CHAPTER 3

RENEWABLE ENERGY SOURCES

3.0 Introduction

A renewable energy source is a natural resource which can replenish with the passage of time, either through biological reproduction or other naturally recurring processes. The renewable resources are a part of earth’s natural environment and the largest components of its ecosphere. The renewable resources may be the source of power for renewable systems. However, if the rate at which the renewable resource is consumed exceeds its renewal rate, renewal and sustainability will not be ensured. This chapter deals with the need of renewable energy sources and its various forms.

3.1 Need for Renewable Energy Sources

The continuing depletion of fossil fuels and the environmental threat posed by the needs of future development are gradually shifting the path of development towards sustainability, better sociability and environmental responsibility which in turn emphasizes the need for renewable energy sources. The area of renewable energy sources is expanding rapidly and numerous innovations as well as applications are taking place. The decentralized renewable energy systems concept has been recognized as an answer to meeting the energy demands. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternative sources.

Presently fossil fuels like coal, oil, natural gas are being utilized to a large extent; it is extremely difficult to determine precise figures on the ultimate availability of fossil fuels. According to the major oil and gas companies, still significant new resources of oil are being developed, or remain to be discovered. A safe assessment is that there is enough oil from traditional sources to provide for the present demand for 30 years. The latest figures for global gas reserves indicate that these are approximately 50% higher than oil at some 60 years of current demand, and gas is far less explored than oil so there is probably more to be found. There are, however, unconventional hydrocarbon resources such as heavy oil and bitumen, oil shale, shale gas and coal bed methane – whose total global reserves have been assessed very roughly to be three times the size of conventional oil and gas resources. These are more expensive to extract but may become exploitable as the price of fossil fuels increases due to the steady depletion of the more easily accessible reserves. Fortunately for fossil fuel dependent economies, coal reserves are considered to be many times those of oil and gas and could last for hundreds of years. The downside of coal is its high carbon content.

Fuel for nuclear fission is not unlimited and several decades ago this has prompted interest in the fast breeder reactor which in effect extends the life of the fuel. However, the political danger inherent in the fast breeder cycle, with its production of weapons grade plutonium, has limited its development to a few prototype reactors which had major operational problems and are now defunct. The lifetime of uranium reserves for conventional fission at current usage has been estimated by some as around 50 years, but such calculations are very dependent on assumptions. If an extremely high ore price is tolerable, then very low grades of uranium ore can be considered as possible reserves.

For the above mentioned reasons, fossil fuels are finite energy sources and also causes pollution and thereby their use degrades the environment. In addition to this, demand of energy is increasing by industrialization and population growth. Hence the fossil fuel based energy sources are not sufficient to meet the growing demand.

It is important to explore and develop renewable energy sources to reduce too much dependence on fossil fuel based energy sources. However, the present trends of developments of renewable energy sources indicate that they will serve as supplements rather than substitute for fossil fuel for some more time to come.

3.2 Renewable Energy Resources and their Importance in Sustainable Development

A secure supply of energy resources is generally agreed to be a necessary but not sufficient requirement for development within a society. Furthermore, sustainable development demands a sustainable supply of energy sources that, in long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts. Supplies of energy resources like fossil fuel and uranium are generally acknowledged to be finite and other energy sources such as sun light, wind, falling water (hydro) are generally considered renewable and therefore sustainable over the relative long term. Wastes convertible to useful energy forms (through, for example, waste to energy incineration facilities) and biomass fuels are also usually viewed as sustainable energy sources.

Environmental concerns are an important factor in sustainable development. For a variety of reasons, activities which continually degrade the environment are not sustainable over time i.e., cumulative impact of such activities on the environment often leads over time to a variety of health, ecological and other problems.

While not all renewable energy resources are inherently clean, there is such a diversity of choices that a shift to renewable carried out in the context of sustainable development could provide a far cleaner system than would be feasible by tightening controls on conventional energy. Furthermore, being site specific by nature, renewable favor power system decentralization and locally applicable solutions, more or less independent of the national network [2].

The exploitation of renewable energy resources and technologies is a key component of sustainable development. There are three significant reasons for it as follows:

(i) They have much less environmental impact compared to other sources of energy since there is no any energy source with zero environmental impact.

(ii) If renewable energy sources are used wisely in appropriate and efficient applications, they can provide reliable and sustainable supply of energy almost indefinitely. In contrast, fossil fuel and nuclear energy sources are finite and can be diminished by extraction and consumption.

(iii) They favor power system decentralization and locally applicable solutions more or less independent of the national network, thus enhancing the flexibility of the system and the economic power supply to small isolated settlements. That is why; many different renewable energy technologies are potentially available for use in urban areas[2].

3.3 Global Status

In 2014, renewable energy sources ended up with an estimated 58.5% of net additions to global power capacity and represented far higher shares of capacity added in several countries around the world [80]. By year's end, renewables comprised an estimated 27.7% of the world's power generating capacity. This was enough to supply an estimated 22.8% of global electricity, with hydropower providing about 16.6%. Over the period 2007–2012, renewable power generation grew at an average rate of 5.9% per year. In contrast, global electricity consumption increased by an annual average rate of 2.7% in the same period, with electricity consumption in non-OECD countries growing twice as rapidly.

The most rapid growth and the largest increase in capacity occurred in the power sector led by wind, solar PV and hydropower. Growth has been driven by several factors, including renewable energy support policies and the increasing cost-competitiveness of energy from renewable sources. In many countries, renewables are broadly competitive with conventional energy sources. Globally, wind and solar PV each saw record capacity additions, each surpassing hydropower and together they accounted for more than 90% of non-hydro installations in 2014.

The largest component of renewable generation capacity is wind power, which has added a record high of 51 GW in 2014 with total installed capacity of 370GW. An estimated 1.7 GW of grid connected capacity was added offshore for a world total exceeding 8.5 GW. Wind energy is the least-cost option for new power generating capacity in an increasing number of locations, and new markets continue to emerge in Africa, Asia, and Latin America. Asia remained the largest market for the seventh consecutive year, led by China, and overtook Europe in total capacity. The United States was the leading country for wind power generation. Wind power met more than 20% of electricity demand in several countries, including Denmark, Nicaragua, Portugal, and Spain. For example, throughout 2014, wind power met 39.1% of electricity demand in Denmark, 27% in Portugal, and 21% in Nicaragua.

Solar PV is starting to play a substantial role in electricity generation in some countries as rapidly falling costs have made unsubsidized solar PV-generated electricity cost-competitive with fossil fuels in an increasing number of locations around the world. In 2014, solar PV marked another record year of growth, with an estimated 40 GW installed for a total global capacity of about 177 GW. Solar PV capacity in operation at the end of 2014 was enough to meet an estimated 7.9% of electricity demand in Italy, 7.6% in Greece, and 7% in Germany.

An estimated 37 GW of new hydropower capacity was commissioned in 2014, bringing total global capacity to approximately 1,055 GW. Generation in 2014 is estimated at 3,900 TWh. China (22 GW) installed the most capacity by far, with significant capacity also added in Brazil, Canada, Turkey, India, and Russia. The industry continued innovation towards ever-more flexible, efficient, and reliable facilities. Demand for greater efficiency and lower generating costs have contributed to ever- larger generating units, including some 800 MW turbines. There also is significant demand for refurbishment of existing plants to improve the efficiency of output, as well as environmental performance in the face of new regulatory requirements.

3.4 National Status and Potential

India is the fourth largest importer of oil and the 15th largest importer of petroleum products and LNG globally. India has the fifth largest power generation portfolio worldwide with a power generation capacity of 271.722 GW. The increased use of indigenous renewable resources is expected to reduce India’s dependence on expensive imported fossil fuels. Renewable energy development in India comes under the Ministry of New and Renewable Energy. India was the first country in the world to set up a ministry of Non-Conventional Energy Resources in early 1980s [81]. India's cumulative grid interactive or grid tied renewable energy capacity (excluding large hydro) has reached about 42.85 GW, surpassing the installed capacity of her hydroelectric power for the first time in Indian history. Almost 63% of the renewable power comes from wind energy and solar energy is contributing nearly 16% of grid connected renewable energy power.

Table 3.1 Installed Grid Interactive Renewable Power Capacity in India as of April 30, 2016[82].

Source	Total Installed Capacity (MW)
Wind Power	26,866.66
Solar Power	6,762.85
Biomass Power (Biomass & Gasification and Bagasse Cogeneration)	4,831.33
Small Hydro Power	4,273.47
Waste to Power	115.08

The Government of India has set targets which will take the total renewable capacity to almost 175 GW by the end of 2022. This includes 60 GW from wind power, 100 GW from solar power, 10 GW from biomass power and 5 GW from small hydro power. India's annual solar installations are expected to grow over four times by 2017[83]. Almost 10.86 GW of solar power capacity will be grid connected by 2016-17. The National Solar Mission aims to promote the development and use of solar energy for power generation and other uses, with the ultimate objective of making solar energy compete with fossil-based energy options.

3.5 Different Types of Energy Resources

There are six ultimate sources of useful energy

(i) Sun

(ii) The motion and gravitational potential of the sun, moon and earth;

(iii) Geothermal energy from cooling, chemical reactions and the radioactive decay inside the earth;

(iv) Nuclear reactions on the earth;

(v) Chemical reactions from minerals sources; and

(vi) Fossil fuel (Coal, Oil and gases)

The renewable energy is derived from sources (i) to (iii) and the finite energy (conventional energy) is derived from sources (iv) to (vi). [3]

The sun energy is the mother of all forms of energy; conventional or non-conventional, renewable or non-renewable, the only exception being nuclear energy. The various sources of energy find their origin in the sun as mentioned below;

(i) Wind energy

(ii) Biomass energy

(iii) Tidal energy

(iv) Ocean wave energy

(v) Ocean Thermal energy

(vi) Fossil fuels and other organic chemicals

(vii) Hydro energy

3.5.1 Solar Energy

The sun radiates energy uniformly in all directions in the form of electromagnetic waves. The sun provides the energy to sustain life in our solar system. It is a clean, inexhaustible, abundantly and universally available source of renewable energy. The major draw backs of solar energy are that it is a dilute form of energy, which is available intermittently and uncertainly, and not steady and continuous. However, it is more predictable than wind energy. Also, peak solar insolation [3] often coincides with peak daytime demand; it can be well matched to suit commercial power needs.

The solar energy can be utilized directly in two ways:

(i) By collecting the radiant heat and using it in a thermal system, or

(ii) By collecting and converting it directly to electrical energy using a photovoltaic system.

The former is referred as 'solar thermal system' and the latter referred as 'solar photovoltaic (SPV) systems'.

A solar thermal system provides thermal energy for various processes. In regions of cold climates a large amount of low grade thermal energy is required to heat air for comfort, and hot water for washing, cleaning and other domestic and industrial needs. Various industrial surveys show that up to 24% of all industrial heat is consumed for heating fluids to a moderate temperature. Thus, solar energy is best suited for low-grade thermal applications. Even in high temperature heating applications, a significant amount of fuel can be saved by using solar energy for preheating. For these reasons, manufacture of solar water heaters has become a thriving industry in several countries. Solar thermal energy is also being utilized in drying and process industries. It can also be converted and utilized as mechanical and electrical energy in the same way as in any conventional thermal systems.

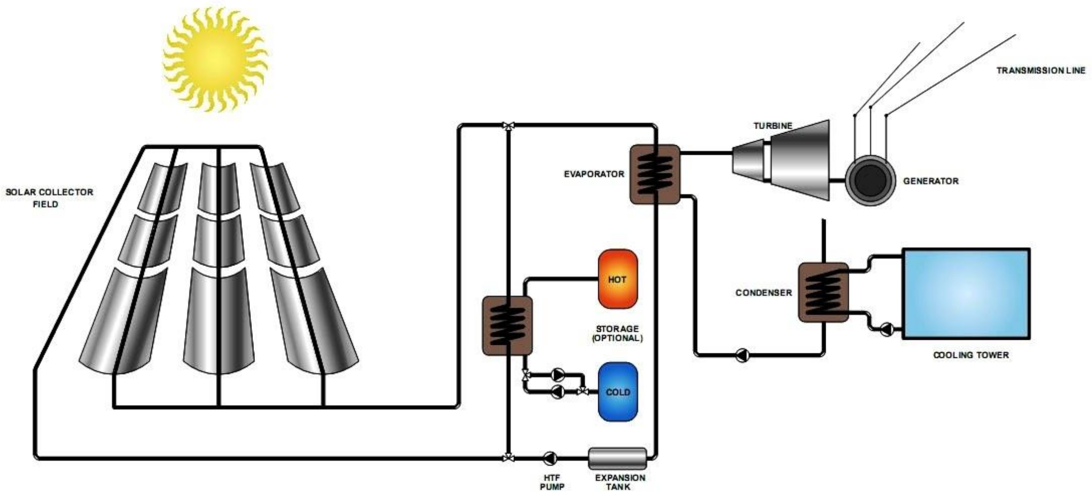

Fig.3.1. Solar Thermal Power Generation

Solar photovoltaic systems convert solar energy directly into electrical energy. The basic conversion device used is known as a solar photovoltaic cell. A solar cell is basically an electrical current source, driven by a flux of radiation.

The efficient power utilization depends not only on efficient generation in the cell, but also on the dynamic load matching in the external circuit.

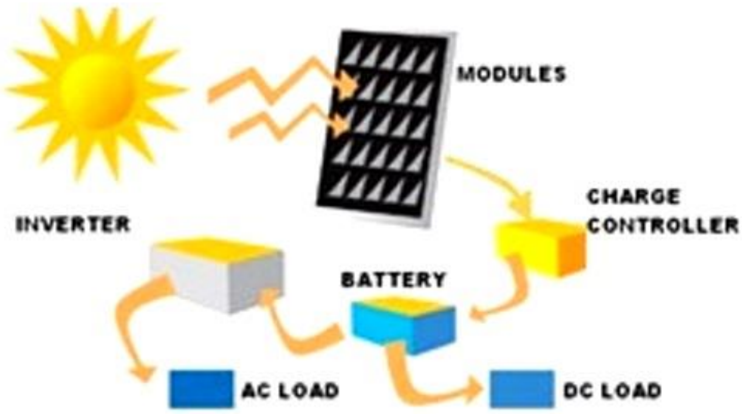

Fig.3.2. Solar Photovoltaic System

The solar cell is the most expensive component in a solar PV system (about 60% of the total system cost) though its cost is falling slowly. Commercial photocells may have efficiencies in the range of 10-20% and can produce electrical energy of 1-2 kWh per sq.m per day in ordinary sunshine.

The major uses of photovoltaic have been in space satellites, remote radio communication booster stations and marine warning lights. These are also increasingly being used for lighting, water pumping and medical refrigeration in remote areas especially in developing countries. Solar-powered vehicles and battery charging are some of the recent interesting applications of solar PV power.

The major advantages of solar PV systems over conventional power systems are given below;

(i) It converts solar energy directly into electrical energy without going through the thermal- mechanical link. It has no moving parts.

(ii) Solar PV systems are reliable, modular and durable.

(iii)These systems are quiet, compactable with almost all environments, respond instantaneously to solar radiation and have an expected life lifespan of 20 years or more.

(iv) Solar PV system can be located at the place of use and hence no or minimum distribution network is required, as it is universally available.

It also suffers from some of drawbacks such as given below;

(i) At present, the cost of solar cells is high, making them economically uncompetitive with other conventional power sources.

(ii) The efficiency of solar cell is low. As solar radiation density is also low, large areas of solar cell modules are required to generate sufficient useful power.

As solar energy is intermittent, some kind of electrical energy storage is required, which makes the whole system more expensive.

3.5.2 Wind Energy systems

The Wind energy is the kinetic energy associated with movement of large masses of air. These motions result from uneven heating of the atmosphere by the sun, creating temperature, density and pressure differences. It is estimated that 1% of all solar radiation falling on the face of the earth is converted into kinetic energy of the atmosphere, 30% of which occurs in the lowest 1000 m of elevation. It is thus an indirect form of solar energy. In contrast to daily availability of solar radiation; wind energy can be available continuously throughout a 24 hours day for much longer periods, though it can vary a great extent including no wind periods. It is a clean, cheap, and eco-friendly renewable energy source. The main disadvantages are that it is a dispersed, erratic and location specific source.

Wind energy is harnessed as mechanical energy with help of a wind turbine. The mechanical energy thus obtained can either be used as such to operate farm appliances and water pumping or converted to electric power and used locally or fed to a grid. A generator coupled to a wind turbine is known as aero-generator. Very slow winds are useless, having no possibility of power generation. On the other hand, very strong stormy winds cannot be utilized due to safety of turbine. Moderate to high speed winds, typically from 5m/s to about 25 m/s are considered favorable for most wind turbines. The global potential in winds for large scale grid connected power generation has been estimated as 9000

TWh/ year or 1 TWe (1T= 10^{12}). It is also estimated that favorable winds for small scale applications such as wind pumps, battery chargers, heaters, etc., are available on about 50% of the earth's surface which means that small scale wind turbines can be practical in many parts of the world.

Several demonstration and commercial wind plants of different sizes, from few kW to few MW are in operation in different parts of the world. Improved turbine designs and plant utilization have contributed to reduction of a large scale wind energy generation cost. With modern blade materials, the expected life of a wind turbine has exceeded 20 years. The installation cost has come down to a level comparable to that of a conventional thermal power plant. The energy payback period of a wind turbine is about one year. Due to these reasons, wind energy is gaining increasing acceptance and competing with conventional power sources. It is the fastest growing energy source among all renewable sources in recent years.

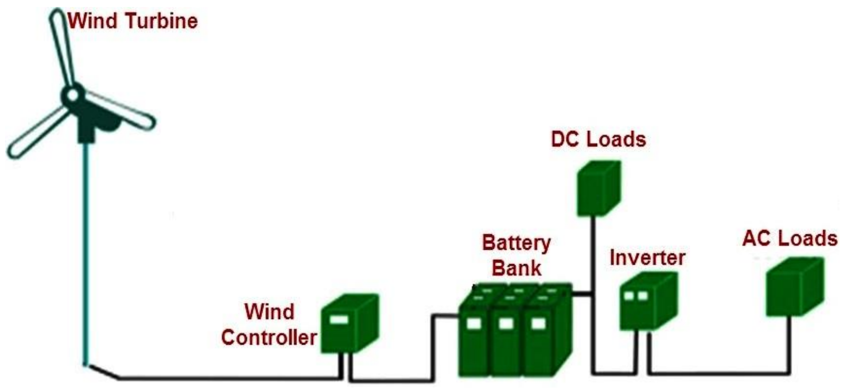

Fig.3.3. Wind Energy System

The major factors that have led to an accelerated development of wind power are as follows;

(i) Availability of high strength fibre composites for constructing large low-cost rotor blades

(ii) Falling prices of power electronic interfaces

(iii) Variable speed operation of electrical generators to capture maximum energy

(iv) Improved plant operation, pushing the availability up to 95%

(v) Economy of scale, as the turbines and plants are getting larger in size

(vi) Accumulated field experience improving the capacity factor

(vii) Short energy payback period of about one year.

3.5.3 Biomass Energy

Biomass is a general term of living material-plants, animals, fungi, bacteria. All together, the earth's biomass represents an enormous store of energy. It has been estimated that just one-eighth of the total biomass produced annually would provide all humanity's current demand for energy. Since biomass can be re-grown, it is a potentially renewable resource.

The energy obtained from biomass is known as biomass energy. Animals feed on plants, and plants grow through the photosynthesis process using solar energy. Thus, the photosynthesis process is primarily responsible for generation of biomass energy. A small portion of solar radiation is captured and stored in plants during the photosynthesis process. Therefore, it is an indirect form of solar energy. The average efficiency of photosynthesis conversion of solar energy into biomass energy is estimated to be 0.5- 1%.

To use biomass energy, the initial biomass may be transformed by chemical or biological process to produce more convenient intermediate bio-fuels such as methane, producer gas, ethanol and charcoal. On combustion, it reacts with oxygen to release heat, but the elements of the material should be available for recycling in natural ecological or agricultural process. Thus, the use of industrial bio-fuels, when linked carefully to the natural ecological cycle, may be non-polluting and sustainable.

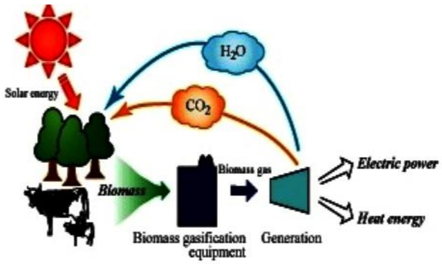

Fig.3.4. Biomass Energy System.

The main advantages of biomass energy are

(i) It is a renewable energy source,

(ii) Energy storage is an in-built feature of it,

(iii) It is an indigenous source requiring little or no foreign exchange,

(iv) The forestry and agricultural industries that supply feed stock also provide substantial economic development opportunities in rural areas,

(v) The pollutant emissions from combustion of biomass are usually lower than those from fossil fuels,

(vi) Commercial use of biomass may avoid or reduce the problems of waste disposal in other industries, particularly municipal solid waste in urban centers,

(vii) Use of biogas plants, apart from supplying clean gas, also leads to improved sanitation, better hygienic conditions in rural areas as the harmful decaying biomass get stabilized,

(viii) The nitrogen rich bio-digested slurry and sludge from biomass plant serves as a very good soil conditioner and improves the fertility of the soil, and

(ix) Varying capacity can be installed; any capacity can be operated, even at lower loads, with no seasonality involved.

The main drawbacks of biomass are given below;

(i) It is a dispersed and land-intensive source,

(ii) It is often of low energy density,

(iii) It is also labor intensive and the cost of collecting quantities for commercial application is significant,

(iii) Capacity is determined by availability of biomass and not suitable for varying loads, and

(iv) Not feasible to set up at all locations.

3.5.4 Ocean Energy

Ocean covers about 71% of the earth surface. They receive, store and dissipate energy through various physical processes. As per present technological status, recoverable energy in oceans exists mainly in the form of waves, tides and temperature difference (between surface and deep layers). Tides and waves produce mechanical energy whereas temperature difference produces thermal energy.

Tidal energy technology is relatively more developed compared to other two technologies, which are still undergoing evaluation and initial development stages. The main disadvantages, common to all of them are

(i) Low energy density,

(ii) Their occurrence at distances remote from the consumption centre.

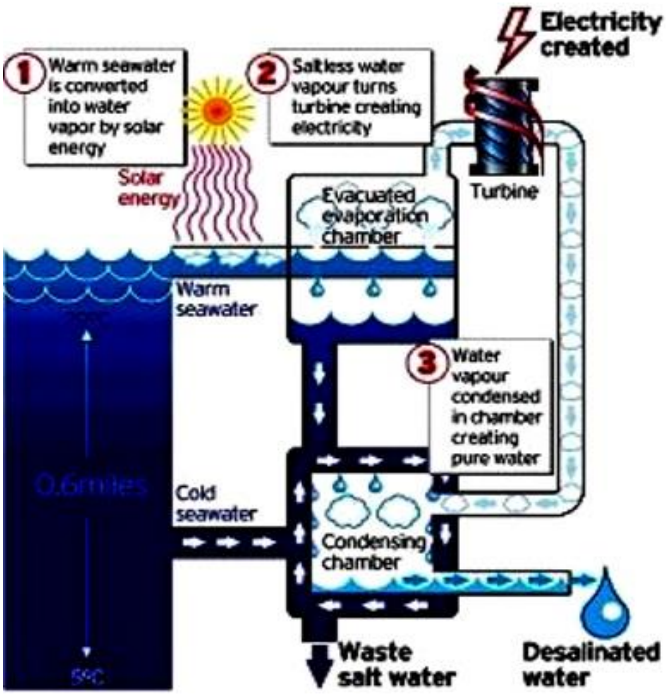

Fig.3.5. Ocean Energy System.

3.5.4.1 Tidal Energy

Tidal energy exploits the natural rise and fall of coastal tidal waters caused principally by the interaction of the gravitational fields of the sun and the moon. The ocean level difference caused due to tides contains large amount of potential energy. The highest level of tidal water is known as flood tide or high tide. The lowest level is known as low tide or ebb. The level difference between the high and low tide is known as tidal range. The tidal range varies greatly with location. Only sites with large ranges (about 5m or more) are considered suitable for power generation.

The principle used for harnessing this energy consists of a pond filled through sluice (rapid controlled gates) when tides are high and emptying it during low tides via an undershot water wheel, producing mechanical power. Even now, the same basic principle with improvements in the design, material and operation techniques is being used to generate electricity in the same manner as in a hydroelectric plant.

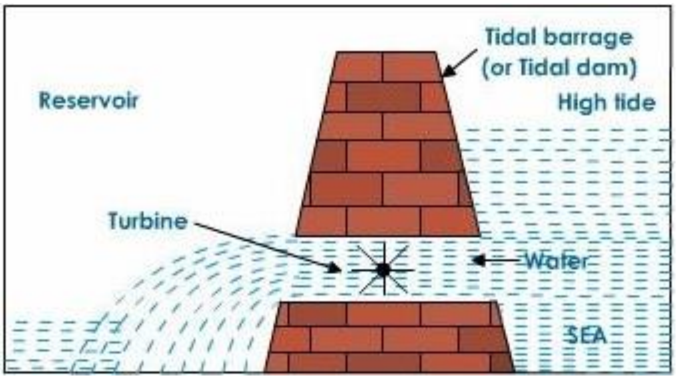

Fig.3.6.(a) At high tide water flows from sea into reservoir and turns turbine

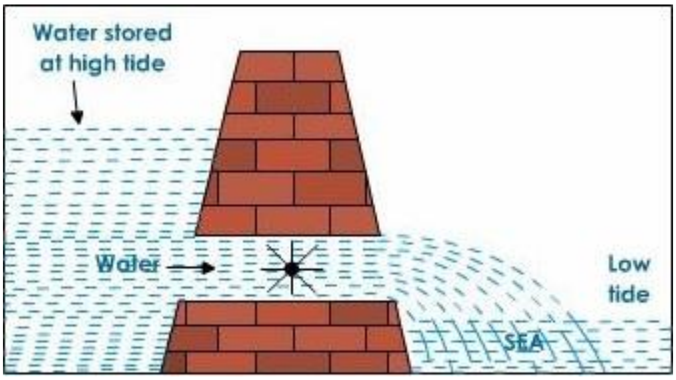

Fig.3.6.(b) At low tide water flows from reservoir into sea and turns turbine

The limitations of tidal energy are the following;

(i) Economic recovery of the energy from tides is feasible only at those sites where energy is concentrated in the form of tidal range of about 5m or more and the geography provides a favorable site for economic construction of a tidal plant. Thus it is site specific.

(ii) Due to mismatch of lunar driven period of 12 hours 25 min and human (solar) period of 24 hours, the optimum tidal power generation is not in phase with demand.

(iii) Changing tidal range in two-week periods produces changing power.

(iv) The turbines are required to operate at variable head.

(v) Requirement of large water volume flow at low head necessitates parallel operation of many turbines

(vi) Tidal plant disrupts marine life at the location and can cause potential harm to ecology.

3.5.4.2 Wave Energy

Wave energy is caused by the transfer of energy from surface winds to the sea. The rate of energy transfer depends upon the wind speed and the distance over which it interacts with water. The energy flux in waves is more than that available from solar, wind and other renewable sources. The power in the waves is directly proportional to the square of its amplitude and to the period of motion. The energy stored is dissipated through friction at shore and turbulence, at rates depending on characteristics of wave and water depth. Larger waves in deep sea lose energy quite slowly and can effectively store it for many days and transmit it over great distances. For instance, large wave appearing off Europe might have been initiated in stormy weather in the mid-Atlantic or as far as the Caribbean Sea. Wave energy in open oceans is likely to be inaccessible. The resource potential near coastlines is estimated as in excess of 20,00,000 MW. Wave power is usually expressed in kilowatts per meter, representing the rate at which energy is transferred across a line of 1m length parallel to the wave front.

Fig.3.7 shows the oscillating water column in a wave energy system, In this system, water columns are formed within large concrete structures built on the shore line or on rafts. The structure is open at both the top and the bottom. The lower end is submerged in the sea and an air turbine fills the aperture at the top. The rising and falling of the water column inside the structure moves the air column above it driving the air through the turbine generator. The turbine has movable vanes which rotate to maintain unidirectional rotation when the movement of the air column reverses.

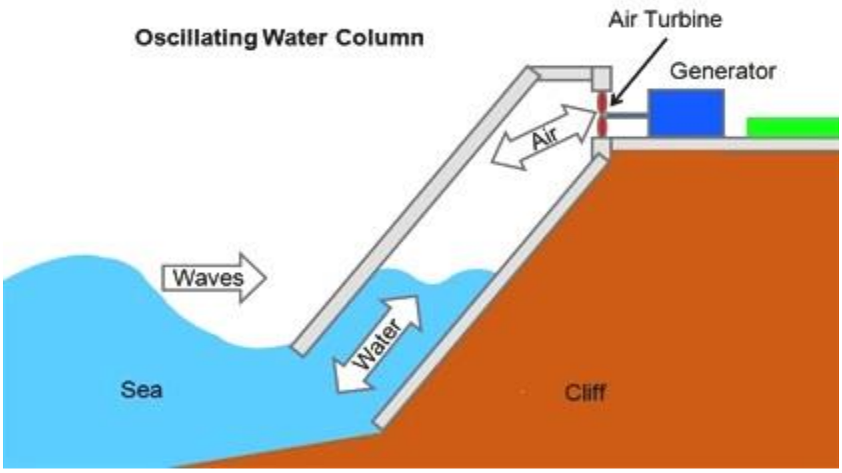

Fig.3.7. Oscillating Water Column Wave Energy System.

The main advantages of wave power are

(i) The availability of large energy fluxes and

(ii) Predictability of wave conditions over periods of days.

The difficulties in the development of wave power are encountered mainly due to the following reasons

(i) Irregularity of wave patterns in amplitude, phase and direction, which makes it difficult to extract power efficiently.

(ii) The power extraction system is exposed to occasional extreme stormy conditions. During unusual extreme conditions, once in several years, the wave amplitude may reach as high as 10 times the normal value and the associated power is about 100 times the normal value. Allowing for this is expensive and would reduce the normal efficiency of power extraction.

(iii)The peak power of deep water waves in available in open sea, where it is difficult to construct, operate and maintain a system and transmit power to the shore.

(iv)The slow and irregular motion of wave is required to be coupled to an electrical generator requiring high and constant speed motion.

3.5.4.3 Ocean Thermal Energy

Ocean Thermal energy exists in the form of temperature difference between the warm surface of water and the colder deep water. A heat engine generates power utilizing a well established thermodynamic principle, where heat flows from a high temperature source to a low temperature sink through an engine, converting a part of the heat into work. In the present case, the surface water work as a heat source and the deep water as a heat sink to convert part of the heat to mechanical energy and hence into electrical energy. The facility proposed to achieve this conversion is known as ocean thermal energy conversion (OTEC). A minimum temperature difference of 20°c is required for practical energy conversion. The resource potential is expected to be many terawatts.

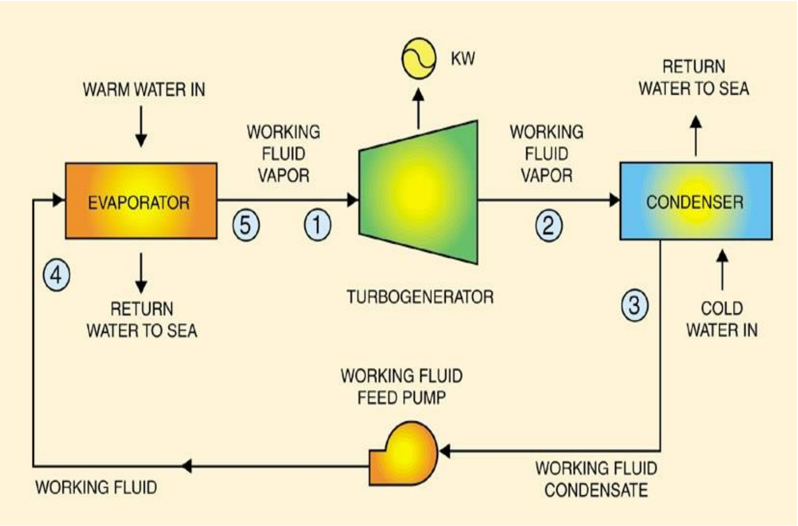

Fig.3.8. Closed Cycle Ocean Thermal Energy Conversion System.

Fig.3.8 shows the closed cycle Ocean Thermal Energy Conversion System. In this, there is a long, closed loop of pipeline filled with a fluid such as ammonia, which has a very low-boiling point (−33°C or 28°F). (Other fluids, including propane and various low-boiling refrigerant chemicals, have also been successfully used for transporting heat in OTEC plants.) The ammonia never leaves the pipe, it simply cycles around the loop again and again, picking up heat from the ocean, giving it up to the OTEC power plant, and returning as a cooled fluid to collect some more.

First, the pipe flows through a heat exchanger fixed in the hot surface waters of the ocean, which makes the ammonia boil and vaporize. The heated ammonia vapor expands and blows through a turbine, which extracts some of its energy, driving a generator to produce electricity. Once the ammonia has expanded, it passes through a second heat exchanger, where cool water pumped up from the ocean depths condenses it back to a liquid so it can be recycled. In OTEC, the ammonia picks up heat from the hot, surface ocean waters (just as the coolant chemical picks up heat from the chiller compartment), carries it to a turbine where much of its energy is extracted, and is then condensed back to a liquid so it can run round the loop for more heat (just as the coolant in a refrigerator is compressed and cooled in the fins around the back of the machine).

The main advantages of OTEC are

(i) The resource supplies steady power without fluctuations and independent on peculiarity of weather,

(ii) The availability hardly varies from season to season,

(iii) At a suitable site the resource is essentially limited only by the size of the system

(iv) The required machinery requires only marginal improvements in well tried engineering devices, example heat exchanger, turbine, etc.,

(v) It also has the ability to create some useful by products such as desalinated water and nutrients for mariculture.

The major disadvantages are

(i)Low efficiency, and

(ii) High installation cost.

3.6 Conclusions

This chapter discusses the need and importance of renewable energy resources and technologies for sustainable development. All the renewable energy sources are having limitations on technology which is used for power extraction and few renewable energy sources are not reliable for power generation. Among all, solar photovoltaic, wind energy systems and fuel cells are rapidly developing and becoming the most promising renewable energy systems worldwide, though they often require power conditioning systems which include inverters and DC-DC converters in order to supply local loads or send electricity to grid. Hence author focuses on renewable energy sources of solar photo voltaic systems and wind energy systems in the forth coming chapters.