1

An Introduction to Energy Sources

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, by 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 ... 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 governments 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 inter continental 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 ...

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 be 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 system.

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 *noncommercial*. 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 an . 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, bitum. nous, and brown coals lignits and peats), 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 1.4.1.

Table 1.4.1

Coal	32.5%	92%
Oil	38.3%	
Gas	19.0%	
Uranium	0.13%	
Hydro	2.0%	
Wood	6.6%	8%
Dung	1.2%	
Waste	0.3%	

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.

Coal. Since the advent of industrialization coal has been the most common 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 Rs. 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 CO_2 and CO. Extensive use of coal as a source of energy is likely to disturb the ecological balance of CO_2 since vegetations in the world would not be capable of absorbing such large proportions of carbon dioxide produced by burning large quantities of coal.

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 tones 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.

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 acetylete, ethylene, methane etc.

(2) Composite industrial gases such as producer gas, coke oven gas, water gas, blast furnace gas etc.

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 equipments 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.

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.

Hydro-electric 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 of energy. 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 hydro electric 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.

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 U^{235}, Th^{232} and artificial element Pu^{239}, 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 U^{235}, is equal to the heat energy obtained by burning 4500 tonnes of high grade coal or 2200 tons 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

(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 can be stored in containers of chemicals called eutectric 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 thes 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 to-day are :

(1) Heating and cooling of residential building.

(2) Solar water heating.

(3) Solar drying of agricultural and animal products.

(4) Solar distillation on a small community scale.

(5) Salt production by evaporation of seawater or inland brines.

(6) Solar cookers.

(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

2. **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 1.6×10^7 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. Savonius 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 b
cause of its irregularity.

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

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

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

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

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

1. CAZRI wind mill at Jodhpur (Rajasthan).
2. WP-2 water pumping wind mill by NAL Bangalore.
3. MP-1 sail wind mill at NAL Bangalore.
4. Wind mills at Central Salt and Marine Chemicals Resea Institute Bhavnagar (Gujarat).
5. 12 PU 500 wind mill at NAL Bangalore.
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 Bangalore, 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 Gujrat ; Tuticorin and Kayattar in Tamil Nadu ; Puri in Orissa ; Deogad in Maharastra ; 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 indigeneous production of various wind machines. A wind energy centre has been set up at National Aeronautical Laboratory Banglore, 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.

3. **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 bio-mass. Bio-mass is produced in nature through photosynthesis achieved by solar energy conversion. As the word clearly signifies, Bio-mass means organic matter. In simplest form the reaction is the

process of photosynthesis in the presence of solar radiation, can be represented as follows

$$H_2O + CO_2 \xrightarrow{\text{Solar energy}} CH_2O + O_2$$

In the reaction, water and carbon dioxide are converted into organic material *i.e.* CH_2O, 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).

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O + 112 \text{ kcal/mole.}$$

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

2. Bio-mass in non-traditional form (converted into liquid fuels).

The first category is to burn the bio-mass directly and get the energy. In the second category, the bio-mass 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 → 55 to 65% Methane, 30—40%. CO_2, and rest impurities *i.e.* H_2, H_2S 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 bio-mass, bio-mass energy plantation.

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.

1.6. 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—3.8×10^{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, ave 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 lasting 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 (1.6.1) contains estimates of the theoretical potential of the world's renewable energy resources and gives an indication of the

Table 1.6.1. World Renewable Energy Resources

Resource	Form of delivered energy (Application)	Comment
Solar Total solar radiation absorbed by the earth and its atmosphere is 3.8×10^{24} J/yr.	Low temperature heat (space heating water heating and electricity)	Millions of solar water heaters and solar cookers are in use. Solar cells and power towers are in operation.
Wind The kinetic energy available in the atmosphere circulation is 7.5×10^{20} J	Electricity	Several multi-megawatt wind turbines are in operation and many more in construction.
	Mechanical energy (Pumping transport)	There are numbers of small wind turbines and wind pumps in use.
Biomass Total solar radiation absorbed by plants is 1.3×10^{21} J/yr.	High temperature heat (cooking, smelting etc.)	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.
The world's standing biomass has an energy content of about 1.5×10^{22} J.	Bio-gas (cooking, mechanical power etc.)	There are millions of biogas plants in operation, most of them are in China.
	Alcohol (transport)	Several thousand, million litres of alcohol are being produced notably in Brazil and the U.S. Production is increasing rapidly ; many countries have lunched liquid biofuel programmes.
Geothermal The heat flux from the earth's interior through the surface is 9.5×10^{20} J/yr.	Low temperature heat (bathing, space and water heating)	Geothermal energy supplies about 5350 MW of heat for use in bathing principally in Japan, but also in Hungary, Ice land and Italy. More than a lakh houses are supplied with heat from geothermal wells. The installed capacity is more than 2650 MW (thermal).
The total amount of heat stored in water or stream to a depth of 10 km is estimated to be 4×10^{21} J; that stored in the first 10 km of dry rock is around 10^{27} J.	Electricity	Installed capacity is more than 2500 MW but output is expected to increase more than seven fold by 2000.

Table cont.

Resource	Form of delivered energy (Application)	Comment
Tidal Energy dissipated in connection with slowing down the rotation of the earth as a result of tidal action is around 10^{26}. J/yr.	Electricity	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.
Wave The amount of energy stored as kinetic energy in waves may be of the order of 10^{18} J.	Electricity	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.
Hydro The annual precipitation land amounts to about 1.1×10^{17} kg of water. Taking the average elevation of land area as 840 m, the annually accumulated potential energy would be 9×10^{20} J.	Electricity	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.