1.1. General

Energy is the primary and most universal measure of all kinds of work by human beings and nature. Every thing what happens in the world is the expression of flow of energy in one of its forms. Most people use the word energy for input to their bodies or to the machines and thus think about crude fuels and electric power.

The energy sources available can be divided into three types:

1. **Primary Energy Sources.** Primary energy sources can be defined as sources which provide a net supply of energy. Coal, oil, uranium etc. are examples of this type. The energy required to obtain these fuels is much less than what they can produce by combustion or nuclear reaction. Their energy yield ratio is very high. The yield ratio is defined as the energy fed back by the material to the energy received from the environment. The primary fuels only can accelerate growth but their supply is limited. It becomes very essential to use these fuels sparingly. Primary fuels contributes considerably to the energy supply.

2. **Secondary fuels** produce no net energy. Though it may be necessary for the economy, these may not yield net energy. Intensive agricultural is an example wherein terms of energy the yield is less than the input.

3. **Supplementary sources** are defined as those whose net energy yield is zero and those requiring highest investment in terms of energy Insulation (thermal) is an example for this source.

Coal, natural gas, oil and nuclear energy using breeder reactor are net energy yielders and are **primary sources of energy. Secondary sources** are like solar energy, wind energy, water energy etc. Solar energy can be used through plants, solar cells and solar heaters. Solar tower is another emerging technology. Solar drying and solar heating are economical applications when passive methods are used. Because of the dilute nature of solar energy it is difficult to classify the source as a primary one. Better sources are wind, tide, wave and hydroelectric applications. Geothermal and ocean thermal are the other sources which may well prove worthwhile. It may be necessary in future to develop the secondary sources like solar, wind etc.

1.2. Energy Consumption as a Measure of Prosperity

Energy is an important input in all sectors of any country’s economy. The standard of living of a given country can be directly related to per capita energy consumption. Energy crisis is due to the two reasons; firstly that the population of the world has increased rapidly and secondly the standard of living of human beings has increased. If we take the annual per capita income of various countries
and plot them against per head energy consumption, it will appear that the per capita energy consumption is a measure of the per capita income or the per capita energy consumption is a measure of the prosperity of the nation. The per capita income of U.S.A. is about 50 times more than per capita income of India, and so also is the per capita energy consumption. The per capita energy consumption in U.S.A. is 8000 kWh per year, whereas the per capita energy consumption in India is 150 kWh. U.S.A. with 7% of world’s population consumes 32% of the total energy consumed in the world, whereas India, a developing country with 20% of the world’s population consumes only 1% of the total energy consumed in the world. Therefore one might conclude that to be materially prosperous, a human being needs to consume more and more energy than his own.

Developing countries, at present export primary products such as food, coffee, tea, jute and ores etc. This does not give them the full value of their resources. To get better value, the primary products should be processed to products for export. This needs energy. Assuming the present consumption of energy is estimated to be of 10 million megawatts, for the year 2000 A.D. this figure would be about 4 times. This assumes that the present pattern of consumption, in which the relative energy consumption of countries remain the same, i.e., the per capita energy in developed countries remain much more than in the developing countries. If the standard of living in the developing countries is improved and approaches that of the developed countries, the energy requirement in the world in the year 2000 A.D. will be much more than estimated above.

1.3. World Energy Futures

If present trend continues, the world in the year 2000 A.D. will be more crowded than that of today. The world population may reach 7 billions by 2000 A.D. The conventional sources of energy are depleting and may be exhausted by the end of the century or beginning of the next century. Nuclear energy requires skilled technicians and poses the safety as regards to radioactive waste disposal. Solar energy and other non-conventional energy sources are the sources, those are to be utilized, in future.

Conclusions of the study on alternate energy strategies are:

1. The supply of oil will fail to meet increasing demand before the year 2000, even if energy prices rise 50 per cent above current levels in real terms. Additional constrains on oil production will hasten this shortage, thereby reducing the time available for action on alternatives.

2. Demand for energy will continue to grow even if Government adopt vigorous policies to conserve energy. This growth must increasingly be satisfied by energy resources other than oil, which will be progressively reserved for uses that oil can satisfy.

3. The continued growth of energy demand requires that energy resources be developed with the utmost vigour. The change from a world economy dominated by oil must start now. The alternatives require 5 to 15 years to develop, and the need for replacement fuels will increase rapidly as the last decade of the century is approached.

4. Electricity from nuclear power is capable of making an important contribution to the global energy supply although worldwide acceptance of it, on a sufficiently large scale yet to be established. Fusion power will not be significant before the year 2000.
5. Coal has the potential to contribute substantially to future energy supplies. Coal reserves are abundant, but taking advantage of them requires an active programme of development by both producers and consumers.

6. Natural gas reserves are large enough to meet projected demand provided the incentives are sufficient to encourage the development of extensive and costly intercontinental gas transportation systems.

7. Although the resource base of other fossil fuels such as oils sands, heavy oil and oil shale is very large, they are likely to supply only small amounts of energy before the year 2000.

8. Other than hydroelectric power, renewable resources of energy e.g., solar, wind, wave are unlikely to contribute significant quantities of additional energy during the century at the global level, although they could be of importance in particular areas. They are likely to become increasingly important in the 21st century.

9. Energy efficiency improvements, beyond the substantial energy conservation assumptions already built into our analysis, can further reduce energy demand and narrow the prospective gaps between energy demand and supply. Policies for achieving energy conservation should continue to be key elements of all future energy strategies.

It was concluded that world oil production if likely to level off very shortly and that alternative fuels will have to meet growing energy demand. Large investments and long lead times are required to produce these fuels on a scale large enough to fill the prospective shortage of oil, the fuel that now furnishes most of the world's energy. The task for the world will be to manage a transition from dependence on oil to greater reliance on other fossil fuels, nuclear energy and later, renewable energy systems.

1.4. Energy Sources and their Availability

1.4.1. Introduction. Today, every country draws its energy needs from a variety of sources. We can broadly categorize these sources as commercial and non-commercial. The commercial sources include the fossil fuels (coal, oil and natural gas), hydroelectric power and nuclear power, while the non-commercial sources include wood, animal waste and agricultural wastes. In an industrialized country like U.S.A., most of the energy requirements are met from commercial sources, while in an industrially less developed country like India, the use of commercial and non-commercial sources are about equal.

1.4.2. Commercial or Conventional Energy Sources

Major Sources of energy include:

(1) Fossil fuels i.e. solid fuels (mainly coal including anthracite, bituminous, and brown coals lignits and peals), liquid and gaseous fuels including petroleum and its derivatives and natural gas.

(2) Water power or energy stored in water.

(3) Energy of nuclear fission.

Minor sources of energy include sun, wind, tides in the sea, geothermal, ocean thermal electric conversion, fuel cells, thermionic, thermoelectric generators etc.
Wood was dominant source of energy in the pre-industrialization era. It
gave way to coal and coke. Use of coal reached a peak in the early part of the
twentieth century. Oil get introduced at that time and has taken a substantial
share from wood and coal. Wood is no more regarded as a conventional source.
Hydroelectricity has already grown to a stable level in most of the developed
countries. A brief account of the various important sources of energy and their
future possibilities is given below.

The percentage use of various sources for the total energy consumption in
the world is given in Table 1.1.

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>32.5%</td>
</tr>
<tr>
<td>Oil</td>
<td>38.3%</td>
</tr>
<tr>
<td>Gas</td>
<td>19.0%</td>
</tr>
<tr>
<td>Uranium</td>
<td>0.13%</td>
</tr>
<tr>
<td>Hydro</td>
<td>2.0%</td>
</tr>
<tr>
<td>Wood</td>
<td>6.6%</td>
</tr>
<tr>
<td>Dung</td>
<td>1.2%</td>
</tr>
<tr>
<td>Waste</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total</td>
<td>92%</td>
</tr>
</tbody>
</table>

Coal, oil, gas, uranium and hydro are commonly known as commercial or
conventional energy sources. Looking at the percentage distribution one finds that
world’s energy supply comes mainly from fossil fuels. The heavy dependence on
fossil fuels stands out clearly. One of the so most significant aspects of the current
energy consumption pattern in many developing countries is that non-commercial
sources such as firewood, animal dung and agricultural waste represent a significant
8% of the total energy used in the world. Then constitute about 4 times the energy
produced by the hydro and 60 times the energy produced by nuclear sources. In
some developing countries non-commercial energy sources are a significant fraction
of the total resources. This dependence of the developing countries is likely to
continue unless replaced by other alternative sources of energy.

(i) Coal. Since the advent of industrialization coal has been the most com-
mon source of energy. In the last three decades, the world switched over from coal
to oil as a major source of energy because it is simpler and cleaner to obtain useful
energy from oil.

Modern steam boilers burn coal in any of its forms as a primary fuel. Coal
developed vegetable matter which grew in past geological ages. Trees and plants
falling into water decayed and produced peat bogs. Gigantic geological upheavals
burried these bogs under layers of silt. Soil pressure, heat and movement of the
earth’s crust distilled off some of the bog’s gaseous matter to form brown coal, or
lignite. Continuing subterrane an activity reduces the coal’s gaseous content
progressively to form different ranks; peat lignite, bituminous and anthracite.

With the commissioning of an additional 500 MW unit at the Korba thermal
power station, on March 23, 1989, the power station has become the largest power
station of India. The plant is located on the west bank at the Hardeo river near
Korba in Bilaspur district of M.P. The project is the second in the series of super
thermal power stations being set up by the National Thermal Power Corporation
(NTPC).
The gigantic complex has been set up in two stages. In the first stage three units of 200 MW were set up. In the second stage three units of 500 MW have been set up. With the commissioning of the last 500 MW unit, the plant has achieved its ultimate capacity of 2,100 MW. The 500 MW generators have been provided by BHEL. The whole project has costed ₹ 1875 crore. World Bank has assisted to the tune of US $600 million.

Madhya Pradesh, Maharashtra, Gujarat and Goa are benefitted from the project.

According to estimates coal is abundant. It is enough to last for 200 years. However, it is low in calorific value and its shipping is expensive. Coal is pollutant and when burnt it produces CO₂ and CO. Extensive use of coal as a source of energy is likely to disturb the ecological balance of CO₂ since vegetations in the world would not be capable of absorbing such large proportions of carbon dioxide produced by burning large quantities of coal.

(ii) Oil. Almost 40% of the energy needs of the world are fed by oil. The rising prices of oil has brought a considerable strain to the economy of the world more, so in the case of the developing countries that do not possess oil reserves enough for their own consumption. With today's consumption and a resource amount of 250,000 million tonnes of oil, it would suffice for about 100 years unless more oil is discovered. The question is whether an alternative to oil would then be available, the world must start thinking of a change from a world economy dominated by oil.

Refining petroleum or crude oil produces our fuel oils. India is not particularly rich in petroleum reserves. The potential oil bearing areas are located in Assam, Tripura, Manipur, West Bengal, Ganga valley, Punjab, Himachal Pradesh, Kutch, eastern and western coastal area (in Tamil Nadu, Andhra Pradesh and Kerala). Andaman and Nicobar Islands, Lakshadweep, and in the continental shelves adjoining these areas.

Diesel power plants in India are installed in isolated places and the total installed capacity is estimated as 0.35 million kW, i.e. less than 2% of the total installed capacity in the country. No addition to this is expected in near future.

(iii) Gas. Gas is incompletely utilized at present and huge quantities are burnt off in the oil production process because of the non-availability of ready market. The reason may be the high transportation cost of the gas. To transport gas is costlier than transporting oil. Large reserves are estimated to be located in inaccessible areas.

Gaseous fuels can be classified as:

(1) Gases of fixed composition such as acetylene, ethylene, methane etc.
(2) Composite industrial gases such as producer gas, coke oven gas, water gas, blast furnace gas etc.

(iv) Agriculture and organic wastes. At present small quantities of agricultural and organic wastes consisting of draw saw dust, bagasse, garbage, animal dung, paddy husk and cornstem accounting a major energy consumption. Most of the remaining material was burnt or left, unused causing considerable environmental problems.

1. The waste should be utilised near the source, in order to reduce the transportation cost.
2. Appropriate equipment for burning, or extracting energy from the materials should be developed to suit the local conditions and meet the requirements of the rural areas.

3. Other non energy uses of the material should also be considered.

Considering the availability and the location of material produced, these resources are regarded as an important energy supply for the rural areas in the near future.

(v) Water Power. Water power is developed by allowing water to fall under the force of gravity. It is used almost exclusively for electric power generation. In fact, the generation of water power on a large scale became possible around the beginning of the twentieth century only with the development of electrical power transmission. Prior to that, water power plants (Hydroelectric plants) were usually of small capacities usual less than 100 kW.

Potential energy of water is converted into mechanical energy by using prime moves known as hydraulic turbines. Water power is quite cheap where water is available in abundance. Although capital cost of hydroelectric power plants is higher as compared to other types of power plants but their operating costs are quite low, as no fuel is required in this case.

Dehar power house of Beas Sutlej link located on the right bank of Sutlej river is equipped with 6 units of 165 MW each, which is the largest size in country.

Hydroelectric power is one of the indirect ways in which solar energy is being used. Thus, the main factor in its favour is that it is the only renewable non-depleting source of the present commercial sources.

In addition it does not create any pollution problem. The development rate of hydropower is still low, due to the following problems.

1. In developing a project, it will take about 6-10 years time for planning, investigation and construction.

2. High capital investment is needed, and some parts of the investment have to be derived from foreign sources.

3. There are growing problems on relocation of villages involved, compensation for damage, selecting the suitable resettlement area and environmental impact.

Because of long transmission line to the villages with low load factor, the electric power will be available to the people in rural areas may not be economical and the setting up of isolated diesel generation plants will also experience high losses with the existing electric tariff rates. This leads to the development of mini or micro hydroelectric projects to supply the electric power to remote areas. These projects may operate as isolated systems or connected to the main grid where it is feasible. The importance or microhydroelectric projects have been observed in some parts of the country with availability of river flow throughout the year with a possibility of medium to higher head development. In order to reduce the cost of development to the acceptable figure, several measures have been considered as follows:

(a) Development of low cost turbines and generators.

(b) Participation of villages in the development and operation of the project.

(c) Using the appropriate technology and tolerable substandard requirement and project civil work component at the beginning stage.
(vi) Nuclear Power. According to modern theories of atomic structure, matter consists at minute particles known as atoms. These atoms represent enormous concentration of binding energy. Controlled fission of heavier unstable atoms such as $^{235}\text{U}$, $^{232}\text{Th}$ and artificial element $^{239}\text{Pu}$, liberate large amount of heat energy. This enormous release of energy from a relatively small mass of nuclear fuels makes this source of energy of great importance. The energy released by the complete fission of one kg of $^{235}\text{U}$, is equal to the heat energy obtained by burning 4500 tonnes of high grade coal or 2200 tonnes of oil. The heat produced by nuclear fission of the atoms of fissionable material is utilized in special heat exchangers for the production of steam which is then used to drive turbogenerators as in the conventional power plants.

However there are some limitations in the use of nuclear energy namely high capital cost of nuclear power plants, limited availability of raw materials, difficulties associated with disposal of radioactive waste and shortage of well trained personnel to handle the nuclear power plants.

The uranium reserves in the world at present are small. These reserves are recoverable but are expensive. Further it is estimated that uranium reserves have only 3% of the energy contained in the oil reserves. A country like France produces about 30% of its total energy by nuclear methods, whereas a country like India has uranium sufficient enough only to produce $6 \times 10^6$ kW, a mere 1% of its current energy requirements.

Development of fast breeder reactor, which is not yet free from technical difficulties, will decide the future of nuclear power. Controlled fusion may also add brighter prospects to the use of nuclear energy. India has considerable resources of nuclear fuel which would help development of nuclear power in the country. The indicated and inferred reserves of uranium at two locations; Jaduguda and Narwapahar and Bhattin (Bihar) total about 33000 tonnes. There are other important deposits in Singhbhum (Bihar) and minor deposits in M.P., H.P., U.P., Rajasthan and are in the exploratory stage. Uranium may be in a position to sustain about 5000 to 10000 MW of nuclear power for its life time. In India, abundance of Thorium deposits are available from monazite sand in the west coast. Therefore, India’s interests lie in Thorium Breeder Reactors.

Nuclear power is having considerable potential. In countries like France and Belgium, it is contributing to the extent of 70 percent and 58 percent to the overall power generated. In India it is still low and by the year 2000, a target of 10,000 MW for nuclear power is set. Three systems are considered for nuclear power generation. The first is based an natural uranium yielding power and plutonium. The second employs fast breeder reactor using plutonium and depleted uranium. The third is by fast breeder reactor using thorium and converting it to uranium. The first method alone has been commercialised in India and the other methods may take some more time for large scale use. Indian ore is poor in uranium content (0.025-0.067 percent) and a 235 MW plant requires about 23 tonnes of uranium besides initial charge of 60 tonnes. Indian’s reserves of uranium ore are estimated at about 50000 tonnes as oxide and of thorium 450,000 tonnes as thorium. Consequently the third method appears to have great potential in view of the large deposits of thorium as monozite sands. A number of scientific and technological hurdles have to be crossed till the stage of thorium based fast breeder reactor is reached. Design and indigenous fabrication capabilities have also to be achieved.
There are following nuclear power plants in India at the moment. The 400 MW (2 × 200) Tarapore (Maharashtra) nuclear power station was commissioned in 1969, which uses enriched uranium as a fuel and boiling water reactors are employed. The plant at Rana Pratap Sagar Kota (Raj.) which also has capacity of 400 MW (2 × 200), uses natural uranium as fuel and pressurized heavy water reactors (CANDU). The station at Kalpakkam (Tamil Nadu) has the capacity at 440 MW (2 × 220), station at Narora has the capacity of 470 MW (2 × 235 MW), while the station at Kakrapar (Gujarat) has the Capacity of 940 MW (4 × 235 MW), the reactors at these, are similar to those at Rana Pratap Sagar.

(vii) Thermal (burner) and Breeder Reactors. As stated above, nuclear fission involves splitting the nucleus of heavy atoms, like uranium or plutonium, in a controlled nuclear chain reaction. During fission, heat is released and this can be used to generate high pressure steam to drive turbo-generators and produce electricity. The current generation of ‘thermal’ or ‘burner’ nuclear reactors is only able to utilize a tiny fraction of the uranium fuel. The nuclear chain reaction is sustained by uranium-235 which constitutes little more than 0.7% of natural uranium. Thermal reactors also make limited use of the more abundant uranium-238 isotope. During the fission process a small proportion of that present in the fuel is converted (by neutron capture) into fissionable plutonium-239, and some of this fissions to produce heat.

Fast breeder reactors are of different design to thermal reactors. They burn enriched uranium (composed of say 20-30% uranium-235) or plutonium which has been separated from spent thermal reactor fuel. In theory they can actually produce more fissionable material than they burn by ‘breeding’ fuel in a special zone around the core. As the nuclear chain reaction progresses, neutron bombard the blanket region, which is composed of Fertile uranium-238 and convert some of this uranium into fissionable plutonium. This uranium can subsequently be extracted by reprocessing, and fabricated into new fuel assemblies.

In practice, breeder technology is not yet commercially developed. Existing prototypes are only able to achieve slow breeding rates, and would take in excess of 25 years to produce sufficient material to fuel a second, identical reactor. Another fertile, thorium-232, could also be used to provide fuel. It can be transformed by neutron capture into fissionable uranium-233. However, there has been little work on this alternative fuel cycle, and it is not known whether it would be practicable.

There are major risks associated with the generation and storage of large quantities of highly noxious radioactive waste created by nuclear fission. The waste must be kept isolated from the biosphere virtually indefinitely regardless of mechanical failure, careless or malicious action, or natural disaster. Despite over a quarter of a century of research there is still no satisfactory solution to the problem of disposal.

The separation and use of plutonium presents a different set of hazards: plutonium is both highly toxic and the raw material for atomic bombs. A large thermal nuclear reactor produces several hundred kilograms of plutonium a year during normal operation. A commercial breeder would require about three thousand kilograms for its initial fuel inventory-sufficient plutonium for several hundred, nuclear weapons. Dependence on plutonium entails grave physical and security risks, and the prospects of theft by terrorist groups or foreign states intent on
acquiring nuclear weapons. Plutonium is already in demand by the weapons states, who wish to increase their nuclear arsenals and by other countries eager to join the growing nuclear club.

**(iii)** The Nuclear option. One response to the problem of increasing fossil fuel dependency has been to advocate a rapid expansion of nuclear power. However, even if thousands of large nuclear reactors could be built over the coming decades, nuclear power would still only make a small contribution to meeting world energy demand. After more than a quarter of a century of development, nuclear power provides only a few percent of the world’s electricity which itself only accounts for a small proportion of the total energy demand. Furthermore, the nuclear path is fraught with dangers. The intractable nature of many of the environmental as well as the social, political and technical problems, and the continued escalation in the costs, have led to widespread disenchantment with nuclear technology.

It is sometimes suggested that nuclear fusion has better prospects, but this may be as much wishful thinking as the early dreams of atomic electricity too cheap to be worth metering. Nuclear fusion is fundamentally different from nuclear fission; it involves fusing together of light atoms rather than the breaking apart of heavy ones. To ignite and sustain a fusion reaction between say, deuterium and tritium (two forms of hydrogen), it would be necessary to heat the fuel to a temperature in excess of 100 million degree centigrade-hotter than the sun—and to confine the resulting plasma for sufficient time to be able to extract useful amount of energy. Even if this daunting problem can be solved, the cost of the machinery that will be required is likely to make fusion wholly uneconomic.

**1.4.3. New Energy Technologies.** Numerous studies are going on around the world in this direction and it would be unwieldy to summarize all of them here. Only a few selected items will be reviewed briefly.

**Coal.** The first major break through is the application of fluidized bed technology for the coal gasification, carbonization and combustion. Vast improvement in performance and efficiency are achieved. The technology is already commercialized. Presently pressurized fluidised bed technology is being developed to further improve the performance. The fluidised bed technique has helped to utilise the low rank as well as high ash coals.

**1.5. Principle of Fluidization and Fluidised Bed Combustion**

When a bed of fine solid particles is subjected to an evenly distributed upward flow of gas, the bed remains static. At higher gas velocities the drag forces on the particles cause them to become suspended in the gas stream or fluidized and such a suspension resembles a boiling liquid and it is called a minimally fluidised bed. When the gas velocity is further increased the bed becomes highly turbulent and rapid mixing of the particles takes place and at this stage the bed of solid attains a pseudo-fluid state (Fig. 1.1). When the solid particles in the fluidised bed are preheated to the ignition temperature of the fuel it will burn imparting heat to the bed material through the volume of the bed. In order to maintain the bed temperature well below the ash fusion temperature, a large amount of heat is extracted by heat transfer coils immersed in the bed.
Thus fluid bed combustion (FBC) is an attractive process for power generation. It is a clean coal technology which can utilise high ash coal, washery rejects, biomass and agricultural residues. The advantages of fluid bed operation like different heat transfer and uniform bed temperature are advantageous for power generation. Fluidised bed combustors operating at atmospheric pressure have been in use for the past few years. Repowering and retrofitting existing power plants are being done in USA. The existing steam turbine and auxiliaries are retained and the existing boiler is replaced by a FBC boiler. A 160 MW has been set up by TVA, Panducah which, it is stated, is the largest unit set up so far. These plants will be on conventional steam turbines with heat exchangers installed in the bed or outside. In India also such plants are used for steam generation. FBC power plants are being set up by coal India Limited and Tata Iron and Steel Co. A few companies like BHEL, IS GEC-Thompson, Thermax are offering FBC for burning different fuels including biomass.
If the FBC is operated under pressure, pressurised fluid bed combustion (PFBC) results and combined cycle system can be evolved. The flue gases are expanded to generate power in a gas turbine. Steam is generated using the hot exhaust gases from turbine. A flow sheet of such a plant is shown in Fig. (1.2). By using an adsorbent like calcium oxide along with coal the sulphur in the coal is fixed in the bed and there is no emission of SO₂. Due to moderate bed temperature of 900°C, NOₓ formation is also minimised. The only problem may be the particulate emission but even this can be avoided by using cyclone and special filters. PFBC are more compact than FBC. However development of PFBC units is yet to be perfected. PFBC plants being more compact than a FBC result in reduced capital costs and cost of production of electricity.

FBC plants use a bubbling bed. A development in the current decade has been the circulating fluid bed combustors (CFBC) which on account of high velocity and circulation of solids results in better performance. A number of CFBC plants are being set up for steam and power generation. Two stage CFBC plant in which coal is gasified partially in the first bed and the resulting char is subsequent burnt in the second bed is being developed. The gas from the first stage can be burnt in a gas turbine, resulting in combined cycle power plant. FBC plants cause minimum pollution and even here cleaning the gases not without cooling them is being attempted. This hot gas clean up will improve the efficiency.

A novel process of coal gasification is the electrogasification. In this process the conventional water electrolysis carried out in presence of crushed coal particles, instead of getting H₂ and O₂ in the two electrode chambers H₂ and O₂ and a small amount of CO were obtained at a lower voltage. It has been observed that coal of any rank including lignite can be gasified at room temperature, and there is possibility of obtaining hydrocarbon in place of CO₂/CO with suitable changes in the experimental conditions. The power input to output bears a favourable ratio.

1.5.1. Advantages of Fluidised Bed Combustion Boilers

1. Ability to burn fuels containing very high inerts, washery rejects containing 73% ash and 1% moisture have been successfully burnt in the prototype FBC boiler at BHEL Tiruchy.

2. Fuel flexibility burning fuels ranging from fuel having HHV (higher heating value) of 10,500 kcal/kg down to rejects having heating value of 1,900 kcal/kg in the same combustor, (demonstrated by BHEL Tiruchy).

3. Higher combustion efficiency of 90 to 92% and boiler efficiency of 80% based on higher heating value was achieved. Even with washery rejects a higher boiler efficiency of 75% was achieved.

4. As the bed is maintained between 850°C and 950°C ash does not get heated to the initial deformation temperature. Hence no clinkering or slagging or hard deposits on heat exchanger tubes.

5. Ash is less erosive hence life of boiler second pass and ID (induced draught) system is increased.

6. Because of low temperature combustion, corrosion caused by alkali compounds in ash significantly reduced.

7. Require much less boiler plan area than a stoker.

8. Uniform temperature throughout the furnace volume.

9. Reduced emission of harmful nitrous oxide.
10. Sulphur dioxide emission can be reduced to acceptable level with less expense.

11. Operation is as simple as that of an oil fired boiler.

**Oil.** On the atomisation and combustion of petroleum fractions extensive work have been reported to improve the energy efficiency. High temperature combustion and flame propagation is now better known from the mechanical point of view. Electric ignition systems have been devised for proper ignition/combustion. Improved efficiencies in the range of 5-15%, (additional) are reported. Oil burner design have been improved in terms of primary air, secondary air mixing and combustion. Another noteworthy development in this area is the finding that the liquid is better atomised at low/zero nozzle pressures if a high voltage of the order of 20 kV, dc is applied to the nozzle. It was observed that this technique generates very fine droplets of high surface area and the power consumption was much smaller than that of the conventional mechanical pressure atomisation. Attempts are underway to use this principle for mass transfer operations where high interfacial area is needed for improved rates with reduced energy requirements.

**Gas.** The earlier concept of simply burning away the natural gas at the oil well head itself has now changed. It has become economical to run long distance pipe lines for the gas to be transported several hundred kilometers to the place where it can be used. This is very significant improvement. Incidentally the natural gas can be more profitable employed as a raw material to produce several important chemicals which have been traditionally obtained from petroleum fractions.

Biogas from rural, urban and industrial waste is another urea presently under development. It is now known clearly that any organic waste can be employed for the production of biogas.

### 1.6. Non-conventional Sources

While fossil fuels will be the main fuels for thermal power, there is a fear that they will get exhausted eventually in the next century. Therefore other systems based on non-conventional and renewable sources are being tried by many countries. These are solar, wind, sea, geothermal and biomass. (There have been many attempts to find a suitable generic term to describe the whole range of technologies designed to tap the earth’s natural energy flows. These technologies have variously been called ‘alternative’, ‘appropriate’, ‘natural’, ‘new’. However the term ‘renewable’ has gained the most widespread acceptance).

Solar energy can be a major source of power. Its potential is 178 billion MW which is about 20,000 times the world’s demand. But so far it could not be developed on a large scale. Sun’s energy can be utilised as thermal and photovoltaics. The former is currently being used for steam and hot water production.

Wind energy uses the high wind velocity available in certain parts. California State in USA is generating 500 MW from 900 wind turbines based on wind mills. Wind energy is used for pumping the water or power generation. About 0.7 million wind pumps are in operation in different countries. A minimum wind speed of 3 m/s is needed. This is considered to have a high efficiency. Coastal, hilly and valley areas are suitable for this process. Potential in India is estimated between 20,000 and 25,000 MW. Coastal areas of Gujarat, Maharashtra and Tamil Nadu are considered as favourable. A number of experimental stations have been set up. The maximum power generated from any single unit is about 1 MW.

Geothermal energy derives the heat in the centre of the earth and it is stated that potential to the extent of 3400 MW exists in New Zealand, USA, Japan
and Iceland. 700 MW of power is generated in Philippines and China. India does not appear to have any major exploitable source. Geothermal energy can also be used for cooling by using heat for vapour absorption system.

Energy from seas can be utilised as wave, tidal or ocean thermal energy. U.K. and Japan are pioneers in this area. About 13 kW per meter height of the wave can be generated. A plant to make 445000 kWh/yr of energy is being set up in Kerala State. This station will generate 75 kW in calm months and 120-150 kW in June-September. Ocean thermal energy conversion utilises the temperature difference between warm surface sea water at about 28°C and the cold deep sea water at 5-7°C at a depth of 800-1000 m in tropical areas. India's potential is large along the coastal length from Mumbai to Vishakapatnam. Tidal energy is energy that can be trapped from sea. France and USSR are developing this source at a level of 240 and 400 MW respectively. In India, the Gulf of Kutch, Gulf of Cambay and Sunderbans are potential sites. The total potential from sea is estimated as 50,000 MW from ocean thermal energy conversion, 40,000 MW from wave energy and 8000 MW from tidal.

Biomass is another renewable source of energy in the form of wood, agricultural residues, etc. The potential for agricultural residues alone is estimated as 480 mt with residues from food grains contributing about 100 mt. These can be burnt directly to generate steam for use in steam turbine for power generation or they can be gasified and the gas used in an internal combustion engine for agricultural pumping or power generation. Power generation is being tried on a small scale upto 1 MW or so, but large scale application is yet to be shown. The main problem with agricultural residues is their collection. In the case of forest wood, the requirement of fuel wood alone is between 250 and 300 mt and this quantity is not readily available. Efforts are being made for cultivating quick growing trees for use in power generation. Similarly biogas obtained by anaerobic digestion of animal dung and sewage is also suitable for use in Internal Combustion Engines. Biomass may prove a useful fuel for localised power generation in rural areas where electric transmission lines have not reached.

1.6.1. Solar Energy. Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy specially when other sources in the country have depleted.

Energy comes to the earth from the sun. This energy keeps the temperature of the earth above that in colder space, causes current, in the atmosphere and in ocean, causes the water cycle and generate photosynthesis in plants.

The solar power where sun hits atmosphere is \(10^{17}\) watts, whereas the solar power on earth's surface is \(10^{16}\) watts. The total world-wide power demand of all needs of civilization is \(10^{13}\) watts. Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is approximately \(1\ kW/m^2\), attempts have been made to make use of this energy in raising steam which may be used in driving the prime movers for the purpose of generation of electrical energy. However on account of large space required, uncertainty of availability of energy at constant rate, due to clouds, winds, haze etc., there is limited application of this source in the generation of electric power. Now-a-days the drawbacks as pointed out that energy cannot be stored and it is a dilute form of energy, are out dated arguments, since the energy can be stored by producing hydrogen, or by storing in other mechanical or electrical devices, or it
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can be stored in containers of chemicals called eutectic or phase changing salts. These salts which store large quantities of heat in a relatively small volume, melt when they are heated and release heat later as they cool and crystallize. The energy can be concentrated in solar furnaces, for example which can achieve temperatures in the region of 5000°C. The facts speak in favour of solar energy, as we have seen in analysis of commercial energy sources, that world's reserves of coal, oil and gas will be exhausted within a few decades. Nuclear energy involve considerable hazards and nuclear fusion has not yet overcome all the problems of even fundamental research, compared with these technologies, the feasibility of which is still uncertain and contested, the technical utilization of solar energy can prove very useful. Utilization of solar energy is of great importance to India since it lies in a temperature climate of the region of the world where sun light is abundant for a major part of the year.

The basic research in solar energy is being carried in universities and educational and research institutions, public sector institution, Bharat Heavy Electricals Limited and Central Electronic Limited are carrying out a co-ordinated programme of research in solar energy.

The applications of solar energy which are enjoying most success today are:

1. Heating and cooling of residential building.
2. Solar water heating.
4. Solar distillation on a small community scale.
5. Salt production by evaporation of seawater or inland brines.
7. Solar engines for water pumping.
8. Food refrigeration.
9. Bio conversion and wind energy, which are indirect source of solar energy.
10. Solar furnaces.
11. Solar electric power generation by—
   (i) Solar ponds.
   (ii) Steam generators heated by rotating reflectors (heliostat mirrors), or by tower concept.
   (iii) Reflectors with lenses and pipes for fluid circulation (cylindrical parabolic reflectors).
12. Solar photovoltaic cells, which can be used for conversion of solar energy directly into electricity or for water pumping in rural agricultural purposes.

The heat from solar collectors is directly used for warming the living spaces of a building in conventional ways e.g., through radiators and hot air registers. When the building does not require heat, the warmed air or liquid from the collector can be moved to a heat storage container. In the case of air, the storage is often a pile of rocks or some other heat-holding material, in the case of liquid, it is usually a large, well insulated tank of water, which has considerable heat capacity. Heat is also stored in containers of chemicals called eutectic or phase changing salts. These salts, which store large quantities of heat in a relatively small volume, melt when they are heated and release heat later as they cool and crystallize. When the building needs heat, the air or water from its heating system passes through the
storage is warmed, and is then fed through the conventional heaters to warm the space. For sunless days or cloudy days, an auxiliary system as a back-up, is always required. The same is true for solar cooling systems.

The heat from solar energy can be used to cool buildings, using the absorption cooling principle operative in gas-fired refrigerators. Presently available equipment, however usually requires extremely high operating temperatures for above those for efficient solar collection. A great deal of current research is being devoted to developing systems requiring lower operating temperatures, but it will probably be several years before solar collectors will be commercially viable.

Solar energy units for heating domestic water are commercially available and are used by millions of people in various parts of the world, for example in Australia, Israel, Japan etc. A solar water heater commonly comprises a blackened flat plate metal collector with an associated metal tubing, facing the general direction of the sun. The collector is provided with a transparent glass cover and a layer of thermal insulation beneath the plate. The collector tubing is connected by a pipe to an insulated tank that stores hot water during non-sunny periods. The collector absorbs solar radiation and by transfer of resulting heat to the water circulating through the tubing by gravity or by a pump, hot water is supplied to the storage tank.

Solar water heating systems for domestic, industrial and commercial applications are at present available. In commercial establishments, there is great potential especially in hotels, hospitals, guest houses, tourist bungalows, canteen etc. For industrial applications solar water heating system can meet the low and medium temperature process heat requirements hot water upto 90°C, hot air upto 110°C and low pressure steam upto 140°C. These are specially useful in engineering, textile, chemicals, pharmaceutical, food processing, sugar, dairy and other industries. Hot water systems have relevance for many agricultural and village industries, such as for handloom fabrics, sericulture, leather tanning and hand made paper.

The basic method of solar distillation is to admit solar radiation through a transparent cover to a shallow, covered brine basin; water evaporates from the brine and the vapour condenses on the covers which are so arranged that the condensate flows there from into collection troughs and hence into a product-water storage tank. In arid, semi arid, or coastal areas, there is abundant sun light that can be used for converting brackish or saline water into potable distilled water.

A traditional and wide-spread use of solar energy is for drying particularly of agricultural products. This is a process of substantial economic significance in many areas. The process is of special interest in the case of soft fruits; these are particularly vulnerable to attack by insects, as the sugar concentration increases during drying. Fruit dryer in which fruit is placed, in carefully designed racks to provide controlled exposure to solar radiation often improves product quality and saves considerable time. A simple cabinet dryer consists of a box, insulated at the base, painted black on the inside and covered with an inclined transparent sheet of glass. Ventilation holes are provided at the base and at the top of the sides of the box to facilitate a flow of air over the drying material, which is placed on perforated trays in the interior of the cabinet base.

Large drying systems like grain, paddy, maize, cash crops like ginger, cashew, pepper, etc., spray drying of milk; timber and veneer drying; tobacco curing; fish and fruit drying, etc. have also been developed.
**Solar refrigeration** is intended for food preservation (or storage of biological and medical materials) and deserves top-priority in country like India. Solar air conditioning can be utilized for space cooling. Solar assisted heat pumps would provide both cooling and heating.

**Cold storages** are very important for preservation and conservation of food articles.

There are two methods of solar refrigeration.

(a) **Vapour absorption refrigeration** system that utilizes low grade thermal energy obtained from flat plate collectors with a little modification.

(b) Concentrating (focusing) collectors to supply heat at a higher temperature to a heat engine which then drives the compressor of a conventional refrigerator.

Solar refrigeration with an absorption system is a better way of direct utilization of energy. The vapour absorption system replacing the compressor by a generator absorber assembly can work with wide range of absorbents and refrigerants. In absorption system motive power required is very small, but still C.O.P. of the system is low.

**1.6.2. Electricity from Solar Energy.** Electricity can be produced from the solar energy by photo voltaic solar cells, which convert the solar energy directly to electricity. The most, significant applications of photo voltaic cell in India, are the energisation of pump sets for irrigation, drinking water supply and rural electrification covering street lights, community TV sets, medical refrigerators and other small power loads.

Electricity is directly generated by utilising solar energy by the photo voltaic process. When photons from the sun are absorbed in a semiconductor, they create free electrons with higher energies than the electrons which provide the bonding in the base crystal. Once these free electrons are created, there must be an electric field to induce these higher energy electrons to flow out of the semiconductor to do useful work. The electric field in most solar cells is provided by a junction of materials which have different electrical properties. The photovoltaic effect can be described easily for $p-n$ junction in semi-conductor materials of solar cells which are silicon, cadmium, sulphide/copper sulphide, Gallium Arsenite etc.

In a **solar thermal power production** system the energy is first collected by using a solar pond, a flat plate collector, focusing collector or heliostates (turnable mirrors). This energy is used to increase the internal energy or temperature of a fluid. This fluid may be directly used in any of the common or known cycles such as Rankine, or through a heat exchanger to heat a secondary fluid (working fluid) which is being used in the cycle to produce mechanical power from which electrical power can be produced easily.

Solar thermal power cycles can be broadly classified as low medium and high temperature cycles. Low temperature cycles generally use flat plate collectors or solar pond, maximum temperatures are limited to above 90 to 100°C. Medium temperature cycles work at maximum temperatures ranging from 150 to 300°C, using concentrating or focusing collectors. High temperature cycles work at maximum temperatures above 300°C.

In solar tower concentration system (Tower power concept), the incoming solar radiation is focussed to a central receiver or a boiler mounted on a tall tower using thousands of plane reflectors which are steerable about two axes and are called heliostates.
Results to-date show solar energy to be quite competitive with other sources of energy, if the solar tower plant size is about 100-200 MWe, with 3-6 hours thermal storage.

Over the last few years, few experiment power plants have been built, or under construction in U.S.A., France, Italy and Japan.

1.6.3. Wind Energy. Energy of wind can be economically used for the generation of electrical energy. Winds are caused from two main factors:

1. Heating and cooling of the atmosphere which generates convection currents. Heating is caused by the absorption of solar energy on the earth’s surface and in the atmosphere.

2. The rotation of the earth with respect to atmosphere, and its motion around the sun.

The potential of wind energy as a source of power is large. The energy available in the winds over the earth’s surface is estimated to be $1.6 \times 10^7$ MW, which is of the same order of magnitude as the present energy consumption on the earth.

Wind energy which is an indirect source of solar energy conversion can be utilized to run wind mill, which in turn drives a generator to produce electricity. Wind can also be used to provide mechanical power, such as for water pumping. In India generally wind speeds obtainable are in the lower ranges. Attempts are, therefore, on the development of low cost, low speed mills for irrigation of small and marginal farms for providing drinking water in rural areas. The developments are being mainly concentrated on water pumping wind mills suitable for operation in a wind speed range of 8 to 36 km per hour. In India, high wind speeds are obtainable in coastal areas of Saurashtra, Western Rajasthan and some parts of Central India. In these areas, there could be a possibility of using medium and large sized wind mills for generation of electricity and feeding the same into the grid.

Many types of wind mills have been designed and developed. However, only a few have been found to be practically suitable and useful. Some of these are:

1. Multiblade type wind mill.
2. Sail type wind mill.
3. Propeller type wind mill.
4. Savonins type wind mill.
5. Darrieus type wind mill.

The first three are the examples of horizontal axis wind mills, while the last two have a vertical axis.

Vertical axis machines are of simple design as compared to the horizontal axis.

Some characteristics of wind energy are stated below:

(i) It is a renewable source of energy.

(ii) Like all forms of solar energy, wind-power systems are non-polluting, so it has no adverse influence on the environment.

(iii) Wind energy systems avoid fuel provision and transport.

(iv) On a small scale, upto a few kilowatt system, is less costly. On a large scale, costs be competitive with conventional electricity and and lower costs could be achieved by mass production.
But with wind energy following problems are associated:

1. Wind energy available is dilute and fluctuating in nature. Because of the dilute form, conversion machines have to be necessarily large.

2. Unlike water energy, wind energy need storage means because of its irregularity.

3. Wind energy systems are noisy in operation; a large unit can be heard many kilometers away.

4. Large areas are needed to install wind farms for electrical power generation.

In India the interest in the wind mills was shown in the last fifties and early sixties. Apart from importing a few from outside, new designs were also developed but it was not sustained. It is only in the last 12–15 years that development work is going in many institutions. An important reason for this lack of interest in wind energy must be that wind velocities in India are relatively low and vary appreciably with the seasons.

Data quoted by some scientists that for India wind speed value lies between 5 km/hr to 20 km/hr. These low and seasonal winds imply a high cost of exploitation of wind energy. Calculations based on the performance of a typical wind mill have indicated that a unit of energy derived from a wind mill will be at least several times more expensive than energy derivable from electrical distribution lines at the standard rates, provided such electrical energy is at all available at the wind mill site. The above argument is not fully applicable in rural areas for several reasons. First electric power is not and will not be available in many such areas due to the high cost of generation and distribution to small dispersed users. Secondly there is possibility of reducing the cost of the wind mills to suitable design. Lastly, on small scales, the total first cost for serving the felt need and low maintenance costs are more important than the unit cost of energy. In our country, as stated earlier, high wind speeds are obtainable in coastal areas of Saurashtra, Western Rajasthan and some part of the Central India, where there could be possibility of using medium and large size wind mills of generation of electricity.

Many projects on the wind mill systems for water pumping and for production of small amount of electrical power have been taken up by the various organisers in our country. Following are some of the developments.

1. CAZRI wind mill at Jodhpur (Rajasthan).
2. WP-2 water pumping wind mill by NAL Bangaluru.
3. MP-1 sail wind mill at NAL Bangaluru.
4. Wind mills at Central Salt and Marine Chemicals Research Institute Bhavnagar (Gujarat).
5. 12 PU 500 wind mill at NAL Bangaluru.
6. Madurai wind mill at Madurai (Tamil Nadu).
7. Tayabji wind mill at Tilonia near Ajmer (Rajasthan).
8. Sholapur wind mill at Sholapur (MS).

12 PU 500 wind mill, designed by NAL Bangaluru, can pump at the rate of about 5 to 6 thousand litres of water per hour over a total head of 5 metres, when the wind speed is in the range of 12 to 14 km per hour. It can develop more power at higher wind speeds upto about 32 km/hr.

The MP-1 sail type wind mill, which is also simple in construction, has same out-put as that of 12 PU 500. The rotor of it, is made of canvas sails and is of
7.5 metres in diameter. These two type of wind mills indicate promise for large scale exploitation and commercialization. The Department of Non-convention Energy Sources (DNES) Government of India has an important land mark in the country’s programme towards the utilization of renewable energy, was the commissioning of four wind farms at Mandavi (Gujarat), 1.15 MW, Tuticorin (Tamil Nadu) 550 kW, Okha (Gujarat) 550 kW, Puri (Orissa) 550 kW and Deogarh (Maharashtra) with a capacity of 550 kW.

During the Seventh plan, nine wind-farm projects of aggregate capacity of 10.10 MW have so far been commissioned at Okha, Mandvi and Okha-Mandhi in Gujarat; Tuticorin and Kayattar in Tamil Nadu; Puri in Orissa; Deogad in Maharasta; Tala Cauvery in Karnataka; and Tirumala in Andhra Pradesh (DNES report).

Barring a few minor problems, the projects are successfully generating and supplying electric power to the respective state grids. Projects of aggregate capacity of 24.10 MW are under construction. During the seventh plan, about 2500 water pumping wind mills have been installed under the wind pump demonstration/field testing programme. Wind pumping technology has been upgraded to cover the deep-well wind pumping applications. Efforts have been made to bring about indigenous production of various wind machines. A wind energy centre has been set up at National Aeronautical Laboratory Bangaluru, to provide technological inputs pertaining to design, development, testing certification, etc. A large data base for wind resource assessment has also been established.

*India has a potential of 20,000 MW of wind power. DNES plans to harness 400 MW of wind energy during eighth plan period.*

### 1.6.4. Energy from Bio-mass and Bio-gas

The potential for application of bio-mass as an alternate source of energy in India is very great. We have plenty of agricultural and forest resources for production of biomass. Biomass is produced in nature through photosynthesis achieved by solar energy conversion. As the word clearly signifies, Biomass means organic matter. In simplest form the reaction is the process of photosynthesis in the presence of solar radiation, can be represented as follows

\[
\text{H}_2\text{O} + \text{CO}_2 \xrightarrow{\text{Solar energy}} \text{CH}_2\text{O} + \text{O}_2
\]

In the reaction, water and carbon dioxide are converted into organic material *i.e.*, CH\textsubscript{2}O, which is the basic molecule of forming carbohydrate stable at low temperature, it breaks at high temperature, releasing an amount of heat equal to 112,000 cal/mole (469 kJ mole).

\[
\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 112 \text{ kcal/mole.}
\]

The absorbed energy of photons should be at least equal to this amount. It is therefore, possible to produce large amount of carbohydrate by growing say, algae, under optimum conditions in plastic tubes or in ponds. The algae could be harvested, dried and burned for production of heat that could be converted into electricity by conventional methods. The bio-mass is used directly by burning or is further processed to produce more convenient liquid and gaseous fuels.

Bio-mass resources fall into three categories:

1. Bio-mass in its traditional solid mass (wood and agricultural residue), and

The first category is to burn the bio-mass directly and get the energy. In the second category, the biomass is converted into ethanol and methanol to be used as liquid fuels in engines.

3. The third category is to ferment the bio-mass anaerobically to obtain a gaseous fuel called bio-gas (Bio-gas $\rightarrow$ 55 to 65% Methane, 30—40% CO$_2$, and rest impurities i.e., H$_2$, H$_2$S and some N$_2$).

Bio-mass resources include the following:

(i) Concentrated waste—municipal solids, sewage wood products, industrial waste, manure of large lots.

(ii) Dispersed waste residue—crop residue, legging residue, disposed manure.

(iii) Harvested bio-mass, standby biomass, biomass energy plantation.

1.7. Energy Plantation

For large scale production of electrical power, the use of fire wood as a fuel for the boilers of a conventional power plant is suggested. This approach is called the “energy plantation” scheme, in which selected species of trees would be planted and harvested over regular time period, on land, near the power plant. A large area is required for it. Trees which are suggested for use in India are eucalyptus, casuarina and babool.

1.7.1. Bio-Gas. The main source for production of bio-gas is wet cow dung or wet livestock (and even human) waste, to produce bio-gas. The production of bio-gas is of particular significance for India because of its large cattle population. The total cattle population in the country is about 250 million. Some of the other sources of bio-gas are:


In big cities, sewage source is the main source for production of bio-gas. Bio-gas thus obtained can be used to run pumps to pumpout the sewage water itself. Pilot plants for such purpose, capable of handling sewage, have already been developed and installed in some areas. The sewage bio-gas is found to contain 84 per cent Methane, which is already pointed out, is a high quality fuel. Methane could be economically used to run engines to drive electric generators.

In the rural sector, bio-gas finds great applications in cooking, lighting, mechanical power and generation of small electricity. The gas can be used with advantage to improve sanitary conditions and also to check environmental pollution. Bio-gas can be used solely or with diesel in I.C. engines, for production of power. For converting I.C. engines of diesel or petrol/kerosene type, to gas engines a special attachment has to be fixed up. Ruston and Hornsby has developed 5 HP engine to work on bio-gas. Remarkable progress has been made in our country in respect of bio-gas plants. More than 7.3 lakh family based on bio-gas plants were installed during Seventh Plan Period, few community and institutional bio-gas plants have also been installed. Some examples of successful institutional Bio-gas plants commissioned by DNES during the year 1985-86 are at Muradnagar (U.P.), Rishikeah (U.P.), Sanganer (Raj.), Sihar (Raj.), Pondicheri, Bhopal (M.P.) etc. About 70 community/institutional type bio-gas plants are set during the year 1985-86.

1.7.2. Ocean Thermal Energy Conversion. This is also an indirect method of utilizing solar energy. A large amount of solar energy is collected and stored in tropical oceans. The surface of the water acts as the collector for solar heat, while the upper layer of the sea constitutes infinite heat storage reservoir. Thus the
heat contained in the oceans, could be converted into electricity by utilizing the fact that the temperature difference between the warm surface waters of the tropical oceans and the colder waters in the depths is about 20–25°C. Utilization of this energy, with its associated temperature difference and its conversion into work, forms the basis of ocean thermal energy conversion (OTEC) systems. The surface water which is at higher temperature could be used to heat some low boiling organic fluid, the vapours of which would run a heat engine. The exit vapour would be condensed by pumping cold water from the deeper regions. The amount of energy available for ocean thermal power generation is enormous, and is replenished continuously. Several such plants are built in France after World War II (the largest of which has a capacity of 7.5 MW). With a 22°C temperature difference between surface and depths, such as exists in warmer ocean areas than the north sea, the Carnot efficiency is around 7%. This is obviously very low.

All the systems for OTEC method work on a closed Rankine cycle and use low boiling organic fluids like ammonia, propane, R-12, R-22 etc.

A schematic diagram of Rankine cycle OTEC plant is shown in Fig. 1.3. The warm surface water is used for supplying the heat input in boiler, while the cold water brought up from the ocean depths is used for extracting the heat in the condenser.

In India, Department of Non-conventional energy sources (DNES) has proposed to install a 1 MW OTEC plant in Lakshadweep Island at Kavaratti and Minicoy. Preliminary oceanographic studies on the eastern side of Lakshadweep Island suggest the possibility of the establishment of shore based OTEC plant at the Island with a cold water pipe line running down the slope to a depth of 800-1000 m. Both the Islands have large lagoons on the western side. The lagoons are very shallow with, hardly any nutrient in the sea water. The proposed OTEC plant will bring up the water from 1000 m depth which has high nutrient value. After providing the cooling effect in the condenser, a part of sea water is proposed to be diverted to the lagoons for the development of aqua culture.

1.7.3. Tidal Energy. The tides in the sea are the result of the universal gravitational effect of heavenly bodies like sun and moon on the earth. Due to fluidity of water mass, the effect of this force becomes apparent in the motion of water, which shows a periodic rise and fall in levels which is in rhythms with the daily cycle of rising and setting of sun and moon. This periodic rise and fall of the water level of sea is called tide. These tides can be used to produce electrical power which is known as tidal power. When the water is above the mean sea level, it is called flood tide and when the level is below the mean sea level, it is called ebb tide.
The use of tides for electrical power generation is practical in a few favourably situated sites where the geography of an inlet or bay favours the construction of a large scale hydroelectric plant. To harness the tides, a dam would be built, across the mouth of the bay. It will have large gates in it and also low head hydraulic reversible turbines are installed in it. A tidal basin is formed, which gets separated from the sea, by dam. The difference in water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices turbine respectively. This principle is explained in Fig. 1.4. By using reversible water turbines, turbine can be run continuously, both during high tide and low tide. The turbine is coupled to generator, potential energy of the water stored in the basin as well as energy during high tide, is used to drive the turbine, which is coupled to generator, generating electricity.

[Fig. 1.4. Principle of tidal power generation.]

Above arrangement of harnessing tidal energy, is known as single basin plant. The plant continuous to generate power till the tide reaches, its lowest level. Again a minimum head will be reached when it pays to shut down the turbine and open the bypass valves to drain the remaining basin water to sea. Single basin plant can not generate power continuously, though it might do so by using a pumped storage plant, if the load is supplied fluctuates considerably. To overcome this difficulty, two basin plants could be used to generate power continuously without interruption.

Such plants can be constructed only in selected places where the height of the tide is sufficient to justify economy.

A tidal power plant has been completed at Rance in France with rating of 240 MW in 1966. It works on single basin, two way system with pumping.

The possible sites for tidal power plants in India are suggested at Gulf of Cambay, Gulf of Kutchh in Gujarat and Sunderban area in West Bengal. However, no such plant has been constructed so far in our country.

**1.8. Geothermal Energy**

This is the energy which lies embedded within the earth. According to various theories the earth has a molten core. The fact that volcanic action takes place in many places on the surface of the earth, supports these theories. The steam and hot water comes naturally to the surface of the earth in some locations of the earth. For large scale use bore holes are normally sunk with depth upto 1000 m, releasing steam and water at temperatures upto 200 or 300°C and pressures upto 30 kgf/cm² (3000 kN/m²). Two ways of electric power production from geothermal energy has been suggested. In one of these heat energy is transferred to a working fluid which operates the power cycle. This may be particularly useful at places of fresh
volcanic activity. Where the molten interior mass of earth vents to the surface through fissures and substantially high temperatures, such as between 450 to 550°C can be found. By embedding coil of pipes and sending

![Diagram of geothermal power plant (wet steam).](image)

water through them can be raised. In the other, the hot geothermal water and/or steam is used to operate the turbines directly. From the well-head the steam is transmitted by pipe lines upto 1 m in diameter over distances upto about 3 km to the power station water separators are usually required to separate moisture and solid particles from steam.

At present only steam coming out of the ground is used to generate electricity, the hot water is discarded because it contains as much as 30% dissolved salts and minerals, and these cause serious rust damage to the turbine. The water, however contains more than 1/3 of the available thermal energy. Research is being carried out to build turbines which can withstand the corrosive effects of hot water coming out of wells.

Significant developments in the use of geothermal energy are expected in several countries of the world including India, in the coming years. This will be advantageous both from the point of view of conserving fossil and of pollution control in the atmosphere. Substantial sources of this form of energy are known to exist in U.S.A., Japan, USSR, New Zealand, Italy and Mexico. In India, the State of Himachal Pradesh is reported to possess geothermal energy in exploitable amount. World’s first geothermal power station was established at Lardarello in Italy in 1905 and it now produces more than 460 MW of power. Other chief installation of geothermal energy is at Wairaki, New Zealand (250 MW).

A 7.5 tonnes capacity cold storage pilot plant based on geothermal energy is installed at Manikarah Himachal Pradesh under the sponsorship of DNES.

### 1.9. Hydrogen Energy

Hydrogen as an energy can play an important role as an alternative to conventional fuels provided its technical problems of production, storage and transportation can be resolved satisfactorily and the cost could be brought down to acceptable limits. One of the most attractive features of hydrogen as an energy carrier is that it can be produced from water which is abundantly available in nature. Hydrogen has the highest energy content per unit of mass any chemical fuel and can be substituted for hydrocarbons in a broad range of applications,
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often with increased combustion efficiency. Its burning process is non-polluting and it can be used in fuel cells to produce both electricity and useful heat.

1.10. Fuel Cells

It may be defined as an electro chemical device for the continuous conversion of the portion of the free energy change in a chemical reaction to electrical energy. It is distinguished from a battery in that it operates with continuous replenishment of the fuel and the oxidant at active electrode area and does not require recharging.

Main components of a cell are (i) a fuel electrode, (ii) an oxidant or air electrode and (iii) an electrolyte.

Hydrogen as a fuel has so far given the most promising results, though cells consuming coal, oil or natural gas would be economically much more useful for large scale application. Some of the fuel cells are hydrogen, oxygen, \((\text{H}_2, \text{O}_2)\), Hydrazine \((\text{N}_2\text{H}_4, \text{O}_2)\), carbon/coal \((\text{C}, \text{O}_2)\), methane \((\text{CH}_4, \text{O}_2)\) etc.

Hydrogen oxygen fuel cells (Hydrox), are efficient and the most highly developed cell. A low pressure hydrogen oxygen cell is illustrated in Fig. 1.6. Two porous carbon or nickel electrodes, are immersed in an electrolyte. Catalyst is embedded in nickel electrodes. The electrolyte is typically 30% KOH because of its high electrical conductivity and it is less corrosive than acids.

Cells reactions are:

\[
\text{H}_2 \xrightarrow{\text{Catalyst}} 2 \text{H}^+ + 2e^- \\
2\text{H}^+ + \text{OH}^- \text{ (hydroxyl ions in electrolyte)} \rightarrow 2\text{H}_2\text{O} \\
\text{O}_2 \xrightarrow{} 2\text{O} \\
\text{O} + \text{H}_2\text{O} + 2e^- \rightarrow \text{OH}^- \\
\]

\(\text{H}_2\) is fed to one electrode and is absorbed gives free electrons and also reacts with hydroxyl ions of the electrolyte to form water. The free electrons travel towards oxygen electrode through the external circuit. The two electrons arriving by the external circuit and one molecule of water to form 2 OH\(^-\) ions. These OH\(^-\) ions migrate towards to H\(_2\) electrode and are consumed there. The electrolyte remains invariant. It is prime requirement that the composition of electrolyte should not change as the cell operates. The cell operates at or slightly above atmospheric pressure and at a temperature about 90\(^\circ\)C. These type of cells are called low temperature cells. In high pressure cells pressure is up to about 45 atmospheric and temperature up to 300\(^\circ\)C.

A single hydrogen-oxygen cell can produce an emf of 1.23 volt at atmospheric pressure and 25\(^\circ\)C. By connecting a number of cells, it is possible to create useful potential of 100 to 1000 volts and power levels of 1 kW to nearly 100 MW.
Some of the advantages of fuel cells are:
1. It is a direct conversion process and does not involve a thermal process, so it has high operating efficiency. Present day fuel cell efficiency is 38% and it is expected to reach 60%.
2. The unit is lighter, smaller and needs less maintenance.
3. Fuel power plants may further cut generation costs by reducing transmission losses.
4. Little pollution, little noise, so that it can be readily acceptable in residential areas.

The primary drawbacks of fuel cells are, their low voltage, high initial costs and low service life.

1.11. Magneto Hydro-Dynamics Generator

The principle of Magneto Hydrodynamics (MHD) power generation enables direct conversion of thermal energy to electrical energy. MHD power generation works on the principle that described by Faraday: When an electric conductor moves across a magnetic field, a voltage is induced in it which produces an electric current. In MHD generators, the solid conductors are replaced by a fluid which is electrically conducting. The working fluid may be either an ionised gas or liquid metal. The hot, partially ionized and compressed gas is expanded in a duct, and forced through a strong magnetic field, electrical potential is generated in the gas. Fig. 1.7. Electrodes placed on the side of the duct pick up potential generated in the gas. In this manner, direct current is obtained which can be converted into AC with the aid of an inverter.

![Fig. 1.7. Principle of MHD power generation.](image-url)

Ionised gas can be produced by heating it to a high temperature. As the gas is heated, the outer electrons escape from its atoms or molecules. The gas particles acquire an electric charge and the gas passes into the state of plasma. High
temperatures in excess of 2800°C are needed to produce necessary ionization of the gas. However, to achieve thermal ionization of products of combustion of fossil fuels or inert gases, extremely high temperatures are needed. Seeding the gas with potassium or cesium helps in ionization and reduces temperature requirement somewhat. The exhaust from MHD generator is at a temperature of about 2500 K and can be used as the heating medium for steam raising in a conventional boiler, thus suggesting the use of a combined cycle.

This system of power generation is simple, and has large power and temperature handling capacity. Having no moving parts, it has high reliability. It can be brought to full power from a standby condition in 45 seconds. The output can be changed from no load to full load in a fraction of a second.

An experimental power plant of 5 MW (Thermal input) has been commissioned at Tiruchirapalli.

1.12. Thermionic Converter

Another form of direct conversion of heat energy to electrical energy has been achieved in the thermionic converter. This consists of two electrodes in a container filled with ionized cesium vapor. Heating one electrode ‘boils out’ electrons that travel to the opposite colder electrode. The positive ions in the gas neutralize the space-charge effect of the electrons that normally prevent the flow of electrons. Ionized gas offsets space-charge effect that tends to repel migration of electrons.

Electrons which are emitted by heating cathode, are migrated to cooler anode collector and flow through outer circuit to develop electric power. The anode materials for thermionic converters should have low work function. Barium and strontium oxides are preferred for this purpose. Cathode material should have higher work function, for it tungsten impregnated with a barium compound is a suitable material for this purpose.

Efficiencies of these tubes is of the order of 8 per cent but researchers expect to produce units working at thermal efficiencies of 30 percent. At this efficiency the emitting cathode will be sized at 100 sq cm for a 1 kW output. Potential will be d.c. about 2-3 volts. The present cathode is heated to about 1400°C.

This device is being designed for space power applications where high temperature operation is advantageous. It can be used for supplying power to boats and power tools, and irrigation pumping. These units can be connected in series or parallel for different plant voltages and capacities. These devices may be used as small power plants for peak load power in commercial power generation system.

1.13. Thermo Electric Power

This device converts heat directly into electric power. This eliminates the conversion of heat into kinetic energy of gas or steam flow. Its principle is based on
the *Seebeck effect* which states that if two dissimilar materials are joined to form a loop and the two junctions are maintained at different temperatures, an emf will be developed around the loop. This principle is already in use in thermocouples to measure temperatures. The magnitude of the emf \(E\) developed by the above process is proportional to the temperature difference between the two junctions.

\[
E \propto (T_2 - T_1) = \alpha (T_h - T_c)
\]

where, \(T_h = \text{Temperature of hot junction}\)
\(T_c = \text{Temperature of cold junction}\)
\(\alpha = \text{Seebeck coefficient}\).

The hot junction is maintained at a temperature of \(T_h\) by the applied heat source which may be small oil or gas burner, a nuclear reactor, or direct solar radiation by paraboloidal concentrator and the cold junction is maintained at \(T_c\) by either water cooling or radiative heat transfer. The principle diagram is shown in Fig. 1.9.

This phenomenon offers one method of producing electrical energy directly from the heat of combustion, where fuel is cheap. This device can generate power for standby or even base load plants. The thermal efficiency is of the order of 3%, it is not attractive for very special power generation. The new semiconductor materials are found those work more efficiently. These materials are also able to withstand at high temperature. Encouraging results have been obtained with ceramic type materials made of semiconductor ‘doped’ with materials to increase their conductivity to a level about half way between semiconductors and metal conductors.

These materials, known as mixed valence metals, include materials, such as manganese, iron, cobalt and nickel treated with oxygen, sulphur, selenium and tellurium. It is hoped that materials would work at 20 percent thermal efficiency. A peak load plant of 100 MW capacity can be developed where fuels are very cheap.

### 1.14 Renewable Energy Resources

Renewable energy sources include both ‘direct’ solar radiation intercepted by collectors (*e.g.*, solar and flat-plate thermal cells) and indirect solar energy such as wind, hydropower, ocean energy and biomass resources that can be managed in a sustainable manner. Geothermal fields tapped with present drilling technologies have a finite life but are sometimes considered renewable for planning purposes. Traditional methods of using biomass and derivatives such as wood and charcoal are highly inefficient, in contrast with modern techniques emphasizing proper forest management sustained yield fuel wood plantations and efficient production.

If broadly interpreted, the definition of renewable resources also includes the chemical energy stored in food and nonfuel plant products and even the energy in air used to dry materials or to cool, heat and ventilate the interiors of buildings. From an operational view point, the correct way to treat renewable energy is as a means to reduce the demand for conventional energy forms. Thus, in performing economic and financial analyses, there is no real distinction between renewable energy technologies and those designed to improve the efficiency of conventional energy use.
A further point is that cost-effective approaches to energy efficiency-ranging from no-or low-cost measures (e.g., reducing excess air in boilers, shutting down equipment when not needed) to systems requiring moderate capital investment, such as heat recuperators, boiler replacements or cogeneration units, can improve the financial and economic feasibility of renewable as well as conventional energy systems. Improvements in the efficiency of energy use can be teamed with a variety of energy supply technologies, and this fact must be recognized when assessing the relative economics of renewable and conventional energy systems.

Three independent primary sources provide energy to the earth: the sun, geothermal forces and planetary motion in the solar system. In particular, direct solar radiation represents an enormous resource for a modern technological civilization. However, human capacity to harness these gigantic natural flows of energy to perform useful work depends largely on the economic feasibility of the required conversion in comparison with fossil fuel options and the extent to which large scale applications affect food production, climate and ecology.


Even though renewable options are not likely to supply a substantial amount of energy to developing countries over the short term, they do have these advantages:

1. Renewable energy is an indigenous resource available in considerable quantities to all developing nations and capable, in principle, of having a significant local, regional or national economic impact. The use of renewable energy could help to conserve foreign exchange and generate local employment if conservation technologies are designed, manufactured, assembled and installed locally.

2. Several renewable options are financially and economically competitive for certain applications, such as in remote locations, where the costs of transmitting electrical power or transporting conventional fuels are high, or in those well endowed with biomass, hydro or geothermal resources.

3. Because conversion technology tends to be flexible and modular, it can usually be rapid deployed. Other advantages of modular over very large individual units include easy in adding new capacity, less risk in comparison with ‘lumpy’ investments, lower interest on borrowed capital because of shorter lead times and reduced transmission and distribution costs for dispersed rural locations.

4. Rapid scientific and technological advantages are expected to expand the economic range of renewable energy applications over the next 8-10 years, making it imperative for international decision makers and planners to keep abreast of these developments.

### Obstacles to the implementation of renewable energy systems

Experience with renewable energy projects in the developing countries indicates that there are a number of barriers to the effective development and widespread diffusion of these systems. Among these are:

1. Inadequate documentation and evaluation of past experience, a paucity of validated field performance data and a lack of clear priorities for future work.

2. Weak or non-existent institutions and policies to finance and commercialize renewable energy systems. With regard to energy planning, separate and completely uncoordinated organisations are often responsible for petroleum, electricity, coal, forestry, fuelwood, renewable resources and conservation.

3. Technical and economic uncertainties in many renewable energy systems, high economic and financial costs for some systems in comparison with conventional supply options and energy efficiency measures.
(4) Skeptical attitudes towards renewable energy systems on the part of the energy planners and a lack of qualified personnel to design, manufacture, market, operate and maintain such systems.

(5) Inadequate donor coordination in renewable energy assistance activities, with little or no information exchange on successful and unsuccessful projects.

1.15. Prospects of Renewable Energy Sources

The one ‘new’ source of energy that promises to replace oil and gas, and ultimately coal is a different kind of fusion reactor—the sun. The total amount of incoming solar energy absorbed by the earth and its atmosphere in one year—$3.8 \times 10^{24}$ J—is equivalent to 15-20 times the amount of energy stored in all of the world’s reserves of recoverable hydrocarbons. Indeed, if just 0.005% of this solar energy could be captured using fuel crops specially designed buildings, wind and water turbines, solar collectors have energy converters and the like, this would supply more useful energy over the year than is currently obtained by burning fossil fuels. Unlike capital energy resources, renewables can not be exhausted. The only limitation is the rate at which they are used—it is not possible to deplete any particular reservoir of energy (such as a column of moving air or falling water) faster than it is replenished.

Renewables already supply a major part of the world’s energy needs. Biomass, for example, accounts for about one seventh of all fuel consumed, and supplies over 90% of that used in some third world countries: hydro generates one quarter of the World’s electricity, and more than two thirds of that used in over 35 countries; and the sun contributes directly to space heating in virtually all buildings, through the walls and windows, although precise estimates of the size of this contribution are not available. However, over the last two decades there has been burgeoning interest in renewables from the more industrialised nations and this has led to growing capital investment.

Renewable energy technologies are in many ways more attractive than most conventional energy technologies.

(i) They can be matched in scale to the need, and can deliver energy of the quality that is required for a specific task, thus reducing the need to use premium fuels or electricity to provide low grade forms of energy such as hot water (which can be supplied in many other ways).

(ii) They can often be built on, or close to the site where the energy is required this minimises transmission costs.

(iii) They can be produced in large numbers and introduced quickly, unlike large power stations which have long lead times, often 10 years or more. Rapid planning and construction lowers unit cost and allows planners to respond quickly to changing patterns of demand.

(iv) The diversity of systems available also increases flexibility and security of supply. In contrast, over dependence on imported fuels makes a country more vulnerable to political pressures from producer nations and multinationals. Generic faults in power plants, serious breakdowns, industrial action or simply bad weather can jeopardise the supply of electricity.

(v) While there are physical and environmental risks associated with the construction and operation of renewable energy technologies—as there are with all energy conversion systems—they tend to be relatively modest by comparison with those associated with fossil fuels or nuclear power. The failure of a solar panel or a remotely sited wind-turbine or wave energy converter might involve temporary inconvenience, but it will not, as a rule, endanger life or limb, nor cause
lastling damage. The most serious consequences could be those associated with such events as the catastrophic failure of a large hydro-electric dam, fire in a biomass plantation, or the explosion of a methane digester.

The Table 1.2 contains estimates of the theoretical potential of the world’s renewable energy resources and gives an indication of the size of the contribution that each makes to current energy demand. (Geothermal energy is included although it is not strictly a renewable source). The practical and economic potential of renewables is order of magnitude less than the theoretical potential. However, renewables could still meet total world energy demand many times over.

**Table 1.2. World Renewable Energy Resources**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Form of delivered energy (Application)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar</strong></td>
<td>Low temperature heat (space heating, water heating and electricity)</td>
<td>Millions of solar water heaters and solar cookers are in use. Solar cells and power towers are in operation.</td>
</tr>
<tr>
<td>Total solar radiation absorbed by the earth and its atmosphere is $3.8 \times 10^{24}$ J/yr.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>Electricity</td>
<td>Several multi-megawatt wind turbines are in operation and many more in construction. There are numbers of small wind turbines and wind pumps in use.</td>
</tr>
<tr>
<td>The kinetic energy available in the atmosphere circulation is $7.5 \times 10^{20}$ J.</td>
<td>Mechanical energy (Pumping transport)</td>
<td></td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td>High temperature heat (cooking, smelting etc.)</td>
<td>Biomass (principally wood accounts for about 15% of the world’s commercial fuel) consumption; it provides over 80% of the energy needs of many developing countries. There are millions of biogas plants in operation, most of them are in China.</td>
</tr>
<tr>
<td>Total solar radiation absorbed by plants is $1.3 \times 10^{21}$ J/yr.</td>
<td>Bio-gas (cooking, mechanical power etc.)</td>
<td></td>
</tr>
<tr>
<td>The world’s standing biomass has an energy content of about $1.5 \times 10^{22}$ J.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alchol (transport)</td>
<td>Several thousand, million litres of alcohol are being produced notably in Brazil and the U.S. Production is increasing rapidly; many countries have launched liquid biofuel programs.</td>
<td></td>
</tr>
<tr>
<td>Geothermal</td>
<td>Low temperature heat (bathing, space and water heating)</td>
<td>Geothermal energy supplies about 5350 MW of heat interior for use in bathing principally in Japan, but also in Hungary, Iceland and Italy. More than a lakh houses are supplied with heat</td>
</tr>
</tbody>
</table>
An Introduction to Energy Sources

<table>
<thead>
<tr>
<th>Resource</th>
<th>Form of delivered energy (Application)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td>Electricity</td>
<td>The total amount of heat stored in water or stream to a depth of 10 km is estimated to be $4 \times 10^{21}$ J; that stored in the first 10 km of dry rock is around $10^{27}$ J. Installed capacity is more than 2500 MW but output is expected to increase more than seven fold by 2000.</td>
</tr>
<tr>
<td>Tidal</td>
<td>Electricity</td>
<td>Energy dissipated in connection with slowing down the rotation of the earth as a result of tidal action is around $10^{26}$ J/yr. Only one large tidal barrage is in operation (at La Rance in France) and there are small schemes in Russia and China. Total installed capacity is about 240 MW and the output around 0.5 TWh/yr. In addition China has several small tidal pumping stations. Several large tidal schemes are being planned.</td>
</tr>
<tr>
<td>Wave</td>
<td>Electricity</td>
<td>The amount of energy stored as kinetic energy in waves may be of the order of $10^{18}$ J. The Japanese wave energy research vessel, the Kaimei, has an installed capacity of about 1 MW. There are, in addition several hundred wave powered navigational buoys. Designs after large prototype wave energy converters are being drawn up.</td>
</tr>
<tr>
<td>Hydro</td>
<td>Electricity</td>
<td>The annual precipitation land amounts to about $1.1 \times 10^{17}$ kg of water. Taking the average elevation of land area as 840 m², the annually accumulated potential energy would be $9 \times 10^{20}$ J. Large hydroschemes provide about one quarter of the world’s total electricity supply and more than 40% of the electricity used in developing countries. The installed capacity is more than 363 GW. The technically usable potential is estimated to be 2215 GW or 19000 TWh/yr. There are no accurate estimates of the number of capacity of small hydroplants currently in operation.</td>
</tr>
</tbody>
</table>

The perspective studies carried out indicate substantial increase in the commercial energy requirements from now to the end of the century. The electricity generation requirements would increase from about 110 Twh at present to about 550 Twh by the year 2000. The requirements of oil are expected to increase from about 30 to 92 million tonnes and coal from 100 to 530 million tonnes.

Coal is the most important commercial source of energy in India. The resource assessment done in 1978 gives the total coal reserves of the country upto
a depth of 600 m and in seams of thickness above 1.2 m as 85,450 million tonnes. A significant amount of coals occur at depths greater than 600 m and in seams of thickness less than 1.2 m, thus the total reserve of coal are put at about 111,700 million tonnes.

The survey and explorations for oil and gas resources are presently being conducted mainly by the ONGC and to some extent by Oil India Limited. The net recoverable reserves of oil are estimated at about 300 million tonnes and natural gas of 73 million cubic metres.

Preliminary assessment of hydro-electric potential indicates that the exploitable potential is about 400 Twh of annual energy generation. Schemes with an energy potential of 40 Twh have already been constructed and are presently in operation. The bulk of untapped hydroelectric potential equipment to 360 Twh of annual energy generation is located in northern and north-eastern regions mainly along the rivers of Himalayan origin. The average load factor of hydroelectric plants presently in operation is about 42 per cent. India has modest reserves of uranium and substantial reserves of Thorium. The established uranium resources are considered capable of supporting a nuclear programme on natural uranium of about 8000 MWe. India’s thorium reserves can support a very large programme of nuclear power development based on breeder reactor technology.

The intensity of use of electrical energy in the Indian economy has shown a steady increase. This trend necessitated substantial increase in the share of investment. The investment made in the power sector was of the order of ₹ 154,000 million in the sixth plan (1978–83). It would be difficult for the economy to sustain such increasing orders of investments in the future. It is therefore essential that the demand for electricity in terms of peak value and energy should be managed with a view to reduce the intensity of electricity used in various sectors. It is also essential to keep transmission and distribution losses and consumption of energy by auxiliaries in the power station to a minimum.

Under conditions obtaining in India hydroelectric power constitutes generally the most economical source for power generation. Accelerating its development will help in achieving the twin objectives of optimising investment and conserving energy resources. India has been following the policy of basing its thermal power development predominantly on coal. This policy would be continued in the future also. The location of thermal power plants is being gradually shifted closer to the coal mines to reduce the energy costs required for transportation of coals.

Due to the limited oil reserves India has to depend on substantial imports for meeting its future requirements. The bulk of the demand for oil is from transport sector, and in order to reduce the pressure from this sector it is necessary to explore possibilities of developing substitute fuels like biomass and producer gas. Accelerating the pace of electrification of rural areas and judicious pace of mechanisation of agriculture could help in reducing demand for oil.

Out of total non-commercial fuels the share of the fire wood is nearly 65 per cent. The availability of animal dung and agricultural waste is likely to increase in the future due to increased agricultural production and animal population. With the popularisation of bio-gas plants there might be an increase in the consumption of animal dung used as a fuel in the household sector.

Bio-gas and solar energy offer the greatest scope for the development of new energy sources. A number of prototype devices have been successfully developed for use of solar energy in areas like grain drying, water and space heating and
power generation. These devices are presently under going field trials for their performance and reliability. Application of wind power for agricultural pumping with certain prototype models are under going field trials and evaluation. Explorations to establish the geothermal and tidal potential are in progress but they are not expected to contribute to any significant extent to the energy supplies by the turn of the century.

**QUESTIONS**

1. What are primary and secondary energy sources?
2. What are the conclusions on alternate energy strategies?
3. What are the conventional and non-conventional energy sources? Describe briefly.
4. Discuss briefly the possibilities of utilizing the following methods of power generation:
   
   (i) Solar energy
   (ii) Magneto hydrodynamics
   (iii) Fuel cells.
5. Describe the types of solar power plant. What are the limitations of a solar power plant?
6. What are the methods of direct energy conversion? Describe in brief.
7. Write short notes on:
   
   (i) Wind energy
   (ii) Tidal energy
   (iii) Bio-mass and bio-gas
   (iv) OTEC
   (v) Thermoelectric generator.
8. What are the prospects of non-conventional energy sources in India? Explain.
9. What is meant by renewable energy sources? Explain in brief these energy sources with special reference to Indian context.
10. What are the advantages and limitations of renewable energy sources?