

CHAPTER TWO

2.SPECIFIC ENERGY TECHNOLOGY

OUT LINE

- ◀ Gothremal Energy
- ◀ Hydropower
- ◀ Biomass energy
- ◀ Solar energy
- ◀ Wind power
- ◀ Tidal and wave energy
- ◀ Nuclear energy
- ◀ Electrochemical energy storage

GEO THERMAL ENERGY

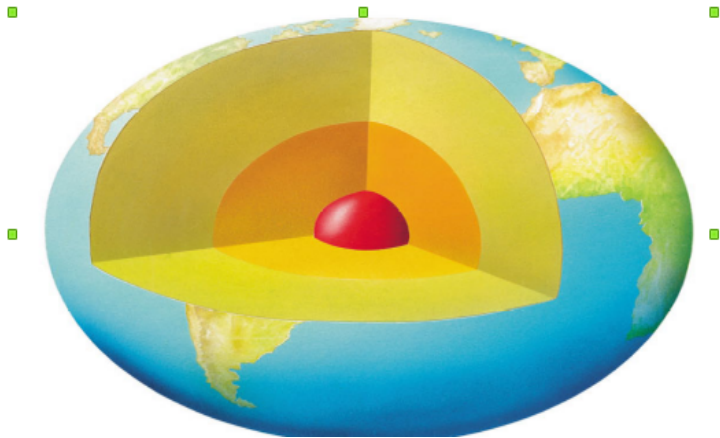


Figure: Earth's layer

RENEWABLE ENERGY

- ✓ Renewable energy is the energy that supplied directly or indirectly from the Sun or the Moon and thermal energy stored or generated below the crust of our planet, the Earth.
- ✓ Can be expected to be available for as long as the Earth is habitable for the human race.
- ✓ It should be replenished at least at the same rate as it is used.

2.1 Geothermal Energy (GE)

- ✓ Geothermal energy is heat generated and stored in the Earth.
- ✓ GE originated from the original formation of planet(20 percent).
- ✓ And radioactive decay of minerals such as thorium, uranium, potassium and their daughters' nuclides (80 percent).

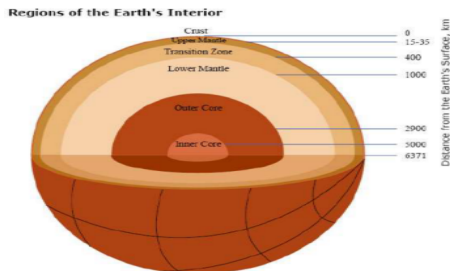
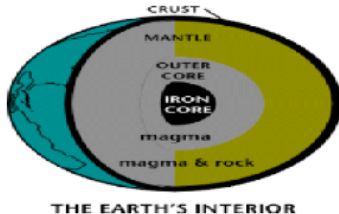


Figure: Regions of the Earth's interior

- ✓ The decay of these isotopes releases particles with high kinetic energy (i.e. $v = 8000\text{km/s}$), which eventually degrades into heat as a result of collisions with surrounding media.
- ✓ The interior of the Earth is expected to remain extremely hot for billions of year and ensuring limitless flow of heat.
- ✓ The heat inside the Earth comes near the surface in the form of **magma**.
- ✓ Temperatures hotter than the sun's surface are continuously produced inside the earth by the slow decay of radioactive particles.
- ✓ This is a process that happens in all rocks.

- ✓ The earth has a number of different layers:
- ◀ The **core** itself has two layers: a solid iron core and an outer core made of very hot melted rock, called magma.
- ◀ The **mantle** which surrounds the core and is about 1,800 miles thick. It is made up of magma and rock.
- ◀ The **crust** is the outermost layer of the earth, the land that forms the continents and ocean floors.
- ✓ It can be three to five miles thick under the oceans and 15 to 35 miles thick on the continents.



WHERE IS GEOTHERMAL ENERGY FOUND?

✓ Most geothermal reservoirs are deep underground with no visible clues showing above ground.

✓ Geothermal energy can sometimes find its way to the surface in the form of:

◀ volcanoes and fumaroles (holes where volcanic gases are released)

◀ hot springs and

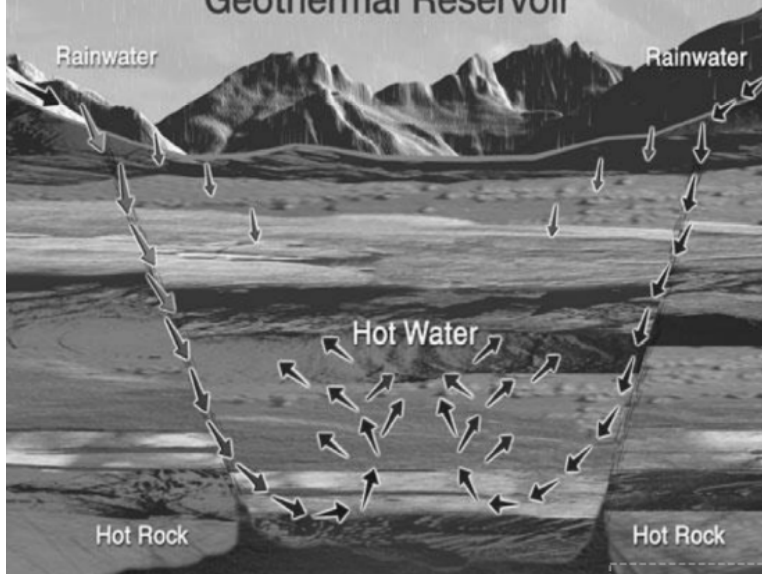
◀ Geysers (a spring that discharges hot water and steam)

✓ Geothermal sources are mostly formed around active fault systems and volcanic and magmatic units.

✓ When magma comes close to the surface it heats ground water found trapped in porous rock or water running along fractured rock surfaces and faults.

- ✓ Such hydrothermal resources have two common ingredients: water (hydro) and heat (thermal).
- ✓ Naturally occurring large areas of hydrothermal resources are called geothermal reservoirs.
- ✓ Drilling a well and testing the temperature deep underground is the only way to be sure a geothermal reservoir really exists.
- ✓ Geothermal energy includes all types of direct or indirect benefit derived from geothermal sources.

Geothermal Reservoir



- ✓ Geothermal energy can be used for electricity production, for commercial, industrial, and residential direct heating purposes.
- ✓ Geothermal areas are mostly identified by the smell of sulfur and hydrogen sulfide.
- ✓ **Heat use:** geothermal heat is used directly without involving a power plant or heat pump, for variety of applications such as;
 - space heating
 - food preparation
 - green house
 - vegetable drying
 - hot spring bathing and spans (balneology)
 - agriculture
 - aquaculture and industrial processes

✓ A geothermal system consists of four elements:

- 1) a heat source
- 2) permeable rock
- 3) a fluid to transport heat to the surface and
- 4) re-charge area.

Geothermal power plants

- ✓ Geothermal electricity is electricity that generated from geothermal energy.
- ✓ In general geothermal power plants consists of three major parts;
A) production well: in which fluids such as hot water, and steam are brought to the surface and piped into the power plant.
- ✓ Its heat energy is converted to electricity at a geothermal power plant.

B) Power plant: inside the power plant the geothermal fluids turn;

1. the turbine blades,
2. spins a shaft
3. spins magnets inside a large coil of wire to generate electricity.

C) Injection well: used geothermal fluids are returned to the reservoir.

✓ The three basic types of geothermal electrical generation facilities are;

A) dry steam (referred to as steam),

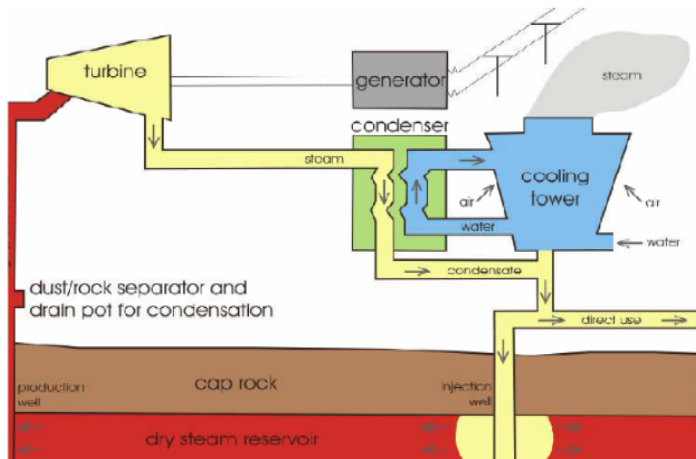
B) flash steam (referred to as flash) and

C) binary system.

✓ Electricity production from each type depends on reservoir temperatures and pressures.

1) Dry steam power plant

- ✓ use very hot ($> 455^{\circ}F$, or $> 235^{\circ}C$) steam and little water from the geothermal reservoir.
- ✓ The steam goes directly to a turbine, which drives a generator that produces electricity.
- ✓ The steam eliminates the need to burn fossil fuels and also eliminates the need to transport and store fuels.
- ✓ Once the steam has passed through the turbine, it condenses and is pumped back into the earth via an injection well, thus creating a closed loop.



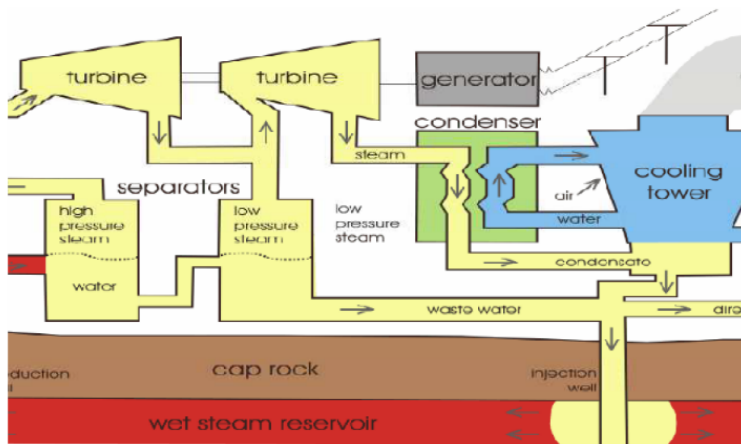
Dry intake condensing power plant for heat production from dry steam fields

2) Flash steam power plant

- ✓ Many underground geothermal sources do not have sufficient heat or pressure to use steam directly.
- ✓ Hydrothermal fluids are above 360°F (182°C) another process can be used called flash vaporization.
- ✓ Fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to rapidly vaporize, or "flash."
- ✓ The sudden drop in pressure causes some of the water to vaporize to steam, which spins a turbine to generate electricity.
- ✓ If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy.

✓ Both dry steam and flash steam power plants emit small amounts of carbon dioxide, nitric oxide, and sulfur, but generally 50 times less than traditional fossil-fuel power plants.

✓ Single or multiple flash steam plants are used to produce energy from the fields by evaporating depressurized liquid water into steam in one or several separators at the surface.

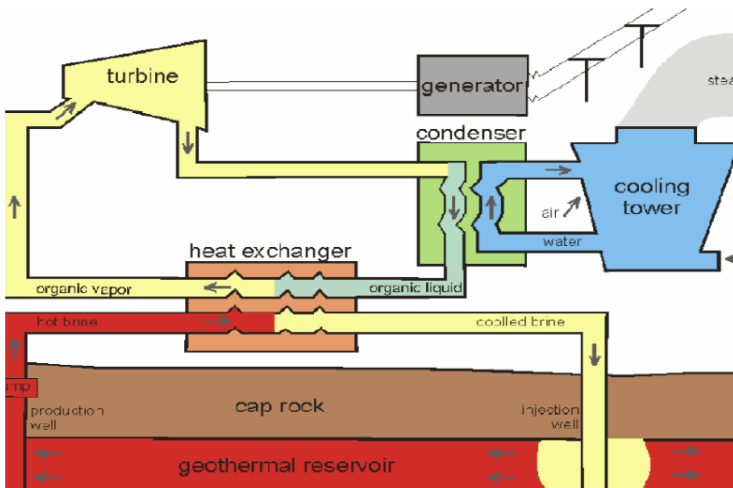


Double flash power plant using a water-dominated geothermal resource with a separator to produce steam

3 Binary power plant

- ✓ Use moderate-temperature water (225°F - 360°F), or 107°C - 182°C) from the geothermal reservoir.
- ✓ Hot geothermal fluids are passed through one side of a heat exchanger to heat a working fluid in a separate adjacent pipe.
- ✓ The working fluid (organic compound with a low boiling point such as iso-butane or iso-pentane).
- ✓ The working fluid is vaporized and passed through a turbine to generate electricity.
- ✓ The binary cycle system is self-contained and therefore, produces virtually no emissions.
- ✓ The two liquids are kept completely separate through the use of a heat exchanger used to transfer the heat energy from the geothermal water to the working-fluid.

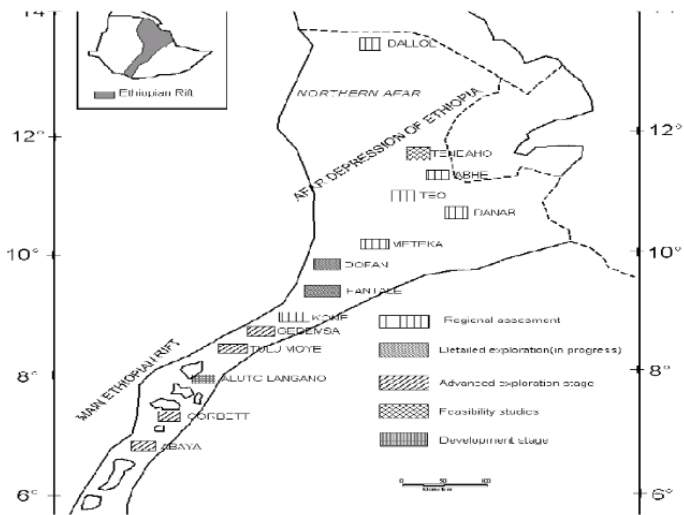
- ✓ A cooling system is essential for the operation of any modern geothermal power plant.
- ✓ Cooling towers prevent turbines from overheating and prolong facility life.
- ✓ Most power plants, including most geothermal plants, use water cooling systems, since it requires less space than air cooling.



Binary power plant (water-cooled) for heat production from hot water or low enthalpy wet steam fields

Geothermal potential in Ethiopia

- ✓ Great East African Rift (EAR) bisects the plateau from the north east to the south west of the country.
- ✓ The rift in Ethiopia has created a conducive environment for the existence of geothermal resources and covers an area of about $150,000\text{Km}^2$ that is close to 13 percent of the total land area.
- ✓ Based on the level of the studies, the status of geothermal exploration in the Ethiopia rift can be grouped into three:
 1. Area where a power plant has been installed (Aluto-langano),
 2. Area tested by deep drilling (Tendaho) and
 3. Areas where various levels of surface exploration have been done



Location of map of Ethiopian and geothermal prospect areas

✓ The first geothermal pilot power plants in the country were built at Aluto-Langano.

✓ The results of the study has showed that a minimum geothermal potential of 4200 MWe and a maximum of 10,800 MWe, in the Ethiopian Rift Valley.

✓ The development of geothermal energy production and direct utilization is slow in both of the Mean Ethiopian Rift and the Afar Rift due to;

- ▶ High cost and risk involved
- ▶ Lack of understanding the benefits of geothermal power (lack of awareness)
- ▶ Lack of proper geothermal management
- ▶ Unavailability of risk mitigation fund
- ▶ Choice of geothermal resources, based on closeness to the power line
- ▶ Lack of training and Operation difficulties

Benefit and Drawback of Geothermal Energy

Benefit

- ✓ Provides clean and safe energy using little land
- ✓ Renewable
- ✓ Conserves fossil fuels and contributes diversity in energy resources
- ✓ Avoids importing and benefits local economics
- ✓ It is homegrown, create jobs and less reliance on oil producing countries

Drawback

- ✓ Extracting large amounts of water can cause land subsidence and can increase in seismic activity.
- ✓ Thermal pollution, which is caused by the heat released to the environment.
- ✓ Hydrogen sulfide, H_2S , the “rotten eggs” gas is another gas that is released from the condenser.
- ✓ Noise, which is always problem with all power plants.

2.2 HYDROPOWER



2.2 Hydropower

- It is derived from the force or energy of falling water.
- Hydroelectricity is electricity generated by hydropower through the use of the gravitational force of falling or flowing water.
- It refers to energy that is derived from water in motion.
- It relies on the water cycle, which is driven by the sun, thus it is a renewable power source.
- It is one of the most widely used for generating electricity on large scale.
- It is renewable since water is available in large quantities from rain, rivers, and oceans.
- This will be available for unlimited time.

Essential features of Hydro-Electric Power Plant

Catchment area:

- It is the whole area behind the dam, draining into a stream or river across which the dam has been built at a suitable place.

How hydropower plant works?

Reservoir (artificial lake) : The place where the water collected from the catchment area can be stored.

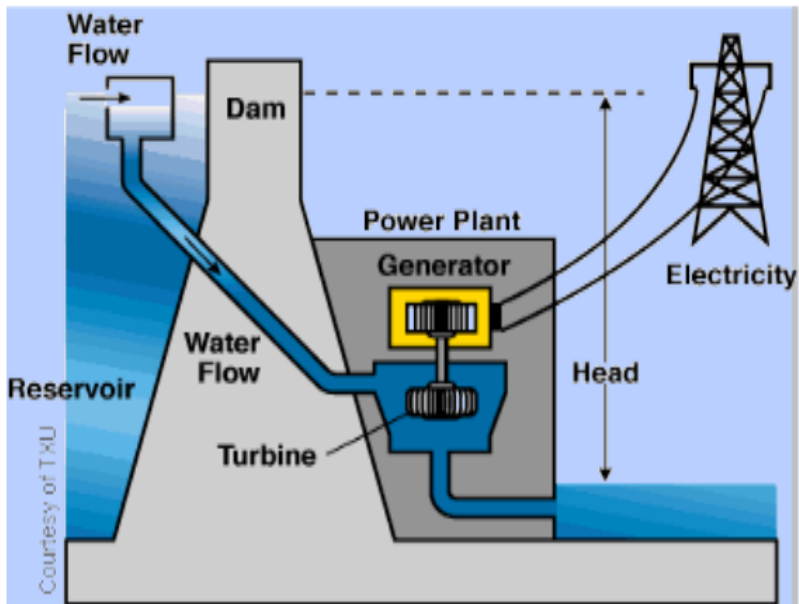
Dam: It helps to store all the incoming water and to regulate the out going flow of water.

Power house: It is a building where the electricity is produced.

- Located in quite remote areas at some distance from major population centers.

Working principles of Hydropower plants

- A dam opens its gate to allow water from the reservoir above to flow down through large tubes called penstocks.
- At the bottom of the penstocks, the fast-moving water spins the blades of turbines.
- The turbines are connected to generators to produce electricity.
- The electricity is then transported via huge transmission lines to a local utility of company.



- The mechanical energy produced by the turbine is converted into electric energy using a turbine generator.
- Inside the generator, the shaft of the turbine spins a magnet inside coils of copper wire.
- It is a fact of nature that moving a magnet near a conductor causes an electric current.

Availability of Head of Water:

1. Low head plant: Operating *head* $< 15m$.
2. Medium: Operating head 15 to 50m.
3. High head plants: Operating *head* $> 50m$.

- The classification of hydro electric power plant depend on the following factors:

Quantity of water:

A) An impoundment: is simply a dam that holds water in a reservoir.

- The water is released when needed through a penstock, to drive the turbine.
- It is the most common type of hydroelectric power generation.

B) A run-of-the-river system: uses the river's natural flow, captures the kinetic energy in rivers or streams, without the use of dams.

- It may involve a diversion of a portion of the stream through a canal or penstock, or it may involve placement of a turbine right in the stream channel.

C) Pumped storage:

- When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir.
- During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

Selection of Site for a Hydro-electric Power Plant

1. Water Available:

- The recorded observation should be taken over a number of years to know the maximum and minimum variations from the average discharge.
- The river flow data should be based on daily, weekly, monthly and yearly flow over a number of years.

2. Water-Storage:

- The output of a hydropower plant is not uniform due to wide variations of rain fall.
- To have a uniform power output, a water storage is needed so that excess flow at certain times may be stored to make it available at the times of low flow.

3.Head of Water:

- The level of water in the reservoir for a proposed plant should always be within limits throughout the year.

4.Distance from Load Center:

- Be economical on transmission of electric power.

5. Hydrology:

- The distribution of water on land beneath the surface of the earth must be considered.

Advantages and Disadvantages

Advantages

- ▶ Cheap to operate

1. Long life and lower operating costs than all other power plant.

- ▶ High yield

1. Lower energy cost than any other method.

- ▶ Pretty plentiful

1. Some countries depend almost entirely on it.

- ▶ Not intermittent (if reservoir is large enough)

- ▶ Reservoirs have multiple uses

1. Flood control, drinking water, aquaculture, recreation

- ▶ Less air pollution than fossil fuel combustion

- Hydropower is fueled by water and clean that is driven by the sun.
- Dams provide domestic water supply and also control flood on rivers.
- The dams creates a variety of recreational opportunities, fishing, swimming and boating, large dams become tourist attraction.

Disadvantages:

- Human population displacement
- Ecosystem impacts;
- Barriers to migrating fish
- Loss of biodiversity both upstream and downstream
- Coastal erosion
- Reduces nutrient flow (dissolved and particulate)
- Siltation a big problem (also shortens dam life).

- Damming rivers floods large areas of land.
- Dams are extremely expensive to build and must be built to a very high standard.
- Some dams cause the spread of waterborne diseases.
- Dams affect the amount of water in rivers downstream.
- The Size Issue
 - ▶ Many (most) of the above problems are significantly worse for larger dams.
 - ▶ Small dams have shorter lifetimes, less capacity, and are more intermittent.

2.3 Biomass

OUT LINE

- ▶ What is biomass?
- ▶ What are Sources of biomass?
- ▶ How does it work?
- ▶ How do we convert biomass energy to useful forms of energy?

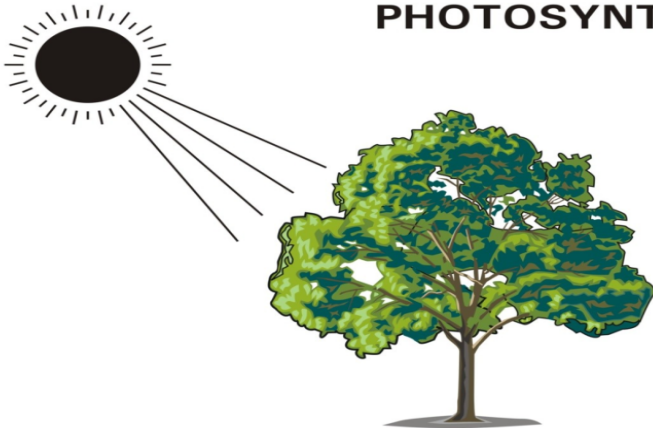
What is Biomass?

- ▶ Biomass is a renewable energy source that is derived from living or recently living organisms(i.e animal/plant waste, industrial and municipal waste).
- ▶ Biomass includes biological material, not organic material like coal.
- ▶ Energy derived from biomass is mostly used to generate electricity or to produce heat.
- ▶ Biomass can be chemically and biochemically treated to convert it to a energy-rich fuel.
- ▶ Through photosynthesis plants convert sunlight energy, less than 1 percent into chemical energy.

- ▶ Biomass is stored sunlight energy that can be converted to:
 - a) Electricity,
 - b) Fuel,
 - c) Heat and
 - d) Fertilizer.
- ▶ This is the same energy that made fossil fuels; fossil fuels are concentrated over time by the heat and pressure within the Earth.
- ▶ Efficiency of burning biomass to electricity is about the same as with fossil fuels.
- ▶ The oldest form of energy used by humans (i.e wood fire).
- ▶ Any plant tissue can be used for energy, but the faster the plant grows, the more useful it is.

- ▶ Switch grass can be grown rapidly (one season).
- ▶ Grasses are attractive also because they can be grown in climates unfavorable to trees.

PHOTOSYNTHESIS



► In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose or sugar.

water + carbondioxide + sunlight $\Rightarrow$ glucose + oxygen



SOURCES OF BIOMASS

- ▶ Matter from any living organism
- ▶ Animal/human waste
- ▶ Food crops
- ▶ Grassy and woody plants
- ▶ Residues from agriculture or forestry
- ▶ Organic component of municipal and industrial

Types of Biomass



Wood fuel



Rubbish



Alcohol fuels



Crops



Landfill gas

Types of Biomass



Wood



Crops



Garbage



Landfill Gas



Alcohol Fuels

Methods of Extracting Biomass Energy

- ▶ Biomass can be converted to;
 - a) thermal energy,
 - b) liquid,
 - c) solid or gaseous fuels and
 - d) other chemical products through a variety of conversion processes.

1. Direct Combustion

- ▶ The simplest method of extracting energy from biomass.
- ▶ Industrial biomass combustion facilities can burn many types of biomass fuel, including wood, agricultural residues, wood pulping liquor, municipal solid waste (MSW) and refuse derived fuel.

► Biomass is burned to produce steam, the steam turns a turbine and the turbine drives a generator to produce electricity.

2. Gasification

► It is a process that exposes a solid fuel to high temperature and limited oxygen, to produce a gaseous fuel.

► The gas produced by the process is a mix of gases such as CO_2 , CO , N , H and CH_4 .

► The gas is then used to drive combined cycle gas turbine.

► Gasification has several advantages over burning solid fuel.

a) One is convenience: one of the resultant gases, CH_4 , can be treated in a similar way as natural gas, and used for the same purposes.

b) It produces a fuel that has had many impurities removed and cause fewer pollution problems when burnt.

► It can also produce synthesis gas, a mixture of CO and H which can be used to make hydrocarbon (e.g., methane and methanol) for replacing fossil fuels.

3. Pyrolysis

► It represents the heating of biomass to drive off the volatile matter and leaving behind the charcoal.

► It has doubled energy density of the original material because charcoal with half weight of the original biomass, contains the same amount of energy, making the fuel more transportable.

► The charcoal also burns at a much higher temperature than the original biomass, making it more useful for manufacturing processes.

- ▶ Pyrolysis techniques are developed recently to collect volatiles and collected volatiles produce a gas which is rich in H (a potential fuel) and CO.
- ▶ These compounds are synthesized into methane, methanol, and other hydrocarbons.
- ▶ Flash pyrolysis is used to produce bio crude, a combustible fuel.
- ▶ Heat is used to chemically convert biomass into pyrolysis oil.
- ▶ The oil, which is easier to store and transport than solid biomass material, is then burned like petroleum to generate electricity.
- ▶ Pyrolysis can also convert biomass into phenol oil, a chemical used to make wood adhesives, molded plastics, and foam insulation.

4. Digestion

- ▶ Biomass digestion works by utilizing anaerobic bacteria.
- ▶ These microorganisms usually live at the bottom of swamps or in other places where there is no air, consuming dead organic matter to produce methane and hydrogen.
- ▶ By feeding organic matter such as animal dung or human sewage into tanks, called digesters, and adding bacteria, we collect the emitted gas to use as an energy source.

- ▶ This process is a very efficient means of extracting useable energy from such biomass.
- ▶ Again to collect methane gas from landfill sites.

5. Fermentation

- ▶ People have used yeasts and other microorganisms to ferment the sugar of various plants into ethanol.
- ▶ Plant materials from sugar cane to wood fiber can be used.
- ▶ Ethanol is then mixed with diesel to produce diesehol, a product used by trucks and buses in Australia.
- ▶ The process has vastly increased the efficiency by which waste paper and other forms of wood fiber is fermented into ethanol.

i) Biofuels:

Biomass is converted into transportation fuels such as ethanol, methanol, biodiesel and additives for reformulated gasoline.

► Biofuels are used in pure form or blended/mixed with gasoline.

ii) Ethanol:

Ethanol, the most widely used biofuel, is made by fermenting biomass in a process similar to brewing beer.

► 1.5 billion gallons of ethanol used in the U.S. each year is made from corn and blended with gasoline to improve vehicle performance and reduce air pollution.

► Sugar crops or starch are grown and through the process of fermentation, ethanol is produced.

iii) Methanol:

► Methanol is produced through gasification.

► The biomass is converted into a synthesis gas (syngas)/ fuel gas that is processed into methanol.

► Used for transportation as a blend or in reformulated gasoline.

iv) Biodiesel:

- ▶ It is made from oils and fats found in micro-algae and other plants, is substituted for or blended with diesel fuel.
- ▶ Plants are grown which naturally produce oil, such as jatropha and algae.
- ▶ These oils are heated to reduce their viscosity after which they are directly used as fuel for diesel engines.
- ▶ This oil can be further treated to produce biodiesel which can be used for various purposes.

Why Biomass is Renewable?

- ▶ “Renewable” is NOT the same as “Green”
- ▶ A renewable energy source simply does not deplete (reduce).
Example: solar, wind, hydroelectric

Green Energy?

- ▶ A “green” energy is also good for the planet because it does not(harm ecosystems, contribute to acid rain, or worsen global warming).
- ▶ All 'green' energy is considered renewable, but not all renewable energy is green.
- ▶ Biofuels are examples of renewable energy sources that are not always green because they produce greenhouse gases.

- ▶ Energy is produced from biomass basically by burning organic matter to release its stored energy.
- ▶ Although plants will release their stored CO_2 and CO_2 is recaptured and used by other plants as they grow.
- ▶ Therefore, theoretically there is no net gain CO_2 because of a cycle of usage of this gas.
- ▶ Biomass energy is an abundant, secure, environmental friendly, and renewable source of energy.
- ▶ It can generate electricity with the same equipment or in the same power plants as burning fossil fuels.

Benefits of Biomass Energy

- ▶ Biomass energy is not associated with environmental impacts such as acid rain, mine spoils, oil spills, radioactive waste disposal or the damming of rivers.
- ▶ Biomass fuels are sustainable.
- ▶ The green plants fix CO_2 as they grow, so their use does not add to the levels of atmospheric carbon.
- ▶ Alcohols and other fuels produced by biomass are efficient, viable, and relatively clean burning.
- ▶ Biomass is easily available and can be grown in all parts of the world.

Constraints to Biomass Energy Use:

- ▶ Biomass is still an expensive source of energy, both in terms of producing biomass and converting it into alcohols, as a very large quantity of biomass is needed.
- ▶ On a small scale there is a net loss of energy as a lot of energy must be used for growing the plant mass; biomass is difficult to store in the raw form.
- ▶ Direct combustion of biomass can be harmful to the environment as burning biomass releases carbon dioxide.
- ▶ Over-collecting wood can destroy forests.
- ▶ When plant and animal wastes are used as fuel, they cannot be added to the soil as fertilizer and Soil is depleted of nutrients and produce fewer crops.
- ▶ Biomass has less energy than a similar volume of fossil fuels.