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28

NON-RENEWABLE SOURCES OF ENERGY

In this lesson we are going to discuss about conventional or non- renewable or exhaustible energy resources. We fully depend on fossil fuel (oil, natural gas and coal) for power production to fulfill our daily energy needs. We in India even lag far behind the current demand of energy for growth in agriculture, and industry as well as in domestic sector. You must be aware of the fact that the world fossil fuel resources, which took millions of years to form, will soon be depleted thus affecting the energy supply. We cannot rely on fossil fuel as they are not a viable long- term option as an energy resource.

In this lesson you will learnt about fossil fuels and their uses. Nuclear energy is also gaining momentum as non-renewable source of energy and is used world wide but health and environmental hazards due to accidents are becoming matter of concern and puts a question mark on future use of nuclear eenrgy.

OBJECTIVES

After completing this lesson, you will be able to:

- *define non-renewable sources of energy;*
- *identify various non-renewable sources of energy;*
- *describe various forms of fossils fuels and list their uses;*
- *describe CNG as a cleaner fuel.*
- *define nuclear energy and list its uses;*
- *explain (in brief) the process of power generations in nuclear plants (nuclear fuel cycle) and its consequences on the environment.*

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28.1 NON RENEWABLE ENERGY SOURCE

Since the discovery fossil fuels, they are one of the most important mineral energy sources. These are a finite energy resource that means they are non-renewable resources and once consumed they are lost for ever. There are three major forms of fossil fuels: coal, oil and natural gas and on worldwide basis they provide approximately 90% of energy consumed.

28.1.1 Fossil fuels

Since the industrial revolution, the major energy resources for the world have been fossil fuels formed from the remains of plants and animals lived in the distant past. Fossil fuels represent stored solar energy captured by plants in the past geological times. Coal, petroleum and natural gas are called **fossil fuels**, as they are the remains of prehistoric plants, animals and microscopic organisms that lived millions of year ago. These remain under the effect of intense heat and pressure underneath the earth's crust over long geological time and got transformed into fossil fuels. For example, the gas cylinder which you see in your kitchen or coal you burn was once the sunlight captured by phototrops. During the Carboniferous period 275-350 million years ago, conditions in the world were suitable for formation of large deposits of fossil fuels. Table 28.1 shows the estimates of the main fossil fuel reserves.

Table 28.1: *Estimates of fossil fuel resources in the world*

Fossil fuel	Total resources	Known recoverable (Measured) reserves
Coal (billion tons)	12,682	786
Petroleum (billion barrels)	2,000	556
Natural gas (trillion cubic feet)	12,000	2100
Shale oil (billion barrels)	2,000	- Not estimated so far
Uranium ore (thousand tons)	4,000	1085

Source: Global 2000 Chiras; One barrel = 159 liters = 35 gallons

In this sub section we will focus on availability, the possibility of exhaustion and environmental consequences of exploitation of fossil fuels, which are most widely used mineral fuel resources.

The terms 'resource' and 'reserves' are often used when discussing the amount of a mineral or fossil fuel resource a country has at its disposal. From a technical point of view the term resource when used as a measurement of mineral or fuel refers to the total amount of a mineral or fuel in a country or on earth. Generally only a small fraction can be recovered. On the other hand reserve means the deposits of energy fuel or minerals that are economically and geologically feasible to extract with current and foreseeable technology.

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28.2 COAL

Coal is formed from plants and vegetation buried, '*in situ*' or drifted in from outside to a place, which got covered by deposits of sediments. (Fig. 28.1).

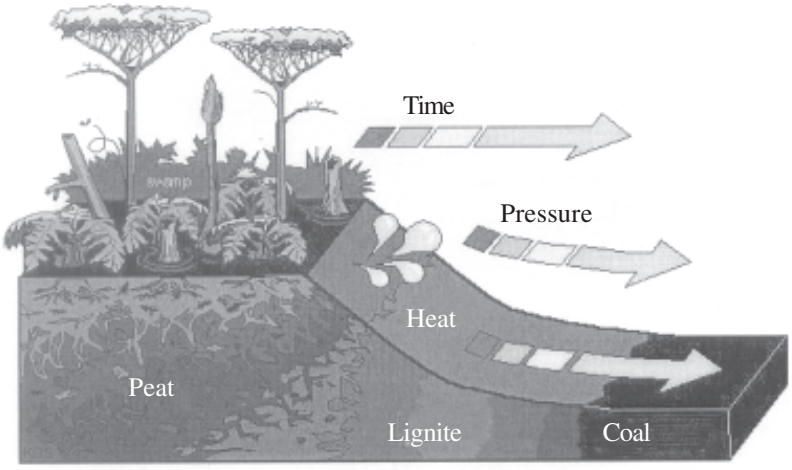

Fig. 28.1: *Stages of formation of coal*

Coal is a solid fossil fuel and a sedimentary rock composed primarily of carbon. There are three basic grades of coal: i) lignite (brown coal), ii) bituminous (soft coal) and iii) anthracite (hard coal). Fig. 28.2.

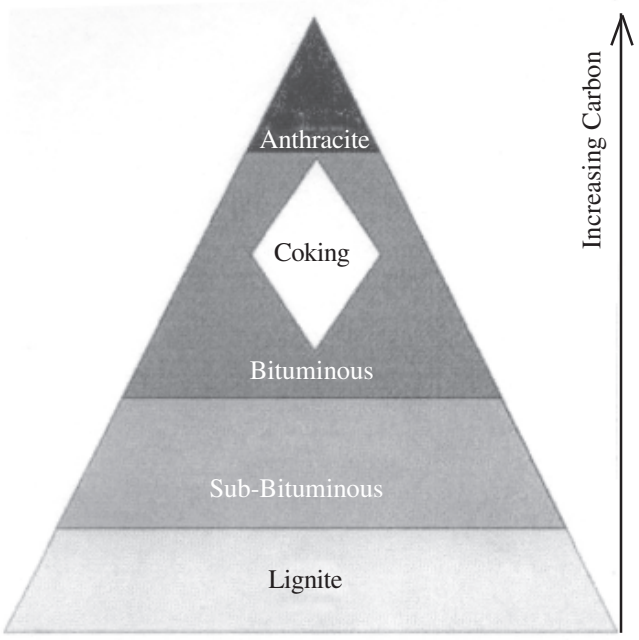

Fig. 28.2: *The grades or quality of the type of coal depends on the pressure and heat*

An estimated nine metres of peat is needed to produce and form a 0.3 metre vein of coal and it would require 300 hundred years to accumulate that much of peat.

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28.2.1 Formation of coal

Coal is the result of plant material that grew in fresh water swamps approximately three hundred million years ago. (Fig. 28.1). As this plant material died and accumulated, peat also called peat bog was formed. Since the plant material accumulated under water, in the swamps decay was inhibited due to lack of oxygen. Oceans inundated many of the areas of peat and sediments from the sea were deposited, over the peat. The weight of these sediments and the heat of the earth gradually changed the composition of the peat bog and coal was formed. Today peat also is used as source of fuel in some parts of the world though its high water content makes it a low-grade fuel.

Peat is changed into coal after many centuries of being compressed by the weight of sediments. It first changes into a low-grade coal known as **lignite** (brown coal).

The percentage of carbon in the lignite is higher than in peat. Continued pressure and heat from the earth changes **lignite** into **bituminous soft coal**. If the heat and pressure were great enough then **anthracite** coal (hard coal) would be formed which has the highest heat and carbon content. Accordingly energy content is greatest in anthracite coal and lowest in lignite. The sulphur content of coal is important because on burning low sulphur coal emits less sulphur dioxide (SO_2) so more desirable as a fuel for power plants.

The coal is used as a source of energy for domestic uses, locomotive engines, various types of furnaces in the industries, thermal power generation, extraction of metals and minerals, production of gas, tar etc. The type of coal determines its use. In India coal supplies nearly 63% of commercial energy as electrical energy generation by coal fired thermal power stations. In industry coal is used principally to purify iron, manufacture of steel.

28.2.2 Problems

Coal is most abundant fossil fuel on earth, but there are problems associated with its mining, transportation and use. Coal is mined from both (i) surface mines, and (ii) underground mines.

(a) **Surface mining**

Surface mining disrupts and drastically changes the natural landscape (Fig. 28.3.) and destroys the natural vegetation and the habitat of many species, some of which may already be endangered. Mining operations, involving digging, blasting, removal of rocks and soil lying over the coal seam, cause serious problems of air and noise pollution. Surface mining may also cause soil erosion and silt loading (the discharge of silts into streams) and nallas

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that disrupt and pollute the aquatic ecosystems as well as ground water in places where aquifers are located near or associated with coal seams.

Fig. 28.3: *Open pit coal mine- Coal mining defaces the land and disturbs the habitat of plants and animals*

(b) **Underground mining**

Underground mining may cause collapse or land subsidence in the mining areas during or after mining operations are over. In case of some mines acid mine drainage from the mine waste and OBD piles polluted long stretches of streams. Coal fires in underground mines may happen which naturally caused give out much smoke and hazardous fumes caused several respiratory disease to people living nearby.

Apart from these problems, burning of coal in thermal power plants for generation of electricity and in industry is the prime source of air pollution.

INTEXT QUESTIONS 28.1

1. Mention the method of coal formation.

   _____

2. State the major uses of coal.

   _____

28.3 PETROLEUM OR MINERAL OIL

Oil and gas were formed from the remains of plants and animals that once lived in the sea. For over millions of years these remains remained buried under mud and rock under great pressure and at high temperatures. Under these conditions marine biomass gradually changed into oil and gas (Fig.28.4) .Oil and gas are primarily found along geologically

young tectonic belt at plate boundaries, where large depositional basins are more likely to occur.

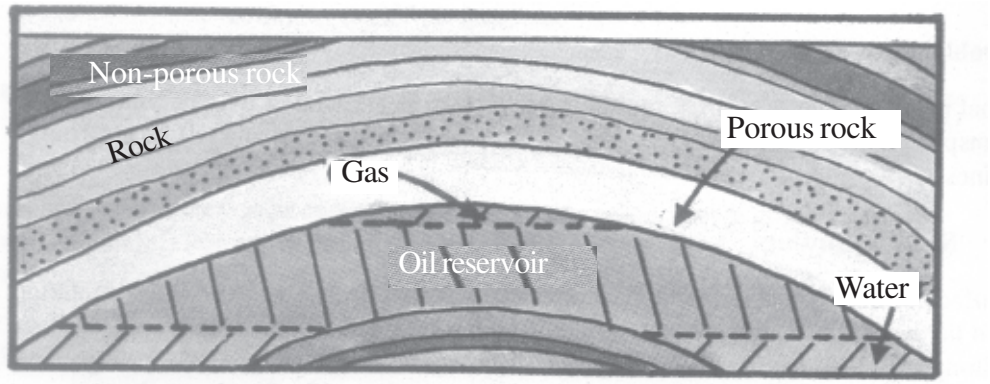

Fig. 28.4: *Some oil and gas makes its way to the earth's surface is escapes. Large amounts of oil and gas are trapped below ground in certain areas of rocks, forming oil reservior*

Petroleum or crude oil (oil as it comes out of the ground), is a thick dark liquid consisting of a mixture hundreds of combustible hydrocarbons along with small amounts of sulphur, oxygen and nitrogen impurities. It is also known as **conventional oil or light oil**. Deposits of crude oil and natural gas are usually trapped together under the sea floor or earth's crust on land. After it is extracted, crude oil is transported to a refinery by pipelines, trucks or ships (oil tanker). In refineries oil is heated and distilled to separate it into components with different boiling points. The important components are gases, gasoline, aviation fuel, kerosene, diesel oil, naphtha, grease and wax and asphalt. Some of the products of oil distillation are called **petro-chemicals** which are used as raw material for the manufacture of pesticides, plastics, synthetic fibers, paints and medicines etc.

The consumption of petroleum products is rising worldwide. In India the demand has risen from 57 million tonnes in 1991-1992 to 107 million tonnes in year 2000. **'The India Hydrocarbon Vision 2025'**, gives the projected need for petroleum products for India to be 368 million tonnes by 2025.

28.4 NATURAL GAS

Natural gas, primarily consist of methane, is often found above reservoirs of crude oil. The natural gas is a mixture of 50 to 90% by volume of methane (CH_4), the simplest hydrocarbon. It also contains small amounts of heavier gaseous hydrocarbons such as ethane (C_2H_6), propane (C_3H_8) and butane (C_4H_{10}) and also small amounts of highly toxic hydrogen sulphide (H_2S). Natural gas is formed through geological processes similar to the processes of crude oil formation described earlier except the organic material gets changed to more volatile hydrocarbons than those found in oil.

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Almost every oil well produces liquid petroleum along varying amounts of natural gas. However, there are large gas deposits without any liquid petroleum being associated with them.

28.4.1 Conventional natural gas

It lies above most reservoirs of crude oil. These deposits can be tapped/used only through pipeline. But the natural gas that comes out along with oil is often looked as unwanted by product and is burned off. Burning of associated natural gas represents a waste of a valuable energy resource and emissions carbon dioxide into the atmosphere from its burning. But after the gas is processed it is piped or compressed into cylinders for use by consumers. This gas is also used for the production of petrochemicals and fertilizers.

28.4.2 Unconventional natural gas

It is found by itself in other underground reservoirs. So far it is very expensive to get natural gas from such unconventional sources but technology is being developed to extract the gases economically.

When a natural gas field is tapped, propane and butane gases, present in natural gas are liquefied and removed as liquefied petroleum gas (LPG). LPG is stored in pressurized tanks or cylinders for use as cooking gas. At a very low temperature natural gas can be converted to liquefied natural gas (LNG). This highly inflammable liquid can be shipped to other countries in refrigerated tanker ships. The production and consumption demand of natural gas has been rising in India for both industrial and domestic uses. After the gas is processed it is piped or compressed into cylinders for use by the consumers

28.4.3 Problems associated with oil and gas

Leakage of natural gas from pipelines, storage tanks and distribution tanks is potential cause of explosion. Methane being major component of natural gas, happens to be a green house gas and its leakage contributes to global warming. But being a clean fuel has advantages over coal and oil and preferred as a better fuel option or energy resource.

Extraction of oil and gas may cause sinking of land or subsidence. For example, in Long Beach Harbor area, in Los Angeles, USA, intensive oil extraction beginning in 1928 caused severe land subsidence. Over the well sites, the ground dropped 9 metres. Extensive subsidence created a need for flood control measures along the coastline. Damage to buildings, roads and other structures were estimated at 100 million dollars. Another major problem in the past with onshore oil wells has been brine (salt water). Typically, for every barrel of oil production ten barrels of brine are also extracted. In early days the brine was simply discarded into nearby streams or on the soil. Today most brine is reinjected into the well. However, brine can contaminate fresh water aquifers if the casing lining the well is missing or corroded.

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Apart from these two problems, oil also contaminates the oceans. About half of the oil that contaminates the ocean comes from natural seepage from offshore deposits (annually approximately 600,000 metric tonnes of oil seeps into the ocean from natural sources). 20% of the oil contaminating the ocean comes from oil well, blowouts, pipeline breaks and tankers. The rest comes from oil disposed off inland and carried into the ocean by rivers. Leakage from offshore wells also occurs during the transfer of oil to shore and also during normal operations.

The harmful effects of oils contamination are felt both in fresh water and marine water environments. Oil kills aquatic plants and animals. After a major spill it may take two to ten years for the organisms to recover. Combustion of oil and gas also cause air pollution.

Even though the natural process of fossil fuel formation is continuing today, but the rate of production is very low. For all practical purposes the world's supply of fossil fuels is limited to what was formed 300 million years ago. When this supply is exhausted we will have no more supply. As a result of realization, people have started exploring and use alternative sources of energy.

28.4.4 Location of fossil fuel deposits in India

India has large reserves of coal and lignite is found in West Bengal, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh as well as in Assam and Tamil Nadu. Oil and natural gas are exploited both from inland and offshore sites. Some of the major oil reserves are located in West coast, Gujarat, Godavari and Krishna delta on the East coast, Assam and Rajasthan. Fossil fuel deposits are also found in India in limited amounts

28.4.5 Uses of natural gas

1. Natural gas is a relatively clean fuel burns readily to produce large amount of heat that is why natural gas is used as the main fuel for domestic and industrial heating purposes. It is used as a fuel in thermal power plants for generating electricity and a feedstock for manufacture of fertilizers.
2. Compressed Natural Gas (CNG) is being increasingly used as a fuel in transport vehicles (buses, trucks and cars). CNG is a good alternative to petrol and diesel because it causes less pollution. These days in Delhi and some other cities are using since the use of CNG as an alternative fuel for automobiles has started, air pollution levels have decreased perceptibly.
3. Natural gas is used as a source of hydrogen gas needed in fertilizer industry. When natural gas is heated strongly, the methane present in it decomposes to form carbon and hydrogen. This hydrogen gas is combined with nitrogen gas to manufacture of ammonia (NH_3). Reaction of ammonia with acids, forms ammonium salts. These ammonium salts are used as fertilizers.
4. Natural gas is used as a source of carbon used in tyre industry. When natural gas is strongly heated, then methane gets in it decomposed to form carbon and hydrogen.

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The carbon thus formed is called carbon black and used as filler in the manufacture of tyres.

28.4.6 Advantages of natural gas

Natural gas is a clear and environmental friendly fuel and used directly for cooking purpose in homes. It can be supplied directly to the homes and factories through a network of underground pipelines thus eliminate the need for additional storage and transport. Natural gas burns with smokeless flame and on burning does not produce any poisonous gas or pollute the environment friendly gas.

INTEXT QUESTIONS 28.2

1. Which are the major fractions obtained from the distillation process of crude oil?

   _____

2. What is the composition of conventional natural gas? Mention any one of its advantages as fuel?

   _____

28.5 NUCLEAR ENERGY SOURCES

Nuclear energy is the energy of the atomic nucleus. Radioactive minerals are used to generate nuclear energy through high technological methods.

28.5.1 Radioactive minerals

Radioactive minerals used for generating energy are alternative to fossil fuels. Similar to other minerals, availability of ore of radioactive material is finite and limited. However, a very small quantity of radioactive minerals can generate large amounts of energy.

Antoine Henri Becquerel discovered radioactivity in 1896 and his name lives on in the units used to measure it – Becquerel's (Bq). One Becquerel = 1 radioactive decay which is a very small amount. It may surprise you to know that every substance is radioactive to some extent. For example,

One loaf of bread = 70 Bq

One kg of coffee = 1000 Bq

One adult human = 3000 Bq

Ten kilogram of granite = 1200 Bq

One kilogram of 50 year old high level radioactive waste = 10,000,000,000,000 Bq.

There are two methods (Fig. 28.5a and b)which can be used to release energy from radioactive minerals:

i) **Nuclear fission** – In this process, the nucleus of heavy atom namely of uranium (U_{235}) or plutonium (P_{239}) breaks apart into smaller fragments, releasing an enormous amount of energy.

ii) **Nuclear fusion** – In this process, small nucleus like those of isotopes of hydrogen, namely deuterium and tritium etc. fuse or join together to form heavier nuclei, releasing vast amounts of energy.

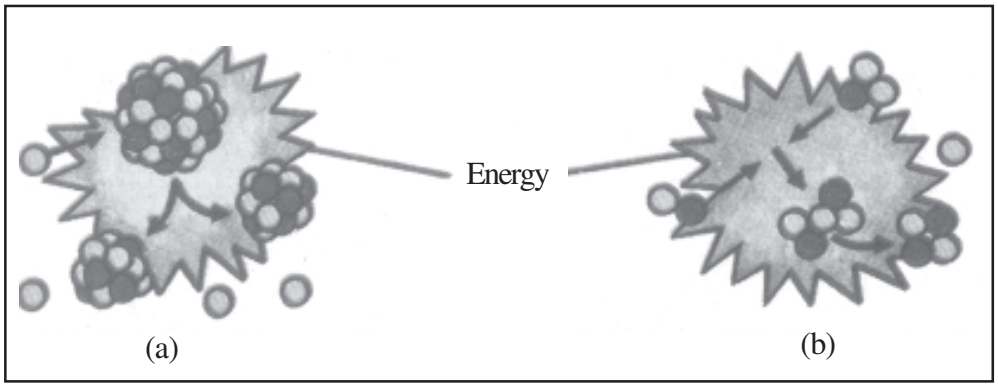

Fig. 28.5: *a) Fission: This happens inside a nuclear reactor at a nuclear power station, and when there is a fission, or atom ("A"), bomb explodes. (b) Fusion: This is happening all the time in the sun. It also happens when the most powerful nuclear weapon, a fusion, or hydrogen ("H"), bomb explodes*

28.5.2 Nuclear fission

Radioactive mineral, which generates nuclear energy through fission, may be considered a non-renewable alternative source of energy as it is an ore and is found in limited quantities. Nuclear fission occurs because the atom of radioactive minerals contains nuclei that are unstable and break or split apart releasing energy (Fig. 28.6). Whenever a neutron strikes a nucleus of U-235, energy is released, krypton and barium are produced, and several neutrons are released. These new neutrons may strike other atoms of U-235 to produce a chain reaction. When this nuclear disintegration takes place particles from the nucleus including neutrons fly out. The neutron may cause other atomic nuclei to split releasing more neutrons and more energy. Once begun this chain reaction continuous to release energy until the fuel is spent or the neutrons are prevented from striking other nuclei (Fig. 28.7).

In the reactor of a nuclear power plant, the rate of nuclear chain reaction is controlled and the heat generated is used to produce high pressure steam, which spins turbine that generate electricity. Heat produced here is carried away by water coolant and transferred by way

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of heat exchanger to the water in a steam-generating unit. The steam produced powers a turbine that produces electricity. Cooling water is used to condense the steam after it has gone through the turbine

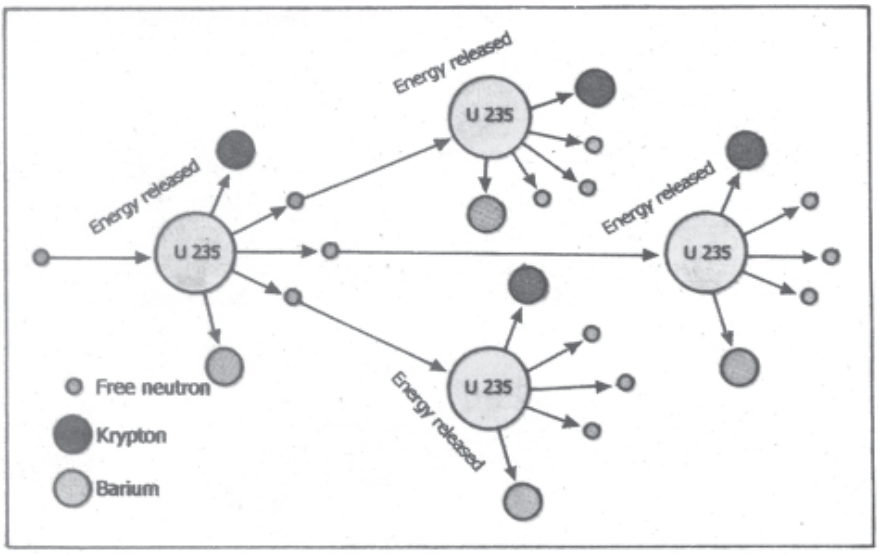

Fig. 28.7: *Nuclear fission showing chain reaction*

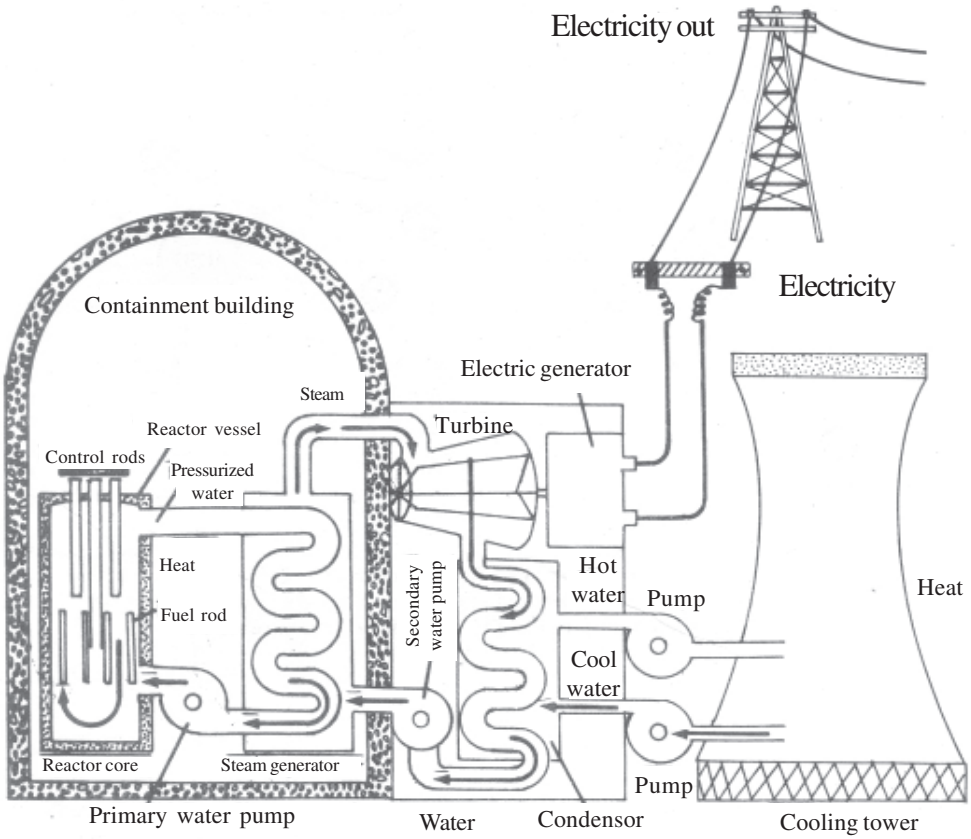

Fig. 28.8: *Conversion of nuclear energy into electrical energy*

Two other nuclear technologies for generating electricity from nuclear fuel in a safe and economic way have also been proposed, but so far they have not proved operationally successful. These are: (i) nuclear breeder reactor, (ii) fusion reactor.

(i) **Nuclear breeder reactor**

The nuclear reactors operating today use uranium very inefficiently. About 1% uranium is actually used to produce steam for generating electricity. A nuclear reactor that can utilize between 40% and 70% of its nuclear fuel is called a **breeder reactor**. Breeder reactors convert more abundant uranium -238 or thorium -232 fissionable isotopes, Plutonium-239 or Uranium -233 respectively, that can sustain a nuclear chain reaction.

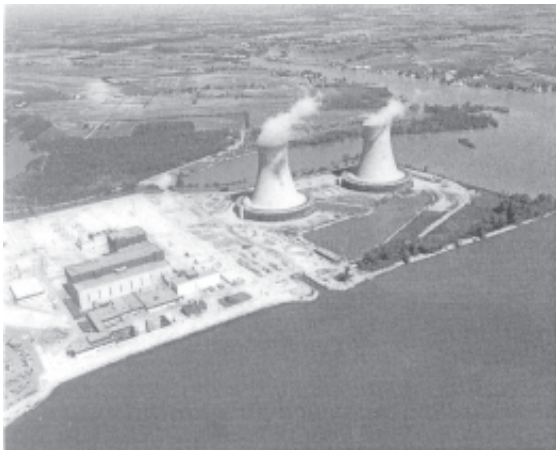

Fig. 28.9: *A breeder reactor*

(ii) **Nuclear fusion reactor**

The principle for nuclear fusion involves, as you are aware, uniting two small atoms to form a large atom with the release of an enormous amount of energy. The energy produced by stars and the sun is the result of nuclear fusion. Generation of energy by this method so far, however, has not been possible though lot of research has focused on the fusion reaction of deuterium (D) and tritium (T) (two isotopes of hydrogen) which fuse at about 100 million degrees.

The advantage of using nuclear material for energy generation instead of coal and oil, is that it produces very little pollution. It requires less strip-mining as nuclear fuel have highly concentrated form of energy. Moreover the cost of transportation of nuclear fuels is much lower than that for coal and oil required for generation of an equivalent amount of energy.

28.5.3 Problems related to nuclear energy generation

Radioactive elements if not disposed properly cause radioactive pollution. However, the major problems associated with the generation of nuclear power are disposal of nuclear

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waste, contamination of environment with long lasting radioactive materials (radioactive pollution) thermal pollution, health effects from exposure to low levels of radiation, limited supplies of uranium ore, high construction and maintenance costs, questionable reactor safety, human or technical error that could result in a major accidents and vulnerability to sabotage, developing nuclear weapons by processing reactor waste.

Problems of dismantling of a nuclear plant's, after their useful life of 30-40 years is over. There are some very important questions left unanswered related to nuclear energy generation. The Chernobyl disaster in USSR and Three Mile Island plant in USA accident have raised serious concern about the safety of nuclear power plants.

Location of radioactive mineral ore in India

In India, monazite that is the main source of thorium, is found in commercial quantities on the Travancore coast between Kanya Kumari and Quilon, while uranite or pitchblende mineral of uranium is found in Gaya (Bihar), Ajmer (Rajasthan) and Nellore (Andhra Pradesh). Utilisation of radioactive minerals is expanding and investigations are being carried out on such deposits to provide definite indications of magnitude, and potential for exploitation.

It is, important to realize that none of these resources can last for ever. It has become, necessary to rely on replenishable and regenerative resource base as well as on those types of technologies, which improve energy use efficiency.

Mostly of the conventional energy sources which are replenishable are called **inexhaustible or renewable** energy sources that include firewood, cattle dung, farm or agricultural wastes etc. Since these energy sources are generally of plant and animal origin, they can be grown and produced. But if they are used recklessly and irresponsible manner, they may get exhausted and may become non renewable.

INTEXT QUESTIONS 28.3

1. What is meant by radioactive pollution?

_____

2. Distinguish between nuclear fission and nuclear fusion reactions.

_____

3. What advantage does nuclear material has as energy source over coal and oil?

_____

WHAT YOU HAVE LEARNT

- The exhaustible non-renewable or finite resources of the earth include fuel mineral resources such as coal, oil and natural gas are collectively called fossil fuels. These non renewable resources are formed over time from the remains of organisms.
- Coal is a solid fossil fuel found under the ground. It is actually fossilized plants turned into sedimentary rocks. The basic grades of coal are lignite, bituminous and anthracite. They are mined and transported to different places.
- Nuclear power is a fuel mineral resource and so is exhaustible resource however only a small quality can generate large amount of electricity.
- It offers many advantages over coal and oil power such as little air pollution, less mining, less disturbance of land.
- But the major problems with nuclear power are disposal of radioactive wastes, contamination of the environment, thermal pollution, health impact from radiation, limited supply of ores, security of nuclear reactors and theft of nuclear materials.
- Another important fossil fuel is natural gas; it burns very easily and produces a lot of heat. Natural gas is found under the earth. Main constituent of natural gas is methane (CH_4), which constitutes up to 95% and remaining is ethane and propane. It can be used directly in homes for cooking purposes.

TERMINAL EXERCISE

1. What actions can you take at a personal level to reduce consumption of fossil fuels?
2. How were fossils fuels formed?
3. Discuss advantages and disadvantages of nuclear energy.
4. Speculate which one of the fossil fuel will run out first.
5. Discuss the importance of energy consumption to the society. What major concerns does it basis?
6. Describe the pros and cons of the following types of fossil fuel.
   i) Coal
   ii) Oil
   iii) Natural gas

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7. Describe the environmental degradation caused by the use of fossil fuel in 20th century.
8. Explain fusion and fission and differentiate them.
9. Give your view on "Nuclear power and energy source".

ANSWER TO INTEXT QUESTIONS

28.1

1. Plant material of swamps died and accumulated under water many centuries ago called peat. Sediments of sand and soil were deposited over the peat. The weight of sediments and heat from the earth change peat into soft coal (bituminous coal) to hard coal (anthracite).
2. Coal is used as a fuel for domestic use. It is used in locomotive engines and various types of furnaces in the industries. It is used as a fuel in thermal power plants for generation of electricity.

28.2

1. The products or fractions obtained from crude oil distillation are gases, gasoline (petrol), aviation fuel, kerosene, diesel oil, naptha, grease and asphalt.
2. Natural gas is a mixture of methane, with small amounts of heavier hydrocarbon such as ethane and butane.

   Advantages of natural gas are : a) It is used directly for cooking purposes at home, (b) It burns with smokeless and does not produce any poisonous gases on burning.

28.3

1. The advantage of nuclear material for energy generation is that produces very little pollution, it requires less mining as nuclear fuel is a concentrated form of energy and cost of transportation of nuclear fuel is lower than that for an equivalent amount of coal.
2. Nuclear fission occurs because atoms of radioactive mineral contains nuclei that are unstable and break or split apart releasing energy. Nuclear fusion involves uniting two small atoms to form a large atom with the release of enormous amount of energy.
3. Radioactive elements if not disposed properly cause disintegration in soil and water causing radioactive pollution which has long lasting effects in human health and the environment.