POWER FROM RENEWABLE ENERGY

Renewable Energy Trends

Renewable energy resources are those that come from natural energy flows of the earth such as solar, wind, geothermal, ocean thermal, tides, waves, hydraulic, agricultural residue, firewood, plant growth, animal dung, municipal wastes, and even domestic garbage. They naturally occur, recur, sometimes periodically, do not deplete, are almost inexhaustible, replenished constantly, and are free for the taking.

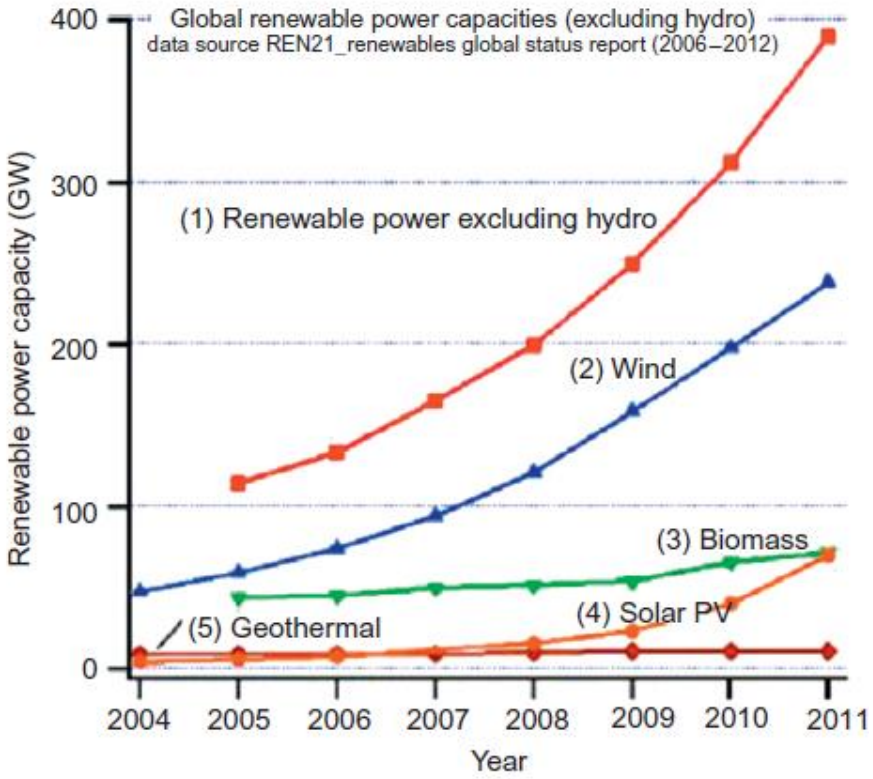


Figure A.2 Growth of a power capacity from renewable energy, barring hydro

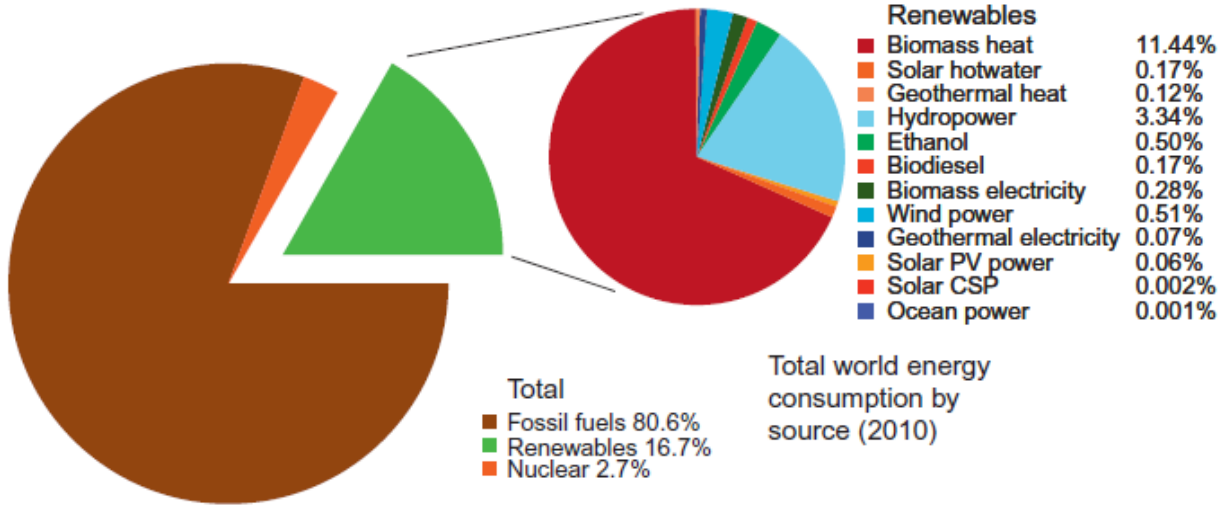


Figure A.1 Sources of worldwide energy consumption

Solar Energy

- Every moment the total quantity of solar energy incident upon the the earth is immense.
- Not withstanding such potential, the main drawback of solar energy is it is very diffusing, cyclic, at times undependable, and it doesn’t work at night without a battery-type storage device. It also suffers from atmospheric interference from clouds, particulate matter, gases, etc.
- Solar technologies are very expensive and requires large space



Solar radiation may either be converted into thermal or photovoltaic energy to generate electricity. In the thermal type, solar thermal collectors, which are mirrors, gather the sun's energy (which spreads over a large area) and focus this distributed energy into a small beam. This high-energy beam is then directed onto receivers containing the working fluid of a thermodynamic cycle to produce mechanical work and electricity.

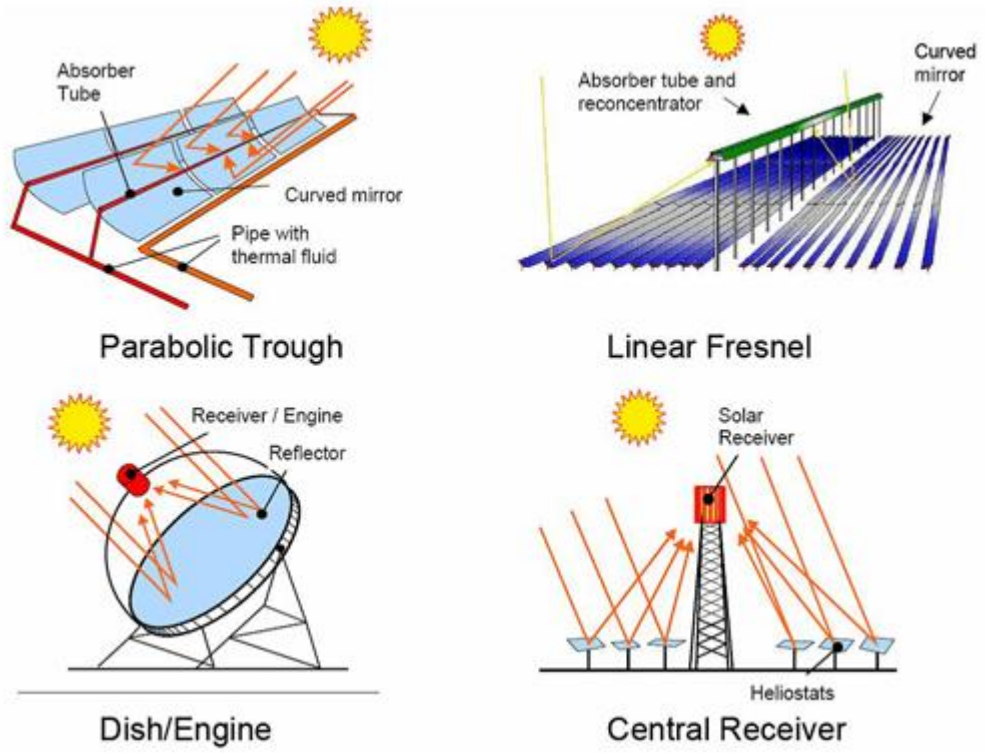
Photovoltaic systems consist of direct-conversion devices in the form of cells made of semiconductor materials. As sunlight hits these cells they convert the solar radiant energy light photons into electric current using the photoelectric effect and generate electricity.

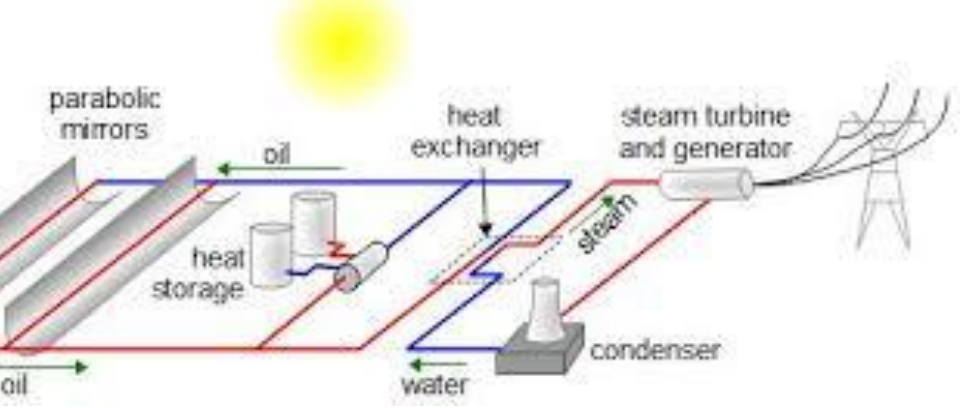


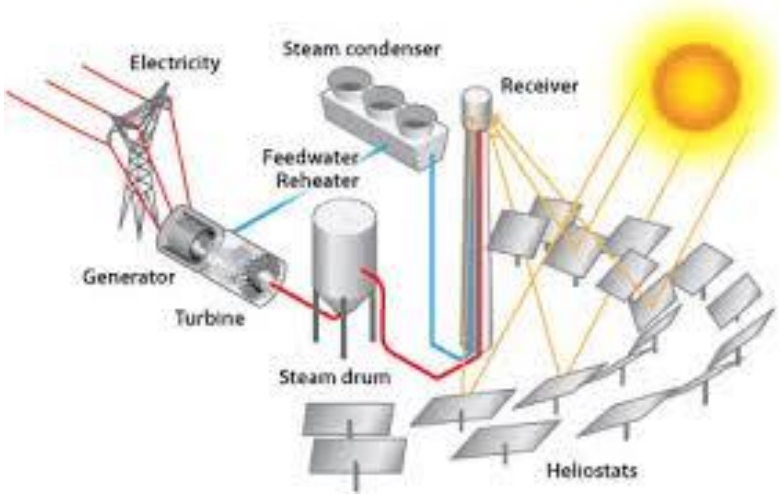
Utility-scale PV system prices

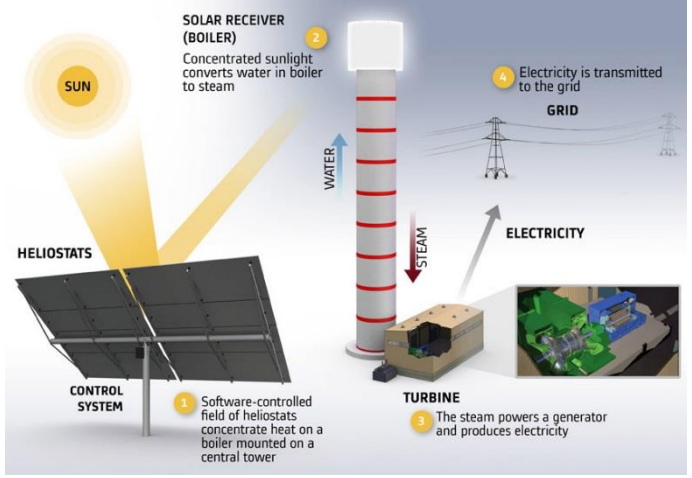
Country	Cost ($/W)
Australia	2.0
China	1.4
France	2.2
Germany	1.4
Italy	1.5
Japan	2.9
United Kingdom	1.9
United States	3.3
For utility-scale PV systems in 2013[120]:15	

In 2011, the International Energy Agency (IEA) stated that “the development of affordable, inexhaustible and clean solar energy technologies will have huge longer term benefits. It will increase countries’ energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise.”

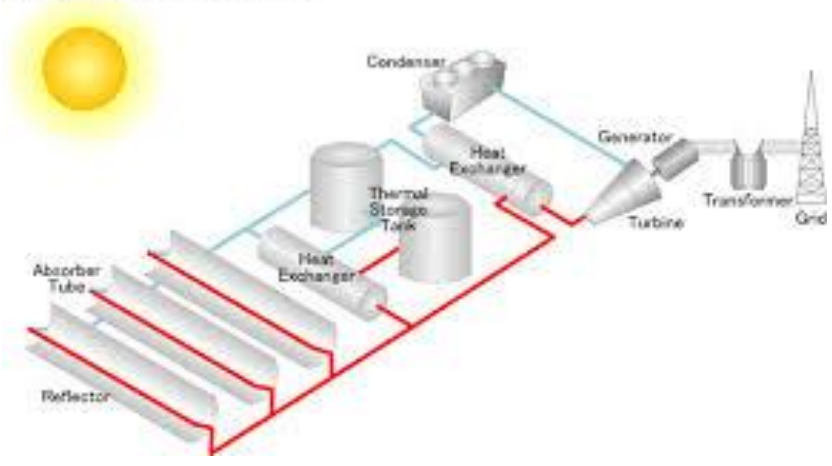


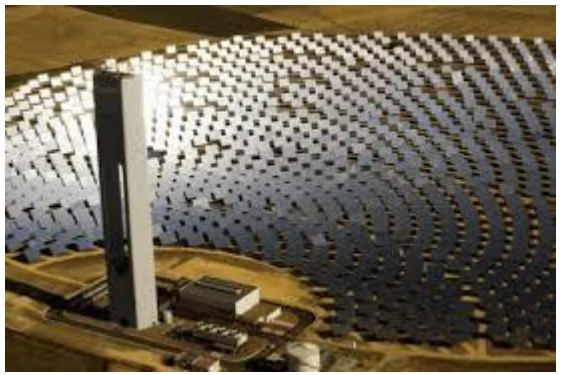


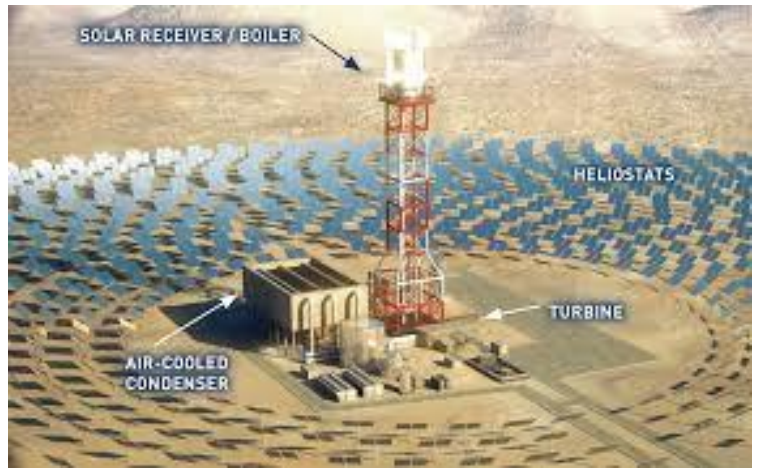




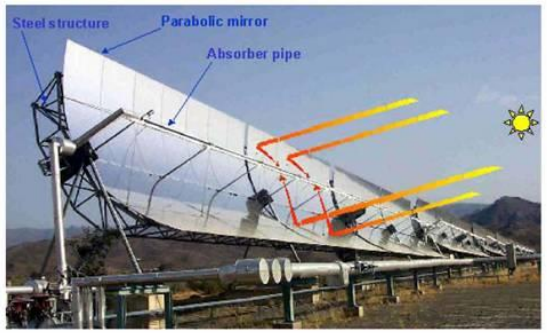
Example of Trough Technology















Solar dish

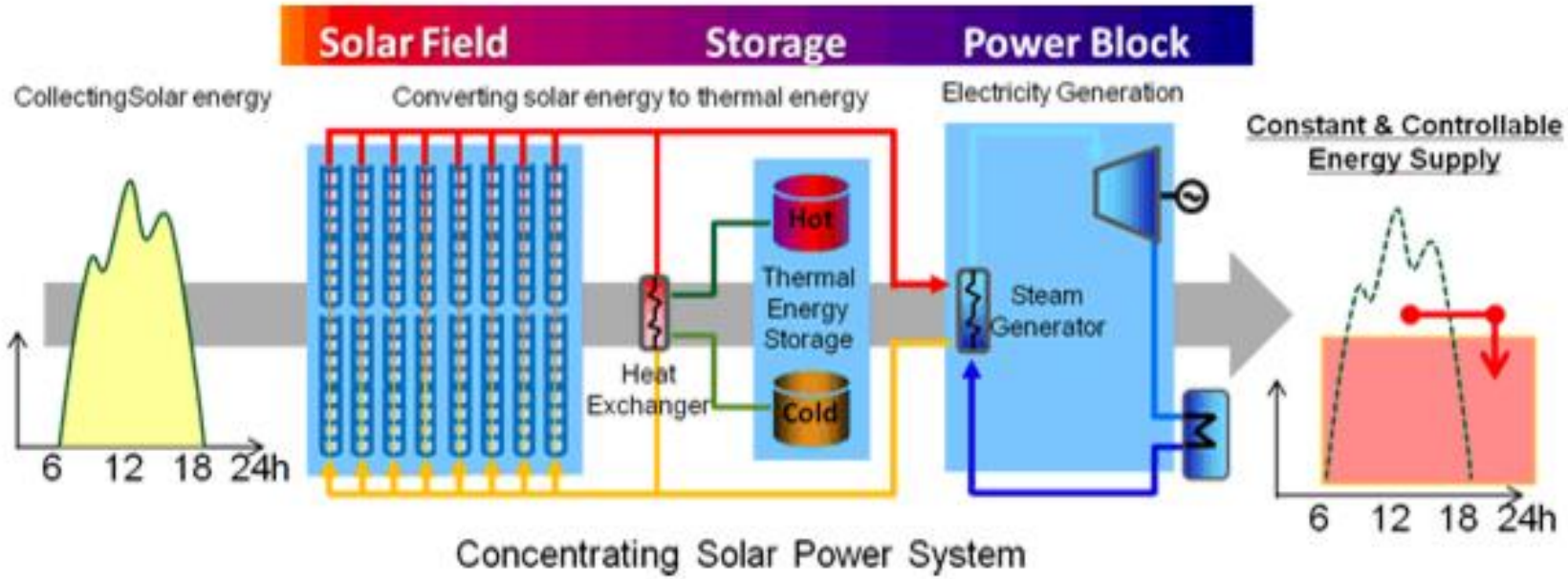
Dish/engine systems use a parabolic dish of mirrors to direct and concentrate sunlight onto a central engine that produces electricity. The dish/engine system is a concentrating solar power (CSP) technology that produces smaller amounts of electricity than other CSP technologies—typically in the range of 3 to 25 kilowatts—but is beneficial for modular use. The two major parts of the system are the solar concentrator and the power conversion unit.

The engine/generator system is the subsystem that takes the heat from the thermal receiver and uses it to produce thermal to electric energy conversion. The most common type of heat engine used in dish/engine systems is the Stirling engine. A Stirling engine uses the heated fluid to move pistons and create mechanical power. The mechanical work, in the form of the rotation of the engine's crankshaft, drives a generator and produces electrical power.





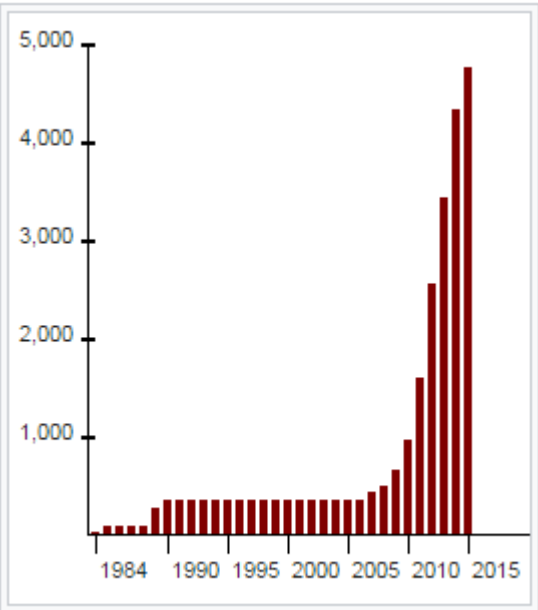
Concentrating solar thermal power plant



Concentrating Solar Power System

National CSP capacities in 2015 (MW_p)

Country	Total	Added
Spain	2,300	0
United States	1,738	110
India	225	0
Morocco	180	160
South Africa	150	150
United Arab Emirates	100	0
Algeria	25	0
Egypt	20	0
Australia	12	0
Thailand	5	0



Worldwide CSP capacity since 1984 in MW_p

WIND ENERGY

Wind power may be considered as a modified solar power, since wind is the effect of solar heat

. As the air temperature increases, hot air starts rising from the earth’s surface causing a drop in the atmospheric pressure near the surface.

This drop in pressure pulls cold air to the evacuated area. Since the earth is warmer in the daytime and cooler at night the air above the earth’s surface warms and cools at different rates, causing ripples in air above the earth’s surface, which is called “wind.”

Although solar radiation is received across the total surface of the earth, it gets absorbed in or reflected from surfaces bearing sand, stone, water, etc. Thus, winds are stronger and more consistent in offshore and high altitude sites than those at land.

Experience reveals that the average wind speed offshore is about 90% greater than on land. This movement of air or airflow may be used to run wind mills or wind turbines) . The power output of a wind mill varies with the wind speed in a proportion cube of the wind speed.
Thus, a small increase in wind speed causes a sharp rise in power output. Wind power is pollution-free, i.e., it doesn’t cause air, soil, or water pollution. Its source of energy is free and it is virtually inexhaustible in producing electricity. However, wind power is only suitable in areas with generally steady winds. The first windmill to drive an electric generator was built in the 19th century.



GEOTHERMAL ENERGY

Geothermal energy is the natural heat from the core of the earth. This energy may be sourced from shallow ground or the upper 3 m deep of the earth's surface as hot water at a temperature ranging from 283 K to 289 K to heat and cool buildings. Geothermal energy may be in the form of steam from hot rock found thousands of meters beneath the earth's surface. The heat has manifested itself for thousands of years. To access this vast source of heat, cold water is injected down one well, circulating it through hot fractured rock, and then hot water is drawn from another well. Thus, the energy is clean and sustainable.
When geothermal energy is spouted as natural steam from the earth it is used to generate electricity in similar way as the energy used in conventional steam power plants having turbo-generators. Electricity is also generated by using the heat from the hot water to boil water in a separate heat exchanger generating steam. Geothermal power is cost effective, reliable, sustainable, and environmentally friendly.
The most powerful geothermal energy may also be sourced from an even deeper area into the core of the earth's surface having extremely high temperatures of molten rock called magma. Unfortunately, the available technology is unable to recover this high-temperature energy directly from magma.

As of 2015 the United States is the highest producer of geothermal power in the world with an installed capacity of 3548 MW, which is 28% of worldwide geothermal power capacity [6].
There are two types of geothermal power plants: dry steam (Figure A.5) and flash steam types (Figure A.6) [6].

In dry steam type hot water on reaching the surface is vaporized into almost dry steam at a pressure of about 0.8 MPa and temperature of about 423 K - 488 K. Flash steam stations tap high-pressure hot water from the interior of the earth. When hot water reaches earth's surface pressure drops to about 0.8 MPa resulting in flashed steam at a temperature ranging from 447 K - 588 K.

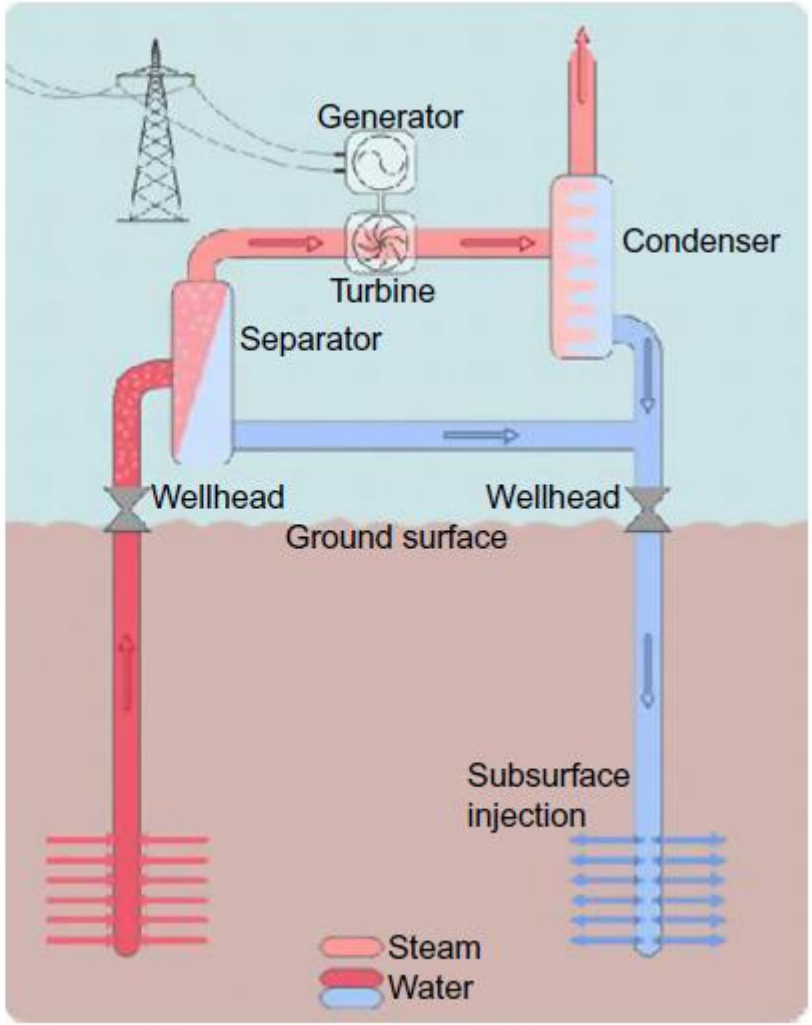


Figure A.6 Flash steam type geothermal power plant [6].

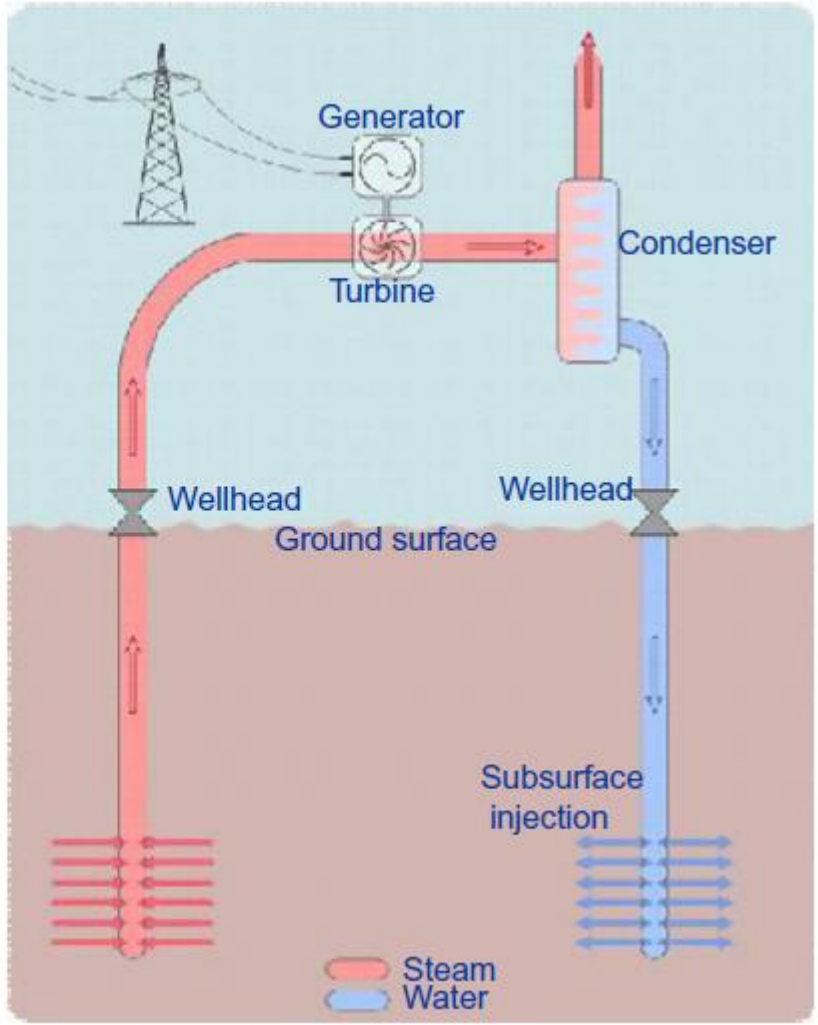


Figure A.5 Dry steam type geothermal power plant [6].

OCEAN THERMAL ENERGY

Seas and oceans absorb solar radiation, resulting in ocean currents and moderate temperature gradients from the water surface to deeper below. Since the surface of water receives direct sunlight it is warmer, but below the surface, it is very cold. Thismtemperature gradient can be used in a heat engine to make energy to generate power Since the surface temperature varies with latitude and season the temperature difference between the surface and below varies between 15-22 K .

Using this type of energy source, which is called Ocean Thermal Energy Conversion, or OTEC, a large quantum of electrical power in the range of gigawatts could be produced. But to build a power plant of this size large diameter of intake pipe submerged to ocean depth of a kilometer or more would be required. Cost of building such plant would be economically prohibitive.

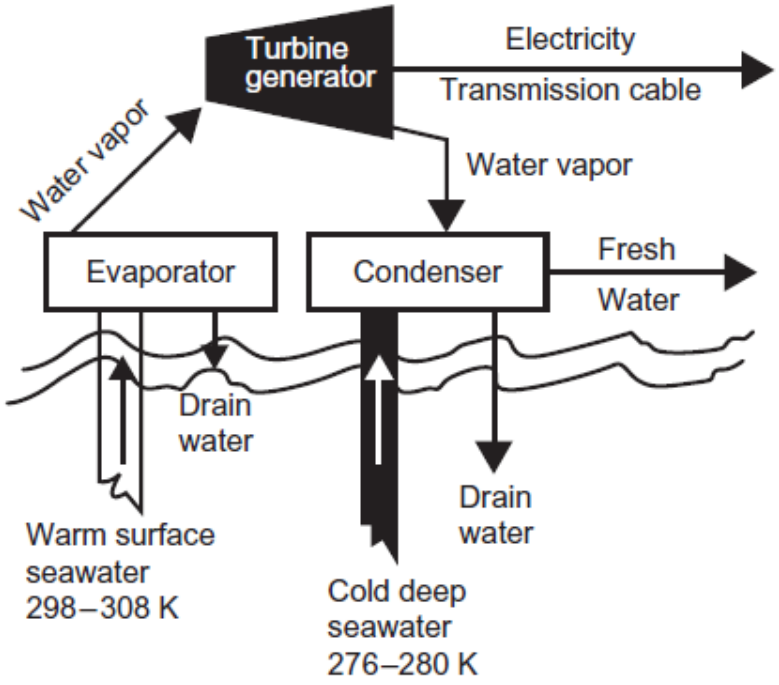


Figure A.7 Typical ocean thermal energy power plant.

Table A.1 Properties of ammonia

Boiling Point at 101.3 kPa:	239.5 K
Critical Point:	11.28 MPa & 405.4 K
Latent Heat of Vaporization at 101.3 kPa:	1371.2 kJ/kg
Vapor Pressure at 294 K:	888 kPa
Liquid Density at Boiling Point:	682 kg/m^3
Gas Density at Boiling Point:	0.86 kg/m^3
Gas Density at 101.3 kPa and 288 K:	0.73 kg/m^3
Gas Specific Gravity at 101.3 kPa and 294 K:	0.597
Gas Specific Volume at 101.3 kPa and 294 K:	1.411 m^3/kg
Gas Auto-ignition Temperature:	903 K

There are three types of OTEC plants: Closed Cycle: In a closed cycle OTEC plant pressurized warm surface water is passed through a heat exchanger where heat transfer takes place to vaporize a low boiling point fluid, such as ammonia (Table A.1). This vapor is then expanded through a turbine to generate electricity. Thereafter, the vapor is condensed into liquid in a separate heat exchanger by cold water from deep below the surface for recycling (Figure A.8).

Open Cycle: In an open cycle OTEC plant pressurized warm surface water is supplied to a low-pressure closed container, where water flashes into steam. This steam then operates a low-pressure turbine to generate electricity. The exhaust steam is condensed by supplying low-temperature water from deep below the surface.
Hybrid: A hybrid OTEC plant is a combination of the above two plants.

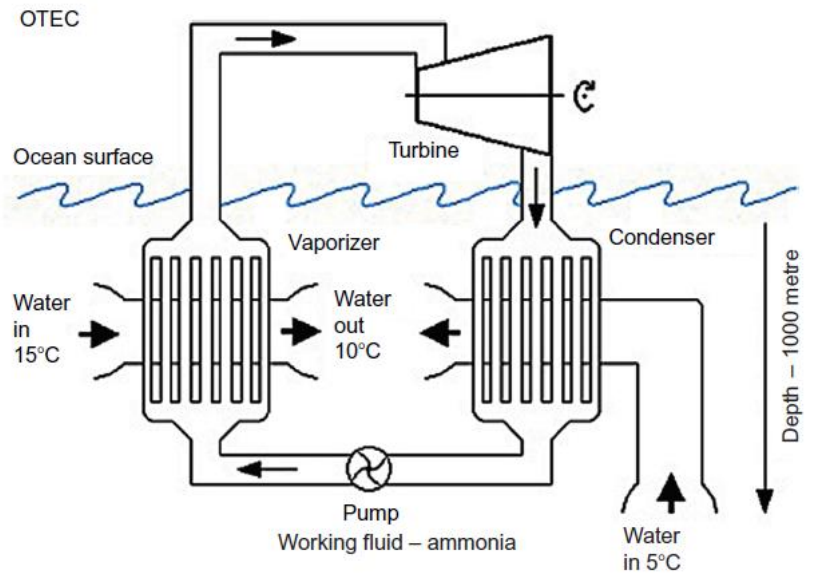


Figure A.8 Closed cycle OTEC power plant. *Source:* http://www.orionsarm.com/eg-article/48571957d8a5b.

TIDAL ENERGY

Ocean tides, caused by lunar and solar gravitational attractions, result in the rise and fall of waters with ranges that vary daily and seasonally [7]. During high tide water is stored in reservoirs behind dams. During low tide this water is released and the potential energy of such tidal waves is utilized generate power in the same way as in a conventional hydel power plant. The main drawback of this type of plant is that it essentially requires large underwater turbines to generate power (Figure A.9). As a result, the cost of this plant is prohibitively high compared to a river dam hydel power plant.

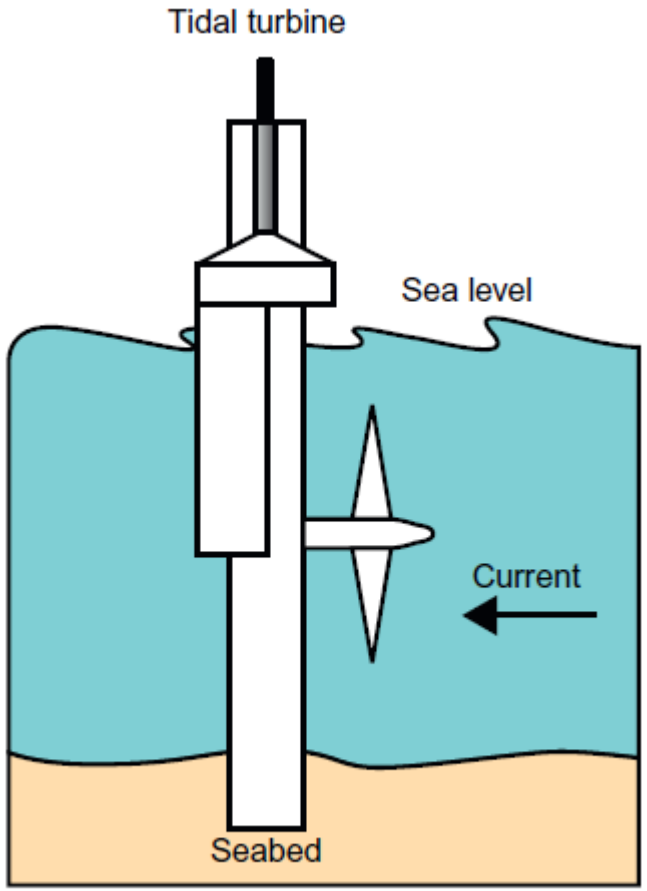


Figure A.9 Typical tidal turbine.

WAVE ENERGY

When wind blows over the surface of oceans large waves with high kinetic energy are generated. This energy is used in turbines to generate power [7]. The working principle of operating such a plant is explained as follows,

i. The incoming wave as it rises inside a chamber forces the air out the chamber and
ii. As the air is driven out it rotates a turbine to generate electricity.

This type of plant can only be located where wave power has high potential.

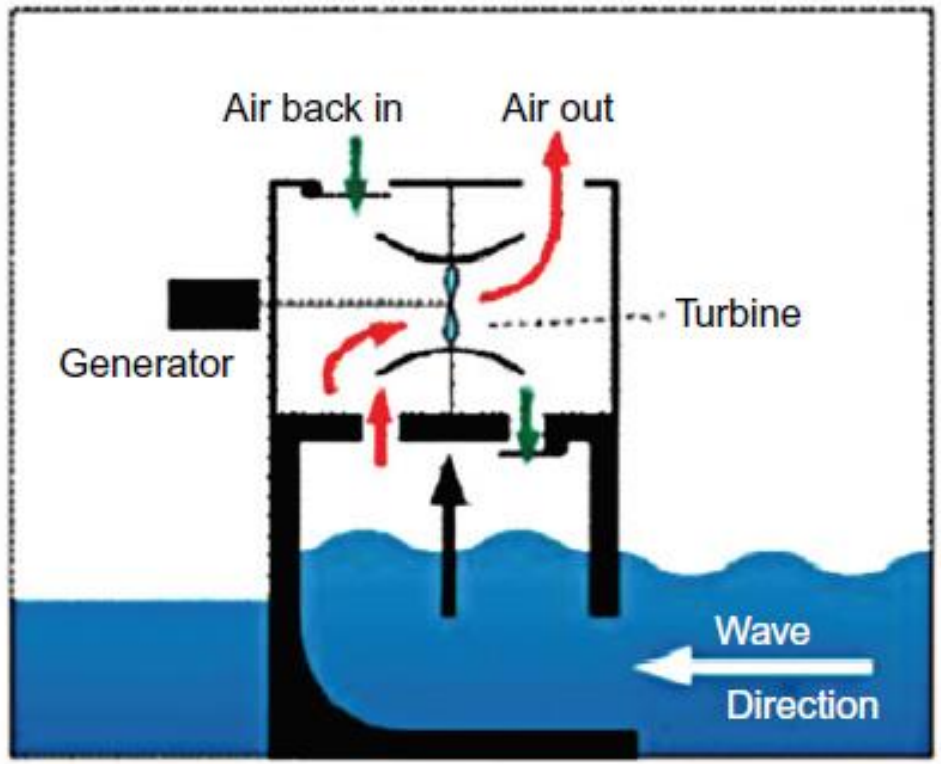


Figure A.10 Typical working diagram of a wave turbine.

HYDRAULIC TURBINE

A hydraulic turbine is a machine that converts the potential energy of supplied water into mechanical energy of a rotating shaft, which in turn drives a generator to produce electricity. This type of turbine operates on either the impulse or reaction principle Hydraulic turbines can be used for either vertical shaft or horizontal shaft. Based on the operational requirements along with head of water available this turbine may be classified into three categories [8]:

Pelton Wheel: Pelton Wheel, invented by Lester Allen Pelton in 1880, is an example of an axial-flow impulse turbine where a fall in pressure of liquid takes place only in the nozzles of the machine, but remains unchanged while flowing through the rotor. It is of relatively low (specific) speed (between 11 and 27 rpm) [8], suitable for high heads (100-1700 m), low flow applications, and receives water supply directly from thepipeline. Pelton wheels generally receive water from reservoirs with downward gradients up to 2,000 meters (Figure A.11). The wheel is built in such a way that on the periphery of its runner spoon-shaped buckets or cups are fitted. After passing through nozzles the water strikes these buckets, which in turn results in rotating the shaft to produce mechanical energy. This energy is then converted to electric power.

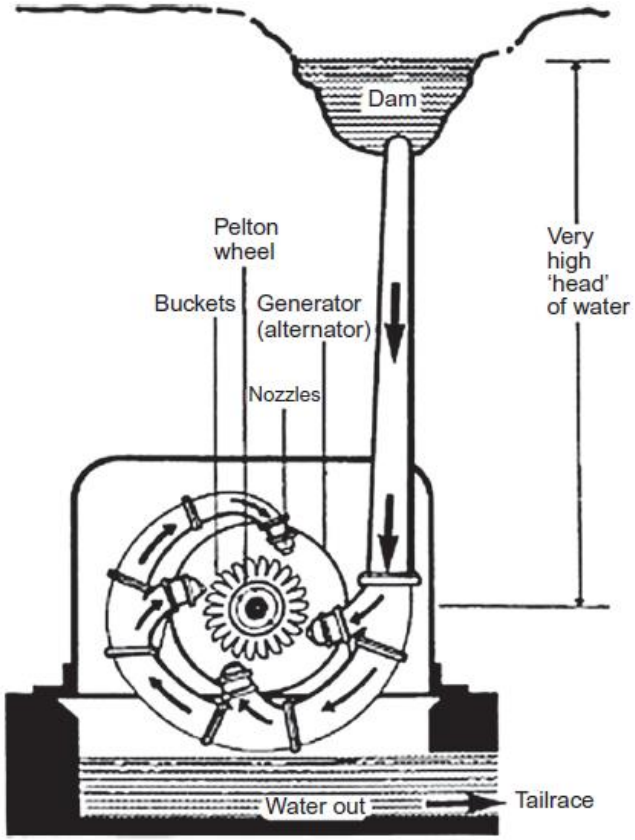


Figure A.11 Layout of a pelton wheel turbine.

Francis Turbine: This is an example of an inward radial-flow reaction turbine and is of relatively medium (specific) speed (between 38 and 380 rpm), suitable for medium heads (between 9 and 185 m) [8]. In Francis Turbine high pressure water enters the turbine with radial inflow and leaves the turbine axially through the draft tube (Figure A.12). The high-pressure water while passing through guide vanes, located at the periphery of the turbine shaft, rotate the shaft for producing power. The speed of the shaft is maintained constant at various loads by changing the vane angle.

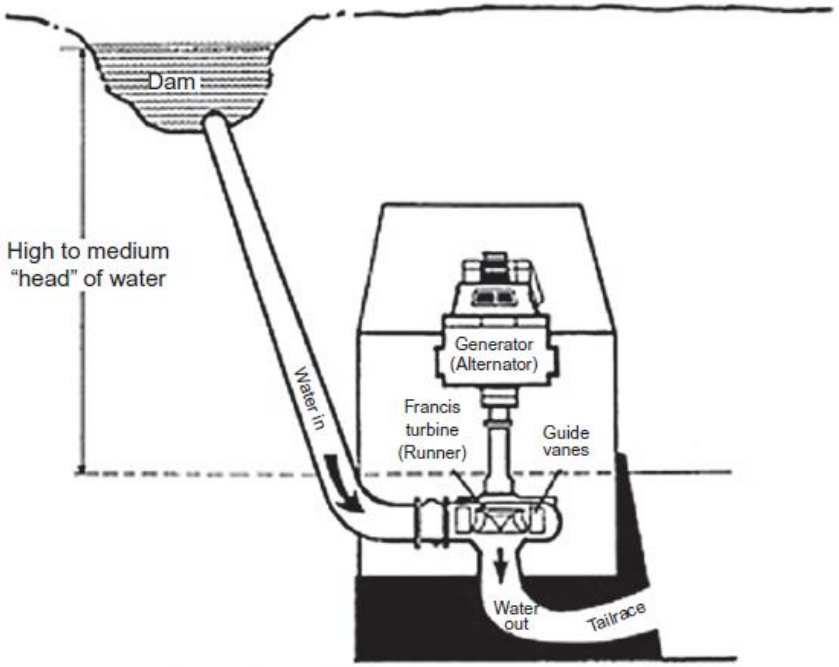


Figure A.12 Water flow through Francis turbine.

Kaplan Turbine: This type of turbine is an axial-flow reaction turbine also called as a propeller type. It is of relatively high (specific) speed (between 305 and 535 rpm) and suitable for low heads (varying from 3 to 15 m), and thus it is essential to pass large flow rates of water through a Kaplan turbine to produce power. At the inlet of the turbine a ring of fixed guide vanes is fitted, where a passage is provided between the guide vanes and the rotor. The rotor is fitted with variable pitch blades, similar to a propeller, the angle of which can be changed in accordance with the load demand and maintaining constant speed. Incoming water enters the passage in the radial direction and is forced to exit in the axial direction, which in turn rotates the
shaft to produce power.
[NOTE: The specific speed of a turbine is defined as the speed of a geometrically similar turbine that would develop 1kW under 1m head.

$$\text{Specific speed, rpm } N_S = (NP^{\frac{1}{2}})/H^{\frac{5}{4}}$$

where

N = the normal working speed, rpm
P = power output of the turbine, kW and
H = the net or effective head in meters]

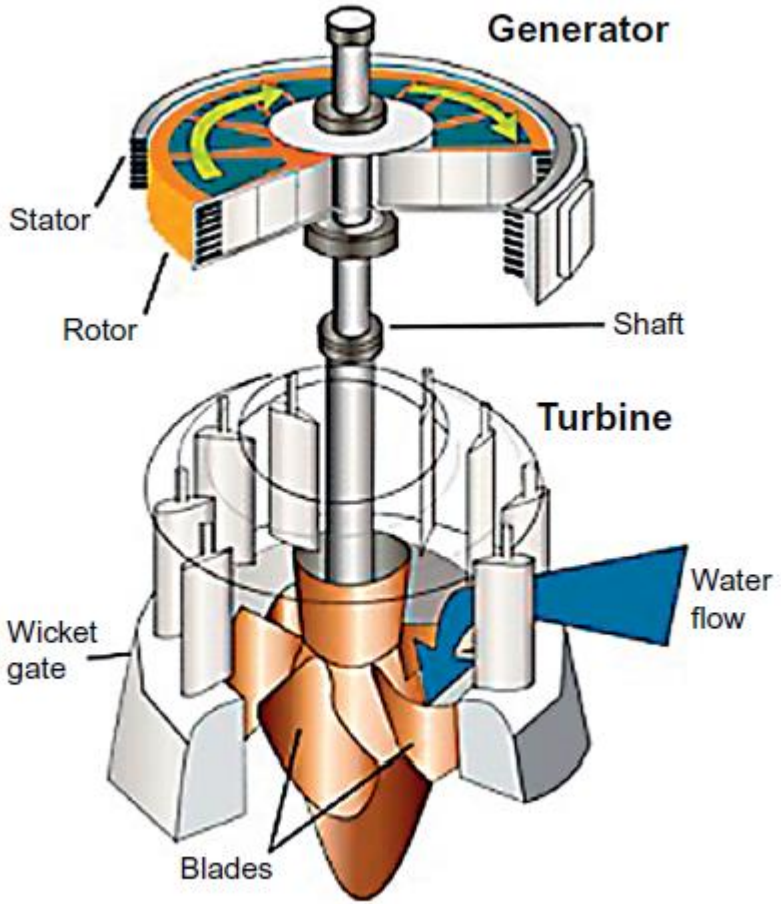


Figure A.13 Sectional view of a Kaplan turbine.

ENERGY FROM BIOMASS

Biomass is a source of renewable energy and is abundantly available. It is an organic matter, which has been used as long as humans have been burning wood to make fire.

Biomass is produced from solar energy by photosynthesis. As such, it absorbs the same amount of carbon when growing as it releases when consumed as a fuel. Therefore, it does not add to carbon dioxide in the atmosphere and eventually mitigates further increase of greenhouse gas emission. In contrast, combustion of fossil fuels only
enhances greenhouse gas emission without any recovery. Biomass is derived from numerous sources, including plant material, byproducts from timber industry, bagasse, agricultural crops, and urban garbage. Animal and human waste and decomposed garbage waste may be used to produce methane for combustion. Biomass can regrow over a relatively short period of time. It is an important source of energy and the most important fuel worldwide after coal, oil, and natural gas. It can be used directly through combustion in a furnace to boil water, and steam thus produced is used in a conventional turbo-generator to produce electricity. Methane produced from biomass can be used directly in combustion turbines to generate electricity. Biomass can also be used indirectly by converting it to ethanol, which is a biofuel, and using it for special cars and motor vehicles, which may eventually reduce our dependence on gasoline for driving cars.

Some of the biomass used to generate bio-power comprises the following:

i. Agricultural wastes, i.e., wheat straw, rice husk, jute stick, etc.
ii. Energy crops, i.e., bagasse, bamboo, special type of grass, e.g. switchgrass, etc.
iii. Wood and forest residues, i.e., dry leaves, twigs, etc.
iv. Wood wastes, i.e., sawdust, wood shavings
v. Clean industrial and municipal wastes
vi. Cattle dung, poultry litter, etc.



Figure A.14 Some example of biomass.