Module-3

The material from this is prepared only for educational use from various text books and material from internet.

Hydrogen Energy: Benefits of Hydrogen Energy, Hydrogen Production Technologies, Hydrogen Energy Storage, Use of Hydrogen Energy, Advantages and Disadvantages of Hydrogen Energy, Problems Associated with Hydrogen Energy.
Wind Energy: Windmills, Wind Turbines, Wind Resources, Wind Turbine Site Selection.
Geothermal Energy: Geothermal Systems, Classifications, Geothermal Resource Utilization, Resource Exploration, Geothermal Based Electric Power Generation, Associated Problems, environmental Effects.
Solid waste and Agricultural Refuse: Waste is Wealth, Key Issues, Waste Recovery Management Scheme, Advantages and Disadvantages of Waste Recycling, Sources and Types of Waste, Recycling of Plastics.

Questions from VTU model papers and few important questions:

Hydrogen Energy

1. Describe various methods of storage of hydrogen
2. What are the problems associated with hydrogen energy
3. Explain the thermochemical hydro production technology
4. Explain electrolytic production technologies used to produce hydrogen
5. List the advantages and disadvantages and applications of hydrogen energy
6. Explain various hydrogen production technologies

Wind Energy

1. Discuss the advantages and disadvantages of Wind energy conversion system.
2. Derive the expression for power developed due to wind.
3. What are the basic components of a Wind Energy Conversion System (WECS), and how do they work together to generate electricity from wind energy?
4. Discuss the factors or guidelines for wind turbine site selection.
5. What are the major problems associated with wind power system.
6. What are the advantages and disadvantages of horizontal axis wind turbine system, explain its construction and working

Geothermal Energy

1. List and explain various types of Geothermal electric power generation schemes
2. What is geothermal system, explain its utility as energy resource
3. What are the challenges associated with geothermal based energy systems

Solid waste and Agricultural Refuse

1. With a neat diagram explain the waste energy management scheme
2. Classify the municipal waste on the basis of its composition
3. List the advantages and disadvantages of waste recycling
4. Discuss various methods for recycling of plastic, its advantages and disadvantages

HYDROGEN ENERGY

Hydrogen is the simplest element and an atom of hydrogen consists of only one proton and one electron. Despite its simplicity and also availability in abundance in the universe, it does not occur naturally as a gas on the earth. It is always combined with other elements. Water H2O, for example, is a combination of hydrogen and oxygen. It is also available in hydrocarbons used as fuels. Hydrogen can be separated from hydrocarbons through the application of heat—a process known as reforming. Another method of hydrogen production is known as electrolysis of water. In this process, a direct electrical current passes through water to separate water into its components of oxygen and hydrogen. Using sunlight as their energy source, some algae and bacteria give off hydrogen under certain conditions.

BENEFITS OF HYDROGEN ENERGY

The three basic benefits of hydrogen energy are as follows:

1. Use of hydrogen greatly reduces pollution: When hydrogen is combined with oxygen in a fuel cell, energy in the form of electricity is produced. This electricity can be used to power vehicles, as a heat source, and for many other uses. The advantage of using hydrogen as an energy carrier is that when it combines with oxygen, the only by-products are water and heat. No greenhouse gasses or other particulates are produced by the use of hydrogen fuel cells.
2. Hydrogen can be produced locally from numerous sources: Hydrogen can be produced either centrally, and then distributed, or onsite where it will be used. Hydrogen gas can be produced from methane, gasoline, biomass, coal, or water. Each of these sources brings with it different amounts of pollution, technical challenges, and energy requirements.
3. A sustainable production system if hydrogen is produced from electrolysis of water: Electrolysis is the method of separating water into hydrogen and oxygen. Renewable energy can be used to power electrolysers to produce hydrogen from water. Using renewable energy provides a sustainable system that is independent of petroleum products and is non-pollut ing. Some of the renewable sources used to power electrolyses are wind, hydro, solar, and tidal energy. After the hydrogen is produced in an electrolyser, it can be used in a fuel cell to produce electricity. The by-products of the fuel cell process are water and heat. If fuel cells operate at high temperatures, the system can be set up as a co-generator, with the waste energy used for heating.

HYDROGEN PRODUCTION TECHNOLOGIES

The choice of production methods will vary depending on the availability of feedstock or resource, the quantity of hydrogen required, and the required purity of hydrogen. Researchers are developing a wide range of processes for producing hydrogen economically and in an environmentally friendly way. These processes can be divided into three major research areas:

1. Thermochemical production technologies
2. Electrolytic production technologies
3. Photolytic production technologies

1 Thermochemical Production Technologies

Hydrogen bound in organic matter and in water makes up 70% of the earth's surface. Breaking up these bonds in water allows us produce hydrogen, and then, to use it as a fuel. There are numerous processes that can be used to break these bonds. Most of the hydrogen now produced on an industrial scale by the process of steam reforming, or as a by-product of petroleum refining and chemical production.

1.1 Steam Reforming

Steam reforming uses thermal energy to separate hydrogen from the carbon components in methane and methanol and involves the reaction of these fuels with steam on catalytic surfaces. The first step of the reaction decomposes the fuel into hydrogen and carbon monoxide. Then, a 'shift reaction' changes the carbon monoxide and water to carbon dioxide and hydrogen. These reactions occur at temperatures of 200°C or greater.

Steam reforming of natural gas is currently the least expensive method and is responsible for more than 90% of hydrogen production worldwide. Natural gas is first cleared from sulphur compounds. It is then mixed with steam and send over a nickel–alumina catalyst inside a tubular reactor heated externally, where carbon monoxide (CO) and hydrogen (H2) are generated. This step is followed by a catalytic water-gas shift reaction that converts the CO and water to hydrogen and carbon dioxide (CO2). The hydrogen gas is then purified.

The endothermic reforming reaction is:

$CH_4 + H_2O + 206\ (kJ/kg) \Rightarrow CO + 3H_2$ -------------------(1)

It is usually followed by the exothermic shift reaction:

$CO + H_2O \Rightarrow CO_2 + H_2 + 41(kJ/kg)$ -----------------------(2)

The overall reaction is:

$CH_4 + 2H_2O + 165\ (kJ/kg) \Rightarrow CO_2 + 4H_2$ ----------------(3)

The residual stream from the initial purification step is part of the fuel gas burned in the reformer in order to supply the required heat. Hence, the CO2 contained in this gas is currently vented with the flue gas. If CO_2 were to be captured, an additional separation step would be needed.The technology is suitable for large reformers (e.g., 100,000 tons per year), where yields higher than 80% can be achieved. Small-scale reformers especially designed for feeding small fuel cells show low efficiencies.

The production of hydrogen from natural gas is an integral part of the strategy to introduce hydrogen into the transportation and utility energy sectors, by reducing the cost of conventional and developing innovative hydrogen production processes that rely on cheap fossil feedstocks.

Today, nearly all hydrogen production is based on fossil raw materials. Worldwide, 48% of hydrogen is produced from natural gas, 30% from oil (mostly consumed in refineries), 18% from coal, and the remaining 4% via water electrolysis.

Modification of the conventional steam methane reforming (SMR) process to incorporate an adsorbent in the reformer to remove CO_2 from the product stream may offer a number of advantages over conventional processes. Disturbing the reaction equilibrium in this way drives the reaction to produce additional hydrogen at lower temperatures than conventional SMR reactors.

Although still in the research stage, the cost of hydrogen from this modified process is expected to be 25%–30% lower, primarily because of reduced capital and operating costs. In addition, the adsorption of the CO2 in the reforming stage results in a high-purity CO_2 stream from the adsorbent regeneration step. This has interesting implications in a carbon-constrained world.

2 Electrolytic Production Technologies

Another way to produce hydrogen is by electrolysis. Electrolysis separates the elements of water—H2 and oxygen (O)—by charging water with an electrical current. Adding an electrolyte like salt improves the conductivity of the water and increases the efficiency of the process.

The charge breaks the chemical bond between the hydrogen and the oxygen and splits apart the atomic components, creating charged particles called ions. The ions form at two poles: the anode, which is positively charged, and the cathode, which is negatively charged. Hydrogen gathers at the cathode and the anode attracts oxygen.

Electrolysis is the process of producing hydrogen and oxygen from water in an electrochemical cell. Two types of electrochemical methods, alkaline or proton exchange membrane (PEM), are used in commercially available equipment commonly referred to as electrolysers.

An alkaline electrolyser immerses the two electrodes, the cathode and the anode, into an aqueous alkaline electrolyte, typically a solution of sodium or potassium hydroxide, and a voltage is applied across the electrodes. The resulting migration of ions in solution results in the production of hydrogen at the cathode and oxygen at the anode according to the following equation:

Cathode reaction $4H_2O + 4e^- — 2H_2 + 4OH$------------------------ (1)

Anode reaction $4OH^- — O_2 + 2H_2O + 4e$---------------------------- (2)

In a PEM electrolyzer, the mobile ion is a proton in an electrolyte that is a proton-conducting polymer memebarane. In this case, the reactions at the electrodes are as follows:

Cathode reaction $4H^+ + 4e^- — 2H_2$ ----------------------------------(3)

anode reaction $2H_2O — O_2 + 4H^+ + 4e$----------------------------- (4)

Currently, the best conversion efficiency (i.e., overall system efficiency for converting electrical power to power stored as hydrogen) for commercial electrolysers is approximately 70%.

3 Photolytic Production Technologies

Solar energy can be used to convert water to hydrogen and oxygen directly. Electricity need not be produced by photovoltaic cell. Hydrogen production can be achieved by using either photoelectrochemical or photo-biological methods.

3.1 Photoelectrochemical Processes

Photoelectrochemical processes use two types of electrochemical systems to produce hydrogen. One uses soluble metal complexes as a catalyst, while the other uses semiconductor surfaces. When the soluble metal complex dissolves, the complex absorbs solar energy and produces an electrical charge that drives the water-splitting reaction. This process mimics photosynthesis.

The other method uses semiconducting electrodes in a photochemical cell to convert optical energy into chemical energy. The semiconductor surface serves two functions: to absorb solar energy and to act as an electrode. Light-induced corrosion limits the useful life of the semiconductor.

HYDROGEN ENERGY STORAGE

When compared to the electrical energy, the development of safe, reliable, compact, and costeffective hydrogen storage technologies is one of the most technically challenging barriers to the widespread use of hydrogen as a usable form of energy. To be competitive with conventional vehicles, hydrogen-powered cars must be able to travel more than 450 km between fills. This is a challenging goal because hydrogen has physical characteristics that make it difficult to store in large quantities without taking up a significant amount of space.

1 Compressed Gas and Liquid Hydrogen Storage Tanks

Hydrogen has a very high energy content by weight (about three times more than gasoline), but it has a very low energy content by volume (liquid hydrogen is about four times less than gasoline). This makes hydrogen a challenge to store. Liquefied hydrogen is denser than gaseous hydrogen, and thus, it contains more energy in a given volume. Similar sized liquid hydrogen tanks can store more hydrogen than compressed gas tanks, but it takes energy to liquefy hydrogen. However, the tank insulation required to prevent hydrogen loss adds to the weight, volume, and costs of liquid hydrogen tanks.

2 Materials-based Storage

Hydrogen can be stored in materials by following different processes. It can be stored on the surfaces of solids (by adsorption process) or within solids (by absorption process).

In adsorption process, hydrogen attaches to the surface of a material either as hydrogen molecules (H2) or hydrogen atoms (H). This is also referred to as surface adsorption storage.

In absorption process, hydrogen molecules dissociate into hydrogen atoms that are incorporated into the solid lattice framework. This is also known as intermetallic hydride storage. This method may make it possible to store larger quantities of hydrogen in smaller volumes at low pressure and at temperatures close to room temperature. Finally, hydrogen can be strongly bound within molecular structures, as chemical compounds containing hydrogen atoms in the form of compressed gas or cryogenic liquid.

USE OF HYDROGEN ENERGY

Aside from the production of hydrogen, the everyday use and acceptance of hydrogen must be carefully introduced. Today, hydrogen is being used to power commercial buses both by internal combustion engines burning a combination of hydrogen and other fuels and solely by hydrogen used in fuel cells. Hydrogen is used in many commercial applications from welding metal to dying fabrics for making electronics, plastics, and fertilizers. When a renewable economically viable production process of hydrogen can be achieved, the advantages will be spread out to many industries. Some of the proving grounds for various production methods can be locally developed to provide hydrogen for these industries.

Hydrogen can be used as a mobile source of power for transportation by being compressed and stored in small tanks for applications similar to gasoline or propane.

The following are the two superior ways of using hydrogen energy:

1. Internal combustion engine (ICE): It is expected that the ICE will act as a transition technology while fuel cells are improving, because the modifications required to convert an ICE to operate on hydrogen are not very significant.
2. Fuel cell (FC): It is expected to be the generator of choice for future hydrogen-powered energy applications owing to its virtually emission-free, efficient, and reliable characteristics. A fuel cell converts stored chemical energy, in this case hydrogen, directly into electrical energy.

ADVANTAGES OF HYDROGEN ENERGY

1. Uncoupling of primary energy sources and utilization.
2. Hydrogen is a gas; thus, it is easier to store than to store electricity.
3. Hydrogen can be obtained from any primary energy source, including renewable energy source.
4. Decentralized production is possible. Hydrogen is viewed as capable of providing services where electricity is not available, in particular as a fuel for vehicles and energy storage in remote areas.
5. Very efficient when used in fuel cells.
6. Very good experience of hydrogen as a chemical reactant (ammonia, methanol, and oil refining).
7. Very good safety records (for a specific range of applications).

DISADVANTAGES OF HYDROGEN ENERGY

1. Poor overall energy effi ciency when produced from electricity made with fossil fuels.
2. Very low density and poor specific volume energy density.
3. Need for high pressures and very low temperatures if stored in the liquid phase.
4. Specifi c safety problems and poor public acceptance (Hindenburg syndrome and Apollo Challenger space shuttle).
5. No existing infrastructures for transport, distribution, and storage.
6. Rather high cost (till today).

PROBLEMS ASSOCIATED WITH HYDROGEN ENERGY

The serious problems that are affecting the development of hydrogen for household and transport applications are as follows:

1. Hydrogen storage: The concerns surrounding the storage of hydrogen are a major issue. It must be stored at extremely low temperatures and high pressure. A container capable of withstanding these

specifi cations is larger than a standard gas tank. Hydrogen storage could be viewed as a problem by consumers.

2. High reactivity of hydrogen: Hydrogen is extremely reactive. It is combustible and fl ammable. The Hindenburg disaster, where a hydrogen-fi lled blimp exploded and many people died, has caused a fear of hydrogen

3. Cost and methods of hydrogen fuel production: Current production of hydrogen takes a lot of energy. If one has to burn fossil fuels to make hydrogen, what has really been gained? New, clean energy technology or hydrogen production methods will need to be developed for hydrogen vehicles to make sense.

4. Consumer demand: Another problem for hydrogen fuel is consumer demand and the cost to change all gasoline fi lling stations and vehicle production lines into hydrogen. The major transport companies will not start to produce hydrogen vehicles until there is consumer demand. Why would a person pay for an expensive hydrogen vehicle?

5. Cost of changing the infrastructure: To accommodate hydrogen equipment and appliances.

WIND ENERGY: Sun is the main source of wind, and hence, wind is considered a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, water bodies, and vegetative cover. The wind flow or motion energy is 'harvested' by modern wind turbines. Wind power has been utilized for several centuries. The invention of sail boats are the first and most important example of driving them by using wind energy. The earliest known wind-powered grain mills and water pumps were used by the Persians, the Indians, and the Chinese. Wind turbines convert the kinetic energy of the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or imparting motion to an electric generator that converts mechanical power into electricity.

WINDMILLS

Figure 3.2

If the mechanical energy is used directly by machinery, such as for a pump or grinding stones, the machine is usually called a windmill.

WIND TURBINES

Wind turbines deliver their power through a revealing shaft, and in this respect, they are similar to other prime movers such as diesel engine and stream turbines. A generator can be coupled to this shaft and the electrical power delivered can be used to serve the multitude of different purposes for which electricity is required today.

In practice, an important difference between the wind turbine and the power delivered by engines and stream turbines is that the power delivered by wind turbines to the same extent uncontrolled and unpredictable over very short periods of time. In most applications for electricity, power is normally required on demand and not whenever available. Therefore, it is important to have some storage or reserve supply. This requirement has been one of the main limitations. If the mechanical energy is then converted to electricity, the machine is called a wind generator.

WIND RESOURCES

Unfortunately, the general availability and reliability of wind speed data is extremely poor in many regions of the world. Large areas of the world appear to have average annual wind speeds below 3 m/s and are unsuitable for wind power systems; further, almost equally large areas have wind speeds in the intermediate range (3-4.5 m/s), where wind power may or may not be an attractive option. In addition, significant land areas have mean annual wind speeds exceeding 4.5 m/s, where wind power would most certainly be economically competitive.

1. Worldwide Wind Energy Scenario in 2010

As per the World Wind Energy Report 2010, wind energy scenario in 2010 is summarized as follows:

1. Worldwide capacity reached 196,630 MW, out of which 37,642 MW were added in 2010, slightly less than the capacity in 2009.
2. Wind power showed a growth rate of 23.6%, the lowest growth since 2004 and the second lowest growth of the past decade. All wind turbines installed by the end of 2010 worldwide can generate 430 TWh per annum; this wind power is more than the total electricity demand of the United Kingdom, the sixth largest economy of the world, and equalling 2,5% of the global electricity consumption.
3. China became number one in total installed capacity and the centre of the international wind industry, and it added 18,928 MW within one year, accounting for more than 50% of the world's market for new wind turbines.
4. Major decrease in new installations can be observed in North America and USA lost its number one position in total capacity to China.
5. Many Western European countries are showing stagnation, whereas there is strong growth in the number of Eastern European countries.
6. Germany keeps its number one position in Europe with 27,215 MW, followed by Spain with 20,676 MW.
7. The highest shares of wind power can be found in three European countries: Denmark (21%), Portugal (18%), and Spain (16%).
8. Asia accounted for the largest share of new installations (54,6%), followed by Europe (27,0%) and North America (16,7%).
9. Latin America (1,2%) and Africa (0,4%) still played only a marginal role in new installations.
10. Africa: North Africa represents still lion share of installed capacity, while wind energy plays hardly a role yet in Sub-Saharan Africa.
11. Nuclear disaster in Japan and oil spill in Gulf of Mexico will have long-term impact on the prospects of wind energy. Governments need to urgently reinforce their wind energy policies.
12. WWEA sees a global capacity of 600,000 MW as possible by 2015 and more than 1,500,000 MW by 2020.

2 Wind Energy in India

The Indian wind energy sector has an installed capacity of 14,158.00 MW (as on March 31, 2011). In terms of wind power installed capacity, India is ranked fifth in the world. Today, India is a major player in the global wind energy market.

The potential is far from exhausted. Indian Wind Energy Association has estimated that with the current level of technology, the 'on-shore' potential for utilization of wind energy for electricity generation is of the order of 65,000 MW. The unexploited resource availability has the potential to sustain the growth of wind energy sector in India in the years to come.

Wind in India are influenced by the strong south-west summer monsoon, which starts in May-June, when cool, humid air moves towards the land; further, the weak north-east winter monsoon, which starts in October, when cool, dry air moves towards the ocean. During MarchAugust, the winds are uniformly strong over the whole Indian Peninsula, except the eastern peninsular coast. Wind speeds during November-March are relatively weak, although high winds are available during a part of the period on the Tamil Nadu coastline. A notable feature of the Indian programme has been the interest among private investors or developers in setting up of commercial wind power projects. The gross potential is 48,561 MW (source C-wet) and a total of about 14,158.00 MW of commercial projects have been established until March 31, 2011.
Wind power potential has been assessed assuming 1% of land availability for wind farms requiring at 12 hectare/MW in sites having wind power density in excess of 200 W/m^2 at 50 m hub-height.

WIND TURBINE SITE SELECTION

The selection of a wind farm site is complex and time consuming, and also it involves multiple disciplines working on parallel paths. Financing, government permits, meteorological studies, land use restrictions, and design have to be completed well along before a site is approved and before the construction can begin.
Generally, there are three principle sources of construction expertise participating in wind farm projects. They are the design team responsible for conceptual and eventual site design, the developer or construction manager of the project, and the wind turbine generator contractor.
Wind is the energy resource that drives a wind turbine. A windmill needs to be placed on a high tower located in wind area. Not just any wind will do, a wind turbine needs air that moves uniformly in the same direction. Eddies and swirls, ‘turbulence’ in short, does not make good resource for a wind turbine. The rotor cannot extract energy from turbulent wind, and the constantly changing wind direction due to turbulence causes excessive wear and premature failure of turbine. This means that turbine must be placed high enough to catch strong winds, and above turbulent air. Since the tower price goes up quickly with height, there is a limit to what is practical and affordable.
1 Turbine Height
In general, wind turbines should be sited well above trees, buildings, and other obstacles. When the wind flows over an obstacle like a building or a tree, the wind is slowed down and turbulent air is created, and if a wind turbine is located in this zone of turbulence, the result will be poor energy production and increased wear and tear on the turbine. One way to get above the zone of turbulence is to put the wind turbine on a tall tower.
Figure 3.2 is an illustration of a simple rule of thumb that is often used to specify a minimum tower height for a residential-sized wind turbine. The rule of thumb is to make sure that the tower is tall enough so that the entire turbine rotor is at least 10 m above the tallest obstacle within 150 m of the tower. Because trees grow and towers do not, the growth of trees over the lifetime of the wind turbine (typically 20-30 years between major rebuilds) should be considered in installation.

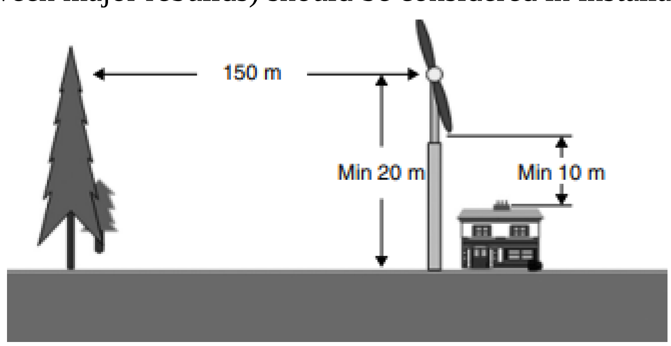

Figure 3.2 Installation of wind turbine (simple rule of thumb)

This should really be regarded as an absolute minimum for a wind turbine; at 10 m above an obstacle, there will still be some amount of turbulence and additional clearance is highly desirable. Changes in height of obstacles should be kept in mind as well. For example, if the obstacle like trees that are expected to grow up to 20 m high, it is advisable to use a 33-m tower.

Likewise, a 20-m tower should only be used when the terrain is very flat with no obstacles in a wide area around; for example, at the edge of the sea, or on top of a cliff with a clear area around it, or in the tundra. For most situations, a 20-m tower will only save a little money up front, while short selling energy production in the long run. To go beyond the rule of thumb, the airflow over any blunt obstruction, including a tree, tends to create a 'bubble' of turbulent air of twice the height of the obstacle, extending 20 times the height of the obstacle behind it.

Therefore, your 10-m high house disturbs the air up to 200 m away. The tree line with 33 m trees disturbs the air up to 70 m high at a distance of 300 m away (see Fig. 3.3). Wind turbine may be located either upwind of the obstructions, or far enough downwind. Notice from Figure (3.3) that preference should be given to a site upwind of obstructions, but keep in mind that tall features downwind of the turbine can also influence the wind going through the blades, as shown in Figure (3.3).

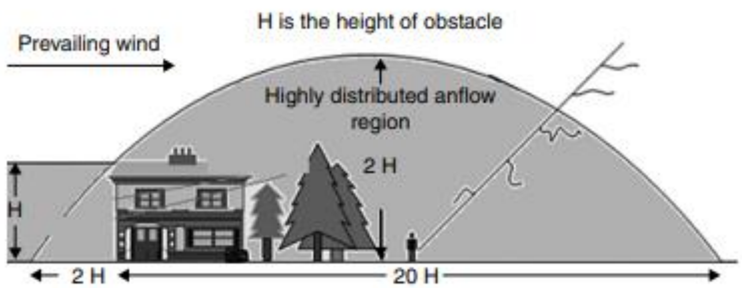

Figure 3.3 Installation of wind turbines

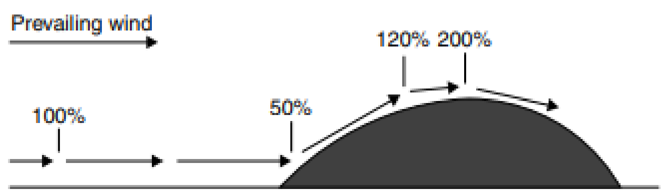

Figure 3.4 Wind speed around a cliff

The Danish Wind Power Association made a very nice, interactive, calculator that allows one to plug in various obstacles (for example, a row of trees), set their height and distance to the wind turbine (see Fig. 3.4), and visually show what effect this will have on wind speed and energy. The calculator shows the percentage of the wind speed at various distances and heights behind the obstacle. It is necessary to remember that although the effect of obstacles is not just to diminish wind speeds, but they also make the air swirl, creating turbulence. Turbulence is an energy reducers when it comes to wind turbines.

2 CONSIDERATIONS AND GUIDELINES FOR SITE SELECTION

When looking for a place for a wind turbine, engineers consider factors such as wind hazards, characteristics of the land that affect wind speed, and the effects of one turbine on nearby turbines in wind farms. The following important factors need careful considerations:

1. Hill effect: When it approaches a hill, wind encounters high pressure because of the wind that has already built up against the hill. This compressed air rises and gains speed as it approaches the crest, or top of the hill. The installation of wind turbines on hilltops takes advantage of this increase in speed.
2. Roughness or the amount of friction that earth's surface exerts on wind: Oceans have very little roughness. A city or a forest has a great deal of roughness, which slows the wind.
3. Tunnel effect: The increase in air pressure undergoes when it encounters a solid obstacle. The increased air pressure causes the wind to gain speed as it passes between, for example, rows of buildings in a city or between two mountains. Placing a wind turbine in a mountain pass can be a good way to take advantage of wind speeds that are higher than those of the surrounding air.
4. Turbulence: Rapid changes in the speed and direction of the wind, often caused by the wind blowing over natural or artificial barriers are called turbulence. Turbulence causes not only fluctuations in the speed of the wind but also wear and tear on the turbine. Turbines are mounted on tall towers to avoid turbulence caused by ground obstacles.
5. Variations in wind speed: During the day, winds usually blow faster than they do at the night because the sun heats the air, setting air currents in motion. In addition, wind speed can differ depending on the season of the year. This difference is a function of the sun, which heats different air masses around earth at different rates, depending on the tilt of the earth towards or away from the sun.
6. Wake: Energy can neither be created nor destroyed. As wind passes over the blades of a turbine, the turbine seizes much of the energy and converts it into mechanical energy. The air coming out of the blade sweep has less energy because it has been slowed. The abrupt change in the speed makes the wind turbulent, a phenomenon called wake. Because of wake, wind turbines in a wind farm are generally placed about three rotor diameters away from one another in the direction of the wind, so that the wake from one turbine does not interfere with the operation of the one behind it.
7. Wind obstacles: Trees, buildings, and rock formations are the main obstacles in the installation of wind turbines. Any of these obstacles can reduce wind speed considerably and increase turbulence. Wind obstacles like tall buildings cause wind shade, which can considerably reduce the speed of the wind, and therefore, the power output of a turbine.
8. Wind shear: It is the differences in wind speeds at different heights. When a turbine blade is pointed straight upward, the speed of the wind hitting its tip can be, for example, 9 miles (14 km) per hour, but when the blade is pointing straight downward, the speed of the wind hitting its tip can be 7 miles (11 km) per hour. This difference places stress on the blades. Further, too much wind shear can cause the turbine to fail.
Choosing the right site for wind turbine is the most important decision. Further, the location plays a vital part in the performance and efficiency of a wind turbine. The following guidelines can be followed to evaluate site for the installation of wind turbines:
1. Turbines work best when on high and exposed sites. Coastal sites are especially good.
2. Town centres and highly populated residential areas are usually not suitable sites for wind turbines.
3. Avoid roof-mounted turbines as there is no guarantee that these devices will not damage property through vibration.
4. The farther the distance between the turbine and the power requirement, the more power will be lost in the cable. The distance of the cabling will also impact the overall cost of the installation.
5. Turbulence disrupts the air flow that can wear down the blades and reduces the lifecycle of the turbine. It is recommended that installing a turbine may be considered only when the distance between the turbine and the nearest obstacle is more than twice the height of the turbine, or when the height of the turbine is more than twice the height of the nearest obstacle.
6. Small turbines require an average wind speed of over 4.5 m/s to produce an efficient level of electricity.

7. If site is in a remote location, connecting wind turbine to the national grid will be very expensive and it may be worth considering an off-grid connection instead using battery storage.

Wind Turbine Power Output Variation with Steady Wind Speed

Figure 3.5 gives the power output from a wind turbine variation with steady wind speed.

There are five important characteristic wind speeds and they are as follows:

1. Start-up speed is the speed at which the rotor and blade assembly begin to rotate.
2. The cut-in wind speed is the speed when the machine begins to produce power.
3. The design wind speed is the speed when the windmill reaches its maximum efficiency.
4. The rated wind speed is the speed when the machine reaches its maximum output power.
5. The furling wind speed is the speed when the machine furls to prevent damage at high wind speeds.

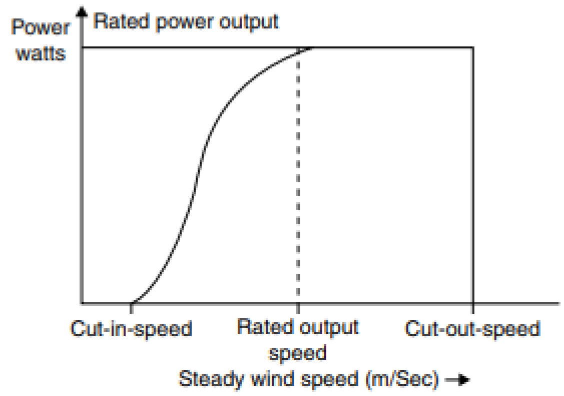

Figure 3.5 Wind turbine power output with steady wind speed

Cut-in speed is the minimum wind speed at which the wind turbine will generate usable power. This wind speed is typically between 7 and 10 mph for most turbines. At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate.

However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 3 and 4 m/s.

Rated speed At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed.

Most manufacturers provide graphs, called 'power curves,' showing how their wind turbine output varies with wind speed. As the wind speed rises above the cut-in speed, the level of electrical output power rises rapidly as shown. However, typically somewhere between 12 m/s and 17 m/s, the power output reaches the limit that the electrical generator is capable of. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind speed. At high wind speeds, the design of the turbine is arranged to limit the power to this maximum level and there is no further rise in the output power. How this is done varies from design to design; however, typically, with large turbines, it is done by adjusting the blade angles so as to keep the power at the constant level.

Cut-out speed At very high wind speeds, usually around 25 m/s, most wind turbines cease power generation and shutdown. The wind speed at which the shutdown occurs is called the cut-out speed, or sometimes the furling speed. Having a cut-out speed is a safety feature that protects the wind turbine from damage. Shutdown may occur in one of the several ways. In some machines, an automatic brake is activated by a wind speed sensor. Some machines twist or 'pitch' the blades to spill the wind. Still others use 'spoilers,' drag flaps mounted on the blades or the hub that are automatically activated by high rotor rpms, or mechanically activated by a spring-loaded device, which turns the machine sideways to the wind stream. Normal wind turbine operation usually resumes when the wind drops back to a safe level. As the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill.

Parts of a Wind Turbine

1. The nacelle contains the key components of the wind turbine, including the gearbox and the electrical generator.
2. The tower of the wind turbine carries the nacelle and the rotor. Generally, it is an advantage to have a high tower, since wind speeds increase farther away from the ground.
3. The rotor blades capture wind energy and transfer its power to the rotor hub.
4. The generator converts the mechanical energy of the rotating shaft to electrical energy.
5. The gearbox increases the rotational speed of the shaft for the generator.

Blade Count

The determination of the number of blades involves design considerations of aerodynamic efficiency, component costs, system reliability, and aesthetics. Noise emissions are affected by the location of the blades upwind or downwind of the tower and the speed of the rotor. Given that the noise emissions from the blades' trailing edges and tips vary by the fifth power of blade speed, a small increase in the tip speed can make a large difference. Wind turbines developed over the last 50 years have almost universally used either two or three blades. Aerodynamic efficiency increases with number of blades but with diminishing return. Increasing the number of blades from one to two yields a 6% increase in aerodynamic efficiency, whereas increasing the blade count from two to three yields only an additional 3% in efficiency.

Blade Materials

Wood and canvas sails were used on early windmills due to their low price, availability, and ease of manufacture. Small blades can be made from light metals such as aluminium. However, these materials require frequent maintenance. Wood and canvas construction limits the airfoil shape to a flat plate, which has a relatively high ratio of drag to force captured (low aerodynamic efficiency) when compared to solid airfoils. The constructions of solid airfoil designs require inflexible materials such as metals or composites. Some blades also have incorporated lightning conductors.

There are five important characteristic wind speeds and they are as follows:

1. Start-up speed is the speed at which the rotor and blade assembly begin to rotate.
2. The cut-in wind speed is the speed when the machine begins to produce power.
3. The design wind speed is the speed when the windmill reaches its maximum efficiency.
4. The rated wind speed is the speed when the machine reaches its maximum output power.
5. The furling wind speed is the speed when the machine furls to prevent damage at high wind speeds

Cut-in speed is the minimum wind speed at which the wind turbine will generate usable power. This wind speed is typically between 7 and 10 mph for most turbines. At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate.

However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 3 and 4 m/s.

Rated speed At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called 'power curves,' showing how their wind turbine output varies with wind speed. As the wind speed rises above the cut-in speed, the level of electrical output power rises rapidly as shown. However, typically somewhere between 12 m/s and 17 m/s, the power output reaches the limit that the electrical generator is capable of. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind.

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CLASSIFICATION AND DESCRIPTION OF WIND MACHINES

Two important wind rotor configurations are as follows:

1. In vertical-axis wind turbines (VAWT), the axis of rotation is vertical with respect to the ground (and roughly perpendicular to the wind stream), as shown in Figure below. The following are the two main types of VAWT: (a) Darrieus (which uses lift forces generated by aerofoils) (b) Savonius (which uses drag forces)

2. Horizontal-axis turbines, in which the axis of rotation is horizontal with respect to the ground (and roughly parallel to the wind stream), as represented in Figure 6.8(b). Horizontal-axis wind turbines (HAWT) can be further divided into three types: (a) Dutch windmills (b) Multi-blade water-pumping windmills (c) High-speed propeller-type wind machines

Figure 3.6 Wind rotor configurations (a) Vertical axis (b) Horizontal axis (c) Savonius drag-type VAWT

The Savonius wind generator was developed by a Finnish engineer known as Sigurd J. Savonius in 1920s. During that time, horizontal axis windmills were already widely used. However, early conventional windmill designs were quite sophisticated and costly to arrange and maintain. The system was adapted for purposes such as water pumping and grain grinding. The Savonius turbine, as shown in figure is one of the simplest turbines. machine would look like an 'S' shape in cross-section . Because of the curvature, the scoops experience less drag when moving against the wind than with the wind. The differential drag causes the Savonius turbine to spin. Because they are drag-type devices, Savonius turbines extract much less of the wind's power than other similarly sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights. They can be made in many different ways with buckets, paddles, sails, and oil drums. The Savonius rotor is S-shaped (when viewed from above). All of these designs turn relatively slow, but yield a high torque. They can be useful for grinding grain, pumping water, and many other tasks. They, however, are not good for generating large amounts of electricity. The drag-based VAWTs usually turn below 100 RPM. One might use a gearbox, but then efficiency suffers and the machine may not start at all easily.

One of the most important advantages of VAWT is their easy maintenance. This refers to the fact that all the working parts are at ground level. Hence, there is no need to climb tall towers to reach the blades. Another advantage involves placement. No calculations for wind direction and speed are required. Its small rotation translates into quiet operation that will produce small but steady electricity. However, one drawback to the Savonius' use on any large scale is its slow turning rotation, which requires a manual start. Thus, this limits the amount of electricity it can generate. They are used in electricity generation with the benefit that they continue to generate electricity in the strongest winds without being damaged, they are very quiet, and they are relatively easy to make. Savonius turbines do not scale well to kilowatt sizes; however, they are useful for small-scale domestic electricity generation. They are ideally suited to applications such as pumping water and grinding grain for which slow rotation and high torque are essential. Because of the torque yield of a Savonius wind turbine, the bearings used must be very sturdy and may require servicing every couple of years.
Advantages of Savonius : Always self-starting, if there are at least three scoops and relatively easy to make
Disadvantages of Savonius : low efficiency, around 15%

Darrieus Lift-type Vertical-axis Machines: The Darrieus wind turbine is a type of VAWT used to generate electricity from the energy carried in the wind. The turbine consists of a number of aerofoil usually but not always vertically mounted on a rotating shaft or framework. This design of wind turbine was patented by Georges Jean Marie Darrieus, a French aeronautical engineer in 1931. The most attractive feature of this type of turbine is that the generator and transmission devices are located at ground level. Additionally, they are able to capture the wind from any direction without the need to yaw. However, these advantages are counteracted by a reduced energy capture. Wind turbines are mechanical devices specifically designed to convert part of the kinetic energy of the wind into useful mechanical energy. Several designs have been devised throughout the times. Most of them comprise a rotor that turns round propelled by lift or drag forces, which result from its interaction with the wind. Furthermore, despite having the generator and transmission at ground level, maintenance is not simple since it usually requires rotor removal.

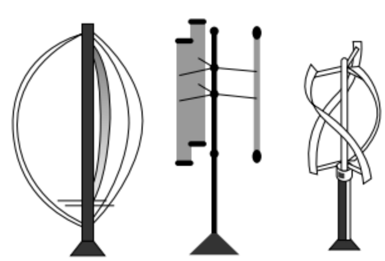

Figure 3.7 Darrieus wind turbine

Advantages of Darrieus:

1. The equipment (gear box and generator) can be placed close to the ground. 2. There is no need of a mechanism to turn the rotor against the wind

Disadvantages of Darrieus

1. The efficiency is not very remarkable
2. The Darrieus is not a self-starting turbine, the starting torque is very low but it can be reduced by using three or more blades that result in a high solidity for the rotor.
3. Because wind speeds are close to the ground level, there is very low wind speed on the lower part of the rotor.
4. They are very difficult to mount high on a tower to capture the high level winds. Because of this, they are usually forced to accept the low, more turbulent winds, and they produce less in possibly more damaging winds.

Advantages of Vertical-axis Wind Turbines (VAWT)

1. The turbine generator and gearbox can be placed lower to the ground, thus facilitating easy maintenance and low construction costs.
2. The main advantage of VAWT is it does not need to be pointed towards the wind to be effective. In other words, they can be used on the sites with high variable wind direction.
3. Since VAWT are mounted close to the ground, they are more bird friendly and do not destroy the wildlife.
4. VAWT is quiet, efficient, economical, and perfect for residential energy production, especially in urban environments.

Disadvantages of Vertical-axis Wind Turbines (VAWT) Despite the abovementioned advantages, VAWT suffer from the following serious drawbacks.

1. As the VAWT are mounted close to the ground, less wind speed is available to harness, which means less production of electricity.
2. VAWT are very difficult to erect on towers, which means they are installed on base, such as ground or building.
3. Another disadvantage of VAWT is the inefficiency of dragging each blade back through the wind.

Horizontal-axis Wind Turbines

Horizontal-axis wind turbines, also abbreviated as HAWT, are the common style that most of us think of when we think of a wind turbine. An HAWT has a similar design to a windmill; it has blades that look like a propeller that spin on the horizontal axis. They have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servomotor. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds.

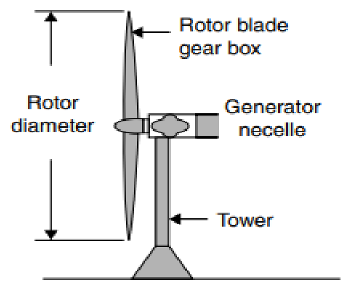

Figure 3.4 Horizontal axis wind turbine

Additionally, the blades are placed in a considerable distance in front of the tower and are sometimes tilted up a small amount. Nowadays, almost all commercial wind turbines connected to grid have horizontal-axis two-bladed or three-bladed rotors, The rotor is located at the top of a tower where the winds have more energy and are less turbulent. The tower also holds up a nacelle. The gearbox and the generator are assembled inside. There is also a yaw mechanism that turns the rotor and nacelle. In normal operation, the rotor is yawed to face the wind in order to capture as much energy as possible. Although it may be very simple in low power applications, the yaw system is likely to be one of the more complicated devices in high power wind turbines. Finally, the power electronics are arranged at ground level. Horizontal-axis wind turbines are the most common type used. All of the components (blades, shaft, and generator) are on top of a tall tower, and the blades face into the wind. The shaft is horizontal to the ground. The wind hits the blades of the turbine that are connected to a shaft causing rotation. The shaft has a gear on the end that turns a generator. The generator produces electricity and sends the electricity into the power grid. The wind turbine also has some key elements that add to efficiency. Inside the Nacelle (or head) is an anemometer, wind vane, and controller that read the speed and direction of the wind. As the wind changes direction, a motor (yaw motor) turns the nacelle so the blades are always facing the wind. The power source also comes with a safety feature. In the case of extreme winds, the turbine has a break that can slow the shaft speed. This is to inhibit any damage to the turbine under extreme conditions.

Advantages of Horizontal-axis Wind Turbines

1. Stability: Blades are to the side of the turbines' centre of gravity, helping stability.
2. Ability to wing warp: This gives the turbine blades the best angle of attack.
3. Ability to pitch the rotor blades in a storm to minimize damage: Variable blade pitch, which gives the turbine blades the optimum angle of attack. Allowing the angle of attack to be remotely adjusted gives great control, so the turbine collects the maximum amount of wind energy for the time of day and season.
4. Tall tower allows access to strong wind in sites with wind shear: In some wind shear sites, every 10 m up, the wind speed can increase by 20% and the power output by 34%.
5. High efficiency: Since the blades always move perpendicularly to the wind, and receives power through the whole rotation. In contrast, all VAWT, and the most proposed airborne wind turbine designs involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle. Backtracking against the wind leads to inherently low efficiency.
6. Tall tower allows placement on uneven land or in offshore locations.

7. Can be sited in forest above tree-line.
8. Most are self-starting.

Disadvantages of Horizontal-axis Wind Turbines

1. It is difficult to transport (20% of equipment costs) and install. Tall masts and blades are more difficult to transport and install. Transportation and installation can now cost 20% of equipment costs. Further, it requires tall cranes and skilled operators.
2. Strong tower construction is required to support the heavy blades, gearbox, and generator.
3. Effect radar in proximity reflections from tall HAWTs may affect side lobes of radar installations creating signal clutter, although filtering can suppress it.
4. Local opposition to aesthetics mast height can make them obtrusively visible across large areas, disrupting the appearance of the landscape, and sometimes creating local opposition.
5. Fatigue and structural failure caused by turbulence downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).
6. Difficult to maintain.
7. They require an additional yaw control mechanism to turn the blades toward the wind.

MATHEMATICAL MODEL OF EXTRACTION OF ENERGY FROM THE WIND

E = kinetic energy (J); r = density (kg/m3); m= mass (kg); S = swept area (m2); v = wind speed (m/s); Cp = power coefficient; P = power (W); r = radius (m); dm/dt = mass flow rate (kg/s); x = distance (m); dE/dt = energy flow rate (J/s); and t = time (s). Under constant acceleration, the kinetic energy of an object having mass m and velocity v is equal to the work done (W) in displacing that object from rest to a distance x under a force F, that is,

$$E = W = Fx$$

According to Newton's Law, $F = ma$. Hence, $E = max$

Using the third equation of motion, $V^2 = U^2 + 2ax$, it can be written that $a = (V^2 - U^2)/2x$

Since the initial velocity of the object is zero, $u = 0$, and hence, $a = V^2/2x$

Substituting it in Equation (6.5), the kinetic energy of a mass in motions is

$$E = ½\, mV^2$$

The power in the wind is given by the rate of change of energy:

$$P = \mathrm{d}E/\mathrm{d}t = ½\ \dot{m}\ V^2$$

The mass flow rate is given by, $= \rho S\mathrm{d}x/\mathrm{d}t$ and the rate of change of distance is given by

$$V = \mathrm{d}x/\mathrm{d}t.\text{Thus,} = \rho SV.$$

Substituting the abovementioned expression in Equation (6.7) yields

$$P = 1/2\ \rho SV^3$$

GEOTHERMAL ENERGY: Geothermal energy is the clean and sustainable heat resource from the Earth. It ranges from the shallow ground to hot water and hot rock found a few kilometres beneath the earth's surface and even deeper down to the extremely high temperatures of molten rock called magma.

The shallow ground of the earth's surface maintains a nearly constant temperature between 10°C and 16°C almost everywhere. The geothermal heat pumps can tap this resource to heat and cool buildings. Well bores can be drilled into underground geothermal reservoirs of hot water for hot water application and for the generation of electricity using binary cycle. Hot water near the surface of earth can be used directly for heating buildings, growing plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes like pasteurization of milk.

Hot dry rock geothermal resources occur at depths of 4–7 km everywhere beneath the earth's surface and at lesser depths in certain areas. The utilization of these resources involves injecting cold water down one well, circulating it through hot fractured rock, and drawing off the heated water from another well.

GEOTHERMAL SYSTEMS

The interior of the earth is shown in Figure 3.6. Under the Earth's crust, there is a layer of hot and molten rock called magma. Heat is continually produced there, mostly from the decay of natural radioactive materials such as uranium and potassium. The amount of heat within 10,000 m of the earth's surface contains 50,000 times more energy than that of all oil and natural gas resources in the world.

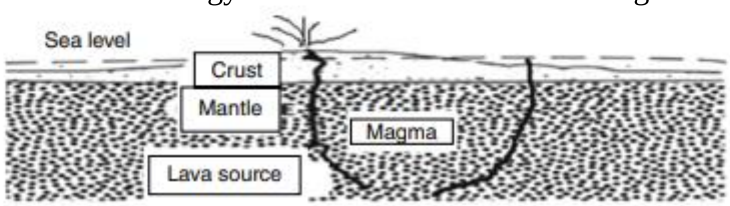

Figure 3.6 Interior of the earth

The temperature gradient between the magma and the earth's surface causes magma's heat to flow slowly towards the surface where it is lost to atmosphere. When magma is cooled, earth's crust is formed, which has reached an average thickness of only 32 km. Due to the highly irregular topography of the earth's surface, it is obvious that the crust has been subjected to considerable strains. As a result, mountain ranges are formed. Earthquakes quickly shift the earth's surface over large areas and some areas are in slow but perceptible motion relative to others. If magma breaks through the surface at the weak spots in the crust, the result is a volcano. In some other areas, deep faults in the crust permit surface water to come in contact with the hot solidifying magma. Additionally, the molten magma itself contains water which it releases as it solidifies. The heated water, or steam, rises to the surface and is emerged as hot springs.

The geothermal resource base is defined as total heat greater than 15°C in the earth's crust; but only a small portion of this storage of heat base can properly be considered as a resource. The magnitude of these resources depends on the evaluation of many physical, technological, economical, environmental, and governmental factors. Physical factors that control the distribution of heat at depth can be evaluated approximately; however, more complicated are the assumptions of technology, economics, and governmental policy. Differences among these assumptions, in large part, are responsible for the varying magnitudes of different geothermal resources.

Since nature allows only a tiny fraction of geothermal energy to leak through the surface, this energy has to be tapped. At present, geothermal exploitation is confined to thermal areas (geysers, hot springs, etc.) where the downward temperature gradient is exceptionally high when compared with the average of about 1°C per 31 m of depth.

In non-thermal areas, there are still immense reserves of heat below the ground level; however, at such depths, these cannot be tapped economically by the existing means. However, it is not inconceivable that, in the course of ways, may be found to penetrate some distance into magma (molten rock that forms the earth's crust) possibly with the help of underground nuclear explosions at a commercially acceptable cost.

Geothermal developments are unique in the sense that all activities related to resource production are localized to the immediate vicinity of the power plant or other utilization facility. Support operations such as mining, fuel processing, transportation, and other handling facilities do not exist. Thus, the environmental effects are solely site-dependent in origin.

CLASSIFICATIONS

From the improved scientific study of different geothermal systems developed so far, these systems have been grouped under the following two categories:

1. Vapour-dominated (dry steam) geothermal systems: This system are uncommon and poorly understood when compared to liquid-dominated system. Vapour-dominated system requires relatively potent heat supplies and low initial permeability. After an early hot water stage, a system becomes vapour dominated; that is, when net discharge starts to exceed recharge, steam boils from a declining water table and some steam escapes to the atmosphere. However, most of the steam condenses below the surface, where its surface of vaporization can be conducted upwards. The main vapour-dominated reservoir actually is a very deep water table, where the transmission is in the upward direction. Most liquid condensate flows down to the water table, but some may be swept out with steam in channels of principal upflow. Liquid water favours small pores and channels because of the high surface tension relative to that of steam. Steam is largely excluded from smaller spaces, but greatly dominates the larger channels and discharge from the wells.
2. Liquid-dominated (hot waters) geothermal systems: Many parts of the world consist of only hot water geothermal field at comparatively modest temperatures and low enthalpies. Despite the unsuitability of hot water for use in power production, there have been direct heating applications far exceeding in total heat equivalent of existing geothermal electricity generating facilities.

GEOTHERMAL RESOURCE UTILIZATION

In the following sections, we discuss about the extensive use of geothermal energy, one can imagine.

1 Direct Use of Low Grade Geothermal Energy

1. Aquaculture and horticulture: Geothermal renewable energy is used in aquaculture and horticulture in order to raise plants and marine life that require a tropical environment. The steam and heat are all supplied by geothermal energy. Many farmers use geothermal power to heat their greenhouses. In Tuscany, Italy, farmers have used water heated by geothermal energy for hundreds of years to grow vegetables in the winter. Hungary is also a major user of geothermal power. Eighty percentage of the energy demand from vegetable growers is met by using geothermal energy. It is also used in fishing farms. The warm water spurs the growth of animals ranging from alligators, shellfish, tropical fish, and amphibians to catfish and trout. Fish growers from countries like Oregon, Idaho, China, Japan, and even Iceland use geothermal power.
2. Industry and agriculture: Industries are another consumers of geothermal energy. Their uses vary from drying fruits, vegetables, and wood, dying wool to extracting gold and silver from ore. It is also used to heat sidewalks and roads to prevent freezing in the winter. Thus, geothermal power generation is playing a major role in industry and agriculture. Timber is dried using heat acquired from geothermal energy, and paper mills use it for all stages of processing. There are many potential uses of geothermal energy in the industry.
3. Food processing: The earth naturally contains an endless supply of heat and steam, which can be utilized to sterilize equipment and rooms. This would put an end to the use of chemicals for this

purpose. There are many potential uses of geothermal energy in food processing, but as yet, this renewable energy source has yet to be utilized to a large degree in this sector.

4. Providing heat for residential use: The most common use of geothermal energy is for heating residential districts and businesses. The first uses of geothermal fluid for heating a district in United States dates back to 1893.

2 Electricity Generation

It provides not just heat and steam, but electricity itself. Geothermal power generation is completely clean, and releases no harmful gas emissions whatsoever. Geothermal fluid is a good electricity generator as well. Conversion technology for electricity generation is as follows:

1. Flashed Steam Plants: The water 'flash' boils and the steam is used to turn turbines.
2. Dry steam plants: These plants rely on the natural steam that comes from the underground reservoirs to generate electricity.
3. Binary power plants: These plants use the water to heat a 'secondary liquid' that vaporizes and turns the turbines. The vaporized liquid is then condensed and reused.
4. Hybrid power plants: In these plants, binary and flash techniques are utilized simultaneously.

RESOURCE EXPLORATION

Geothermal exploration involves outlining broad regions where the heat flow is significantly greater than 1.5×10^{-6} cal cm^{-2} s^{-1}. Most of these regions with high heat flow are in zones of early volcanic and tectonic activity, and most of them are characterized by hot springs. Techniques for identifying potentially economic concentrations of geothermal energy within broad regions of high heat flow are not well developed. Important consideration included distribution of hot springs, evaluation of volcano and tectonic setting, and chemical analysis of hot springs fluids. In particular, the silica content and the ratio of sodium, potassium, and calcium provide information about the minimum subsurface temperature to be expected. The methods that play major role in geothermal exploration techniques are geological, geochemical, electrical, seismic, gravitational, magnetic, and thermal methods.

Some important geological research problems are concerned with the determination of age, size, and magnetic type of igneous occurrences related to convective hydrothermal and permeable rock systems and the relationship of convective hydrothermal systems to broad region of elevated heat flow. Geological study of the surface is done by the collection and analysis of samples. With the refinement of aerial photography, geological study has greatly been simplified. Aerial photography is the most useful method to detect the geothermal sources by means of remote sensing and thermal scanning. Such photographs are invaluable in the geothermal surveys. The use of radar is of great help for obtaining good quality pictures through cloud covers.

Infrared scanners can distinguish negligible temperature differences. Thus, aerial surveys with infrared scanners have great future in the detection of geothermal resources.

Several geophysical techniques have proved useful in the final delineation of geothermal targets. Of these techniques, perhaps most unambiguous is the direct measurement of temperature gradient at the depth 25–100 m. However, it can be misleading primarily owing to the effect of seasonal changes in the temperature and to the shallow movement of groundwater. Several techniques that measure the electrical conductivity at depth have had great success in geothermal exploration. The conductivity at depth varies directly with temperature, porosity, salinity of terrestrial fluid, and content of clays and zoolatrous. All these factors tend to be high within good, and consequently, the electrical conductivity in these geothermal reservoirs is relatively high. Electrical conductivity at depth can be measured by electrical (galvanized) or electromagnetic (induction) methods. Among the electrical techniques, only direct methods are reliable owing to skin effects of an AC current. Electrical resistivity techniques should be directed towards the understanding of the variation of porosity, water salinity, and temperature in actual geothermal reservoirs, improving electric field techniques and procedures for extracting true resistivity values from field data, and developing complementary exploration techniques that will improve the interpretation of resistivity data. Other electrical exploration research should include further work on the resistivity, self-potential, electromagnetic, telluric, and magnetotelluric techniques.

GEOTHERMAL-BASED ELECTRIC POWER GENERATION

Geothermal-based electric power generation technology represents the entire process of turning hydrothermal resources into electricity. Of the four available to developers, one of the fastest growing is the binary cycle, which includes a Rankine cycle engine.

1 Dry Steam-based Geothermal Power Plants

Figure 3.7 shows a dry steam plant. The basic cycle for steam plants remains similar to the structure that was first operated in 1904 in Larderello, Italy. Even so, incremental technology improvements continue to advance these systems.

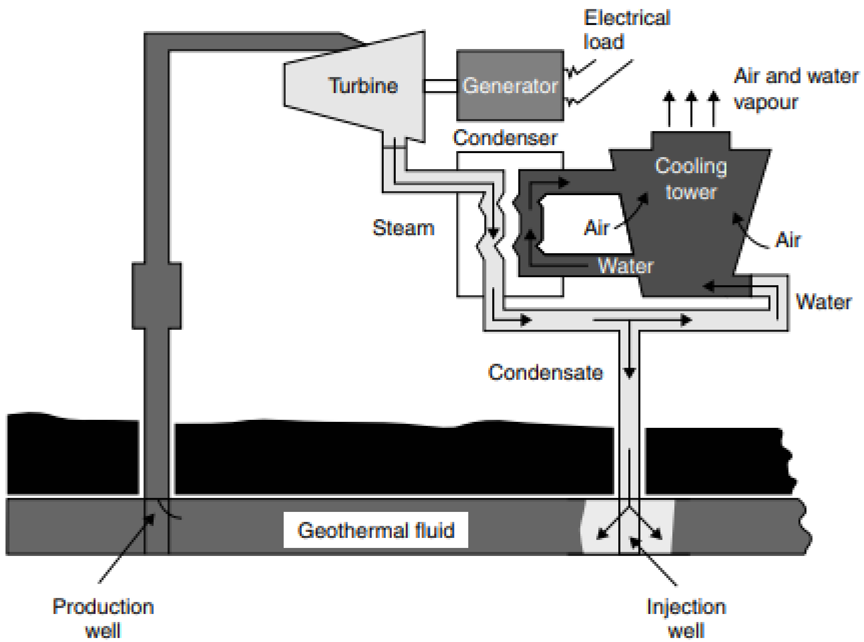

Figure 3.7 Dry steam geothermal electric power plant

Dry steam plants have been operating for over 100 years—longer than any other geothermal conversion technology, though these reservoirs are rare. In a dry steam plant, steam produced directly from the geothermal reservoir runs the turbines that power the generator. Dry steam systems are relatively simple, requiring only steam and condensate injection piping and minimal steam cleaning devices. A dry steam system requires a rock catcher to remove large solids, a centrifugal separator to remove condensate and small solid particulates, condensate drains along the pipeline, and a final scrubber to remove small particulates and dissolved solids.

BINARY CYCLE-BASED GEOTHERMAL PLANTS

In the binary process, the geothermal fluid, which can be either hot water, steam, or a mixture of the two, heats another liquid such as isopentane or isobutane (known as the 'working fluid'), that boils at a lower temperature than water. The two liquids are kept completely separate through the use of a heat exchanger that is used to transfer heat energy from the geothermal water to the working fluid. When heated, the working fluid vaporizes into gas and (like steam) the force of the expanding gas turns the turbines that power the generators. Technology developments during the 1980s have advanced lower temperature geothermal electricity production. These plants, known as 'binary' geothermal plants, today make use of resource temperatures as low as 74°C (assuming certain parameters are in place) and as high as 177°C. Approximately 15% of all geothermal power plants utilize binary conversion technology. It is shown schematically in Figure 3.8

Source: Geo-Heat center

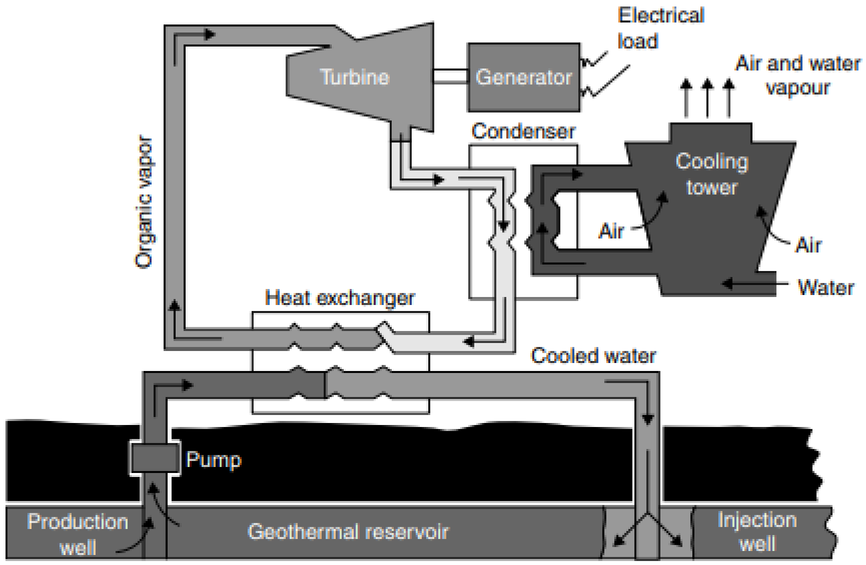

Figure 3.8 Binary cycle-based geothermal electric power plant

ASSOCIATED PROBLEMS

A major problem of geothermal power is the estimation of the power life of the reservoir to make a reasonably accurate decision on the size of station to be built. The financial life of such a station should be sufficiently long in which the borrowed money methods have been developed for predicting the reservoir with unique features, and the prediction of life of reservoir is only determined on the basis of historical development; thus, the assessment of field life remains a subject of current interest.

The second problem is associated with the separation of steam from the steam-water mixtures at the well heads and transmission of steam only through a long pipeline to the power house.

In spite of large and extensive commercial development at Larderello and Geysers, the origin and nature of the geothermal systems that yield dry steam and why they differ from the abundant hot water systems are yet unknown.

Another important problem is the selection of materials that are suitable for geothermal systems and plants. Materials should have large resistance to corrosion for the gaseous products and properties to fulfil the electromechanical and other requirements.

As the automatic-start control is rather expensive, manual-start control is used. Thus, an operating condition serious enough to trip the unit requires investigation at the plant before the unit is restarted.

ENVIRONMENTAL EFFECTS

Considerable attention has been made that can have relatively small effect on the environment. Although environmentalists have reasons to believe that geothermal energy may prove to be the cleanest source of convertible power readily available, certain undesirable effects can extend for several kilometres from the geothermal field itself; thus, they introduce environmental problems into the surrounding regions. These damages to environment that are inherent in geothermal development need careful study and solutions must be found to control them at reasonable costs. The potential effects on the environment of most immediate concern are gaseous and particulate emission, land pollution, subsidence potential, and seismic consideration, biological, and social effects. Research should be directed towards accurate determination and evaluation of their characteristics and magnitude.

1 Gaseous and Particulate Emission

Fluids drawn from the deep earth carry a mixture of gases, notably carbon dioxide (CO_2), hydrogen sulphide (H_2S), methane (CH_4), and ammonia (NH_3). These pollutants contribute to global warming, acid rain, and noxious smells if released. Existing geothermal electric plants emit an average of 122 kg of CO_2 per megawatt-hour (MWh) of electricity and a small fraction of the emission intensity of conventional fossil fuel plants. Plants that experience high levels of acids and volatile chemicals are usually equipped with emission-control systems to reduce the exhaust emissions. In addition to the dissolved gases, hot water from geothermal sources may hold in solution trace amounts of toxic chemicals such as mercury, arsenic, boron, and antimony. These chemicals precipitate as the water cools and can cause environmental damage, if released. The modern practice of injecting cooled geothermal fluids into the earth to stimulate production has an additional benefit of reducing this environmental risk. Some of the noxious materials creating air pollution from the existing geothermal steam power plants are hydrogen sulphides, mercuric compounds, radioactive materials such as lead 210 and radon 222. Research must be applied to identify the chemical composition of the noncondensable gas derived from geothermal reservoirs and to quantity permissible exposure limit. Based on these findings, methods for containment and safe disposal of these materials must be developed. Concomitant with these research efforts, there is a need to develop the analytical techniques and instrumentation to monitor and control the discharge of these materials.

Similar research must be directed towards the emission of particulate matter. Particulate emission from an operating geothermal power plant may not readily appear, but it can occur. The basic needs of research are thus to identify, quantity, and regulate the disposal of gaseous and particulate matter from geothermal resources.

2 Land Pollution

In relation to the problem of land surface pollution, research is to be directed towards preventing the degradation of usable soil and towards the control of on-site surface disposition of pollutant that may be transported subsequently from the site of production to the surrounding environment. Types of the geothermal field complicate these problems. With regard to vapour-dominated system, research is needed to identify and quantify all pollutants (such as Hg, As, Se, and Pb210) in the vapour phase of a geothermal source and at each site proposed for development.

In connection with the water-dominated geothermal system, the effects of accidental run off of geothermal fluids from the production site to surrounding land areas need to be assessed with an identification of surface-deposited material that may harm plant, soil sterility, or be subjects to biological magnification and entrance into food chains. Blowout contingency plans to minimize land pollution by chemical deposition and to control possible erosion are needed at each developed site.

3 Subsidence Effect

It has been investigated that subsidence occurs in some areas when a fluid is removed from the ground, while in other areas, the removal of equal quantities of fluid produced no measurable subsidence. Subsidence effects are better understood from studies of booth petroleum and groundwater reservoir; however, very little has been gathered from the production of geothermal fluids. The tools and techniques for these studies are presently available.

4 Seismic Hazards

Mostly, the geothermal resource areas are closely associated with the regions of high geologic activity, which is manifested most commonly as earthquakes. Studies have shown that if fluid pressures are changed in regions of tectonics stresses, fluid pressures are also changed in regions of earthquake activity. Present research is being directed towards resolving many questions regarding seismic activities and some of the information can be applied to geothermal field. However, seismic monitoring stations should be established near productive geothermal areas to determine if patterns emerge; these patterns appear to be related to the removal or injection of fluids from geothermal reservoirs.

5 Water Pollution

A possible risk associated with the development and utilization of geothermal resources is the contamination of surface and groundwater by geothermal fluids. Although earlier tools and techniques developed can be applied, but specific research is required to identify those chemical constituents, which may have a detrimental effect. Sample collection, analysis, and procedures should be developed where they are presently lacking or are too expensive for widespread field application with particular reference to injection of geothermal fluids. Chemical and isotopic studies should be undertaken to determine if geothermal fluids will return to the reservoir from which they are produced or if they migrate into other reservoirs.

6 Biological Effects

Numerous unknown effects exist regarding the impact of geothermal operation upon the bionature to prospective resource area as well as areas presently under exploration or development. Given the delicate balance of natural environment, damage to many species of plant and animal life can take place through changes of chemical balance in soil and water, the use of toxic substances in industrial application, the destruction of such specialized habitants as thermal pools alpine meadow, the interruption of migratory patterns, long term alteration in humidity, and the introduction of human presence, and activity into formerly unaffected regions. These and other factors need critical study in representatively selected geothermal resource areas to determine necessary procedures for the adequate protection of plants and animal life in regions of development.

7 Social Effects

Serious social effects arising from geothermal resource development, which need research, involve problems of noise and land use. Sociological, economical, and planning studies are greatly needed to determine public policy for the equitable resolution of conflicts of land use arising in these cases.

SOLID WASTES AND AGRICULTURAL REFUSE

Waste has always been the negative side of the economy. In production and consumption, it is wasteful matter always available in energy activity system that is rejected as useless, harmful things that damage the environment. Waste is also known as the garbage waste, rubbish, refuse, etc. The social task of waste management has been to either minimize or to completely get rid of it. Traditional way of waste removal is to carry away them through sewers and dustbins, dispatched in the air through burning, dumped in disused quarries or the oceans, or fly-tipped in gutters or behind hedges. The availability of free places for dumping waste in near future and associated environmental problems have created the need to find some new ways for efficient waste utilization and environmental protection.

WASTE IS WEALTH

All the wastes and waste management concepts are, therefore, now changing. Globally, the focus is to modify all resources from waste to wealth or from trash to cash; both are as good as having the better of two words. Three basic drivers of change are turning waste and waste management into a dynamic, fast changing, and international economic sector. This transformation presents new choices and opportunities and provides lessons and pointers for industrial, social, and environmental policy in the new post-industrial landscape. The following are some of the driving forces of change:

1. Growing concern about the hazards of waste disposal
2. Broad environmental concerns, especially global warming and resource depletion
3. Economic opportunities created by new waste regulations and technological innovation
4. Since the fuel shortage today is widely recognized not only as a political problem but also as agricultural problems as they are also consuming the great proportions of fuels and hence they have started thinking that fuels can be produced as an agricultural crop.The following are the three main concepts have been introduced for converting waste materials to usable fuel and energy with main concern of minimizing the environmental damage.

1. Heat energy generation: Waste is used as supplemental boiler fuel and heat energy is obtained by the direct combustion of the waste to heat energy.
2. Bioenergy generation: It is a modern method of hazards control of waste disposal and for the recovery of fuels and energy (such as methane). Biological methane generation have commercially potential for energy resource recovery.
3. Eco-modification through recycling: Improved and efficient design of process and products reduces the health hazards and increases the resource productivity. Recycling conserve material, fuel, and energy by lengthening their life span.
4. Fuel and energy generation from forest and agricultural and municipal wastes: In order to cope up with fuel and energy shortages, all such wastes are considered as raw resources for converting them into improved fuels and energy.

1 Incinerators

Incinerator is precisely a furnace where waste is burnt to produce energy. Burning waste in incinerators only reduces the volume of solid waste, but it does not dispose the toxic substances contained in the waste and creates the largest source of dioxins.

The burning of waste produces heat that boils the water. Thus, the steam obtained is used to convert heat energy into electrical energy by thermo electromechanical converters. As already stated, the flue gases coming out of simple incinerator contain toxic gases (hazardous gases such as furans and dioxins).

Modern incinerators are equipped with pollution improvement systems to remove health hazardous gases. Incinerator combustion temperature of about 1000°C is maintained for complete combustion of wastes to reduce chlorine-enriched organic substances. Flue gases are sent through scrubbers for the removal of dangerous chemicals. A high chimney having cooling systems is installed as it removes the hazardous gases. Cost and efficiency are considered as the main parameters for selecting incinerator as a method of waste disposal. However, they can be thought of as a sustainable energy production system.

Incineration with recovery of energy is considered the best method of waste management and dominates over plain incineration and landfill. Incineration converts solid waste into ash, flue gas, and heat. Still with the incineration, some quantity of about 10% waste is produced that of original wastes.

2 Pyrolysis

Pyrolysis provides an alternative to methods of municipal waste disposal (such as anaerobic digestion, landfill storage, and more specifically incineration). In this technology, organic waste is burnt at relatively low temperatures to produce char (like charcoal), oils, and combustible gases. The oils can be used as a chemical feedstock and as fuel. Feedstock includes mixed waste, plastics, tires, and sewage sludge. Essentially, it involves chemically mining (a form of treatment that chemically decomposes organic waste materials by heat in the absence of oxygen under pressure and at operating temperatures above 430°C) the waste to produce elements that can be used for energy generation or chemical inputs.

In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur. Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. The off-gases may also be treated in a secondary thermal oxidation unit (secondary combustion chamber), flared, and partially condensed. Particulate removal (such as fabric filters or wet scrubbers) is also required. Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, and fluidized bed furnace. These units are similar to incinerators except that they operate at low temperatures and with less air supply.

Pyrolysis transforms hazardous organic materials into gaseous components, small quantities of liquid, and a solid residue (coke) containing fixed carbon and ash. Pyrolysis of organic materials produces combustible gases, including carbon monoxide, hydrogen and methane, and other hydrocarbons. If the off-gases are cooled, liquids condense producing an oil or tar residue and contaminated water.

Pyrolysis liquids can be used directly (e.g., as boiler fuel and in some stationary engines) or refined for high quality uses such as motor fuels, chemicals, adhesives, and other products. Direct pyrolysis liquids may be toxic or corrosive.

3 Anaerobic Digestion

Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. Anaerobic digester is an airtight chamber in which organic waste is decomposed and transformed into biogas by a biological process called anaerobic digestion.

One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.

A range of anaerobic digestion technologies are converting livestock manure, municipal wastewater solids, food waste, high strength industrial wastewater and residuals, fats, oils and grease (FOG), and various other organic waste streams into biogas for 24 × 7. Separated digested solids can be composted, utilized for dairy bedding, directly applied to cropland, or converted into other products. Nutrients in the liquid stream are used in agriculture as fertilizer.

4 Recycling

Waste control and reduction depends on complex flows and simple or specialist treatment. It is organized around material streams and creates a circular flow of separate materials as an alternative to the linear flow of mass waste. Its central concept is the ‘closed loop’. As a result, the innovations of eco-modified recycling are in collection systems rather than high tech plants. The cost of collection and sorting has been one of the main barriers for increasing recycling among households and small traders. It involves the collection of used and discarded materials in order to process these materials and make them into new products. It reduces the amount of waste that is thrown into the community dustbins, thereby making the environment clean and the air fresh to breathe. Recycling is an economic development as well as an environmental tool. Reuse, recycling, and waste reduction offer direct development opportunities for communities. When collected with skill and care, and upgraded with

quality in mind, discarded materials are local resources that can contribute to local revenue, job creation, business expansion, and the local economic base.
Recycling-based economic development has been the heart of Waste to Wealth program of national economy. Recycling and reusing reduce the pressure on primary resources. In some sectors, such as machinery, cars, and household appliances, there has been a long-term practice of scrap recycling; however, substantial amounts are still landfilled along with precious metals and other materials in electronic goods. Alongside its potential for the environment, economy, and local regeneration, recycling also offers many social benefits.

5 Bioenergy Conversion
Bioenergy conversion seems to be the most promising energy conversion techniques, specifically for India in near future probably because of the following points:
1. Absence of or the difficulties related to the installation of centralized power supply systems.
2. Increasing energy demand for energy even in remote rural areas or isolated parts of the country.
3. Basic need for large amounts of protein for food and feeding purpose.
4. Inexpensive methods available for collecting and storing of energy.

Energy schemes utilizing plant (biomass) as source of liquid fuel (such as ethanol or methanol) are therefore worth attempting in addition to electrical power generation. The production of usable energy through algal and similar crops includes the following three important conversion steps.
1. Photosynthesis production of organic matters.
2. Collection and processing of plant materials.
3. Fermentation of the organic matters, leading to liquid and gaseous fuels and storage.

Sugar crops, trees, grains, and grasses are various aquatic fuel sources and have relative potentials on each other utilized in any biomass production schemes. Sugar crops and algal crops seem to be the most promising crops of importance suitable for bioenergy conversion in India.

KEY ISSUES
The following are the key issues that must be investigated before the economic viability of a refuse-derived fuel (RDF) scheme:
1. Collection of waste from doorsteps, commercial places, community dump, and final disposal sites.
2. The volume and nature of refuse to be processed.
3. The type of efficient RFD process required and market for fuel products.
4. The required potential users and the revenue obtainable.
5. The economy of the alternative method of disposal of the refuse.
6. The utilization of solar thermal energy for increasing the temperatures of digesters.

WASTE RECOVERY MANAGEMENT SCHEME
A simple waste, refuse resource recovery scheme can be understood from Figure 3.9, which represents the various important scheme components as energy use and solid waste generation, transportation, storage, energy recovery, treatment, and final disposal of the waste. The major part of waste obtained after the energy utilization are non-organic that have diversified nature and characteristics, and thus, their identification and separation from the main waste stream by improved techniques are an essential parameter of any energy recovery scheme. On-site processing of waste for the reduction of in-home compactors and industrial shredders through improved technology should be employed, which may be environmentally acceptable. Collection and transportation components of the waste energy conversion scheme are the most expensive components owing to many varying social, technical, and other reasons. A careful cost analysis and implementation of this vital component will minimize the running cost of the

scheme. The storage of waste for resource recovery and final disposal after suitable treatment is another component of scheme and selection of storage station and other associated problems invite careful attention. Normally, two types of energy recovery systems are used:

1. Separation of metals, paper, and glass from the remaining waste through the process such as size reduction, screening, vibrating sorting, and electronic scanning; however, a truly homogeneous, inexpensive separation system will provide competitive input to waste energy utilization.
2. Conversion of the remaining waste product to usable form of energy and energy conversion may include the following:

(a) Generation of methane gas (biogas conversion) or other fuels (biological conversion)
(b) Generation of electricity either from (a) or through thermo-mechanical process
(c) Composting of fertilizers

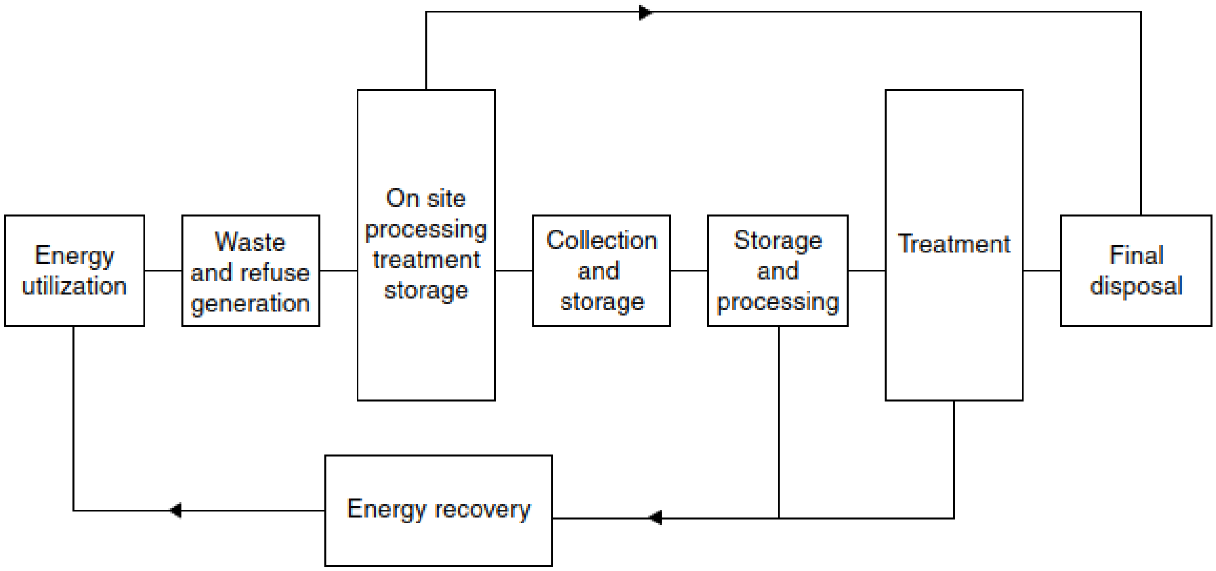

Figure 3.9 Schematic representation of waste refuse energy management

1 Treatment

Here, the treatment means that those process designed to reduce waste to innocuous forms without or after energy recovery. The most familiar techniques are the burning of waste at high temperatures in the presence of oxygen (known as incineration) and the breaking down of the complex compounds using heat in the absence of oxygen (known as pyrolysis). However, treatment techniques should be selected so as to be accepted socially, environmentally, and economically. The cheapest method for final disposal of waste before or after energy recovery is a systematic burial in ground.

ADVANTAGES AND DISADVANTAGES OF WASTE RECYCLING

1 Advantages of Waste Recycling

Recycling is a process of using old or waste products into new products; this is an important step towards energy conservation (to reduce energy usage and reduce the consumption of fresh raw materials) and reduction in pollution (to reduce air, water, land pollution, and greenhouse emissions).

1. Reduced damage to environment: This is the foremost advantage of recycling and this promotes environmental protection in a balanced manner. For instance, let us consider the case of cutting down trees for paper production; here, individuals can create balance by recycling old used papers and new paper products made from trees. In such a way, deforestation and felling is reduced. Natural resources are conserved this way.

2. Reduced consumption of energy: Large amount of energy is consumed when raw materials are processed during manufacturing. Therefore, recycling helps reduce energy consumption making production process beneficial and cost effective. It leads to reduced utilization of raw materials. It ensures additional energy availability and saving money. It reduces the creation of waste at source.

3. Reduced environmental impact and pollution: At present, industrial waste is major source of pollution. Recycling industrial products such as plastics and cans help a lot in cutting down levels of pollution for the reason that these materials are being reused instead of being thrown away irresponsibly. It saves on requirement of open landfill spaces, the surroundings clean and healthy. It also reduces environmental impact of traditional methods of waste treatment and disposal.

4. Mitigate global warming: Recycling aids in alleviating or lessening global warming and its harsh effects. Today, massive waste is being burned producing large amount of greenhouse gas emissions. Therefore, recycling is an effective way of ensuring that the process of burning is reduced and waste are regenerated and converted to useful and eco-friendly products without creating harmful impact to the environment.

5. Promotes sustainable utilization of resources: Recycling promotes sustainable and wise use of resources. This activity helps ensure that there is no discriminate use of materials and resources saving them for possible use in the future.

2 Disadvantages of Waste Recycling

1. High cost of recycling: The establishment of separate facilities in order to process products and make them reusable is cost effective. This might somehow trigger pollution in terms of transporting the materials and cleaning activities.

2. Durability and small life span of recycled items: The durability and efficiency of recycled products does not guarantee 100%. Recycled products are sometimes taken from cheap and overused materials; therefore, there is no assurance that it can last for long.

3. Unsafe and unhygienic process: Recycling sites and processes are often unhygienic and unsafe and this might pose dangers to your health.

SOURCES AND TYPES OF WASTES

The following are some of the wastes:

1. Residential wastes: These are single family or multifamily dwellings. They constitute kitchen wastes, paper and cardboards, clothes and leather materials, plastics and rubber materials, glass, wood and metal crockery and furniture, electrical and electronics appliances and gadgets, etc.

2. Municipal services wastes: They include general wastes collected from street sweeping, park, recreational places, sludge, landscaping, and tree trimming.

3. Industrial and commercial wastes: They are housekeeping and food wastes, packaging and demolition material wastes, scraps, hazardous wastes, wood, cardboard paper, plastics, etc.

4. Building construction and demolition: They constitute various types of wastes such as wood, concrete, steel, and dust.

5. Agriculture: It consists of dairy and agriculture farm crop wastes, hazardous pesticides, etc.

RECYCLING OF PLASTICS

Plastics play an important role in almost every aspect of our lives. Plastics are durable; their toughness and inertness are what make them so useful. Unfortunately, they are so durable that they break down very slowly in a landfill. Plastics are used to manufacture everyday products such as beverage containers, toys, and furniture. The widespread use of plastics demands proper end of plastic life management. The largest amount of plastics is found in containers and packaging (e.g., soft drink bottles, lids, shampoo bottles), but they also are found in durable (e.g., appliances, furniture) and nondurable goods (e.g., diapers, trash bags, cups and utensils, medical devices). The recycling rate for different types of plastic varies greatly. Plastics are a versatile material that can be a valuable asset to recycling program.

Plastics can be divided into two major categories:

1. Thermosets: A thermoset solidifies or 'sets' irreversibly when heated. They are useful for their durability and strength and are, therefore, used primarily in automobiles and construction applications. Other uses are adhesives, inks, and coatings.
2. Thermoplastics: A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres.

According to most estimates, 80% of post-consumer plastic waste is sent to landfill, 8% is incinerated, and only 7% is recycled.

Since the production of plastics uses 8% of the world's oil production, it is in the best interests to recycle plastics. In addition to reducing the amount of plastics waste requiring disposal, recycling plastic will reduce the consumption of non-renewable fossil fuels, energy, the amount of solid waste going to landfill, and the amount of carbon emissions.

Recycling plastic material is one of the important environmental agenda defined in the three R's. Instead of simply reusing the material as it is, successful chemical reusing is a more effective way for reducing the use of natural resources and environmental damage incurred thereof. An effective process and a pertinent effective plant that successfully converts plastic wastes into wax-free hydrocarbon such as naphtha and diesel oil is an important plastic recycling system. Plastics from Municipal Solid Wastes (MSW) are usually collected from curbside recycling bins or drop-off sites. Then, they go to a material recovery facility, where the materials are sorted by plastic type, baled, and sent to a reclaiming facility. At the facility, any trash or dirt is sorted out, then the plastics are washed and ground into small flakes. A flotation tank may be used to further separate contaminants based on their different densities. Flakes are then dried, melted, filtered, and formed into pellets. The pellets are shipped to product manufacturing plants, where they are made into new plastic products.