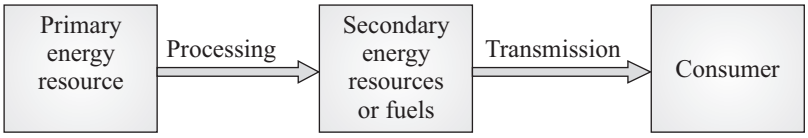

Figure 1.13 Energy chain or route.

The sequence of energy transmission from primary to secondary energy is called energy chain or energy route as shown in Figure 1.13. Mechanical energy, electrical energy and thermal energy can be obtained from primary and secondary energy resources.

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