Renewable Energy and Green Technology

Course Code : AENGG-311
Credit Hours : 2(1+1)

Theory Part:

Classification of energy sources, Contribution of these sources in agricultural sector, Familiarization with biomass utilization for bio-fuel production and their application, Familiarization with different types of biogas plants and gasifiers, bio-alcohol, biodiesel. Familiarization with briquetting techniques, Introduction of solar energy, Solar collectors and their application, Familiarization with solar energy gadgets: solar cooker, solar water heater. Application of solar energy: solar drying, solar distillation, solar photovoltaic system and their application, introduction of wind energy and its application.

Lecture schedule: Theory

S. No.	Topic	No. of lectures
1.	Classification of energy sources, contribution of these sources in agricultural sector.	1
2.	Familiarization with biomass utilization for bio fuel production and their application.	2
3.	Familiarization with different types of biogas plants.	2
4.	Biogas production techniques and various uses of biogas.	2
5.	Biomass gasification and familiarization with different gasifiers.	2
6	Concept of briquetting and familiarization with briquetting machines.	1
7	Introduction of solar energy, solar collectors and their application.	2
8	Solar thermal applications in different gadgets.	2
9	Solar photovoltaic techniques and applications.	1
10	Introduction of wind energy and its application.	1

Practical Part:

Familiarization with renewable energy gadgets. To study biogas plants. To study gasifier.
To study briquetting machine. Familiarization with different solar energy gadgets. To study solar photovoltaic system: solar light, solar pumping, solar fencing. To study solar cooker. To study solar dryers. To study solar distillation system.

Lecture schedule: Practical

S.N.	Topic	No. of lectures
1	Study of fixed dom and floating drum type biogas plants	2
2	Study of cross draft, updraft and down draft gasifiers	2
3	To study briquetting machine	1
4	Study of box type solar cooker	1
5	Study of solar water heating system	1
6	Study of solar distillation system	1
7	Study of solar dryer	2
8	Study of solar animal concentrate cooker	1
9	Study of solar photovoltaic water pumping system and visit to nearby solar photovoltaic water pumping system	2
10	Study of solar photovoltaic sprayer	1
11	Study of wind mill	1
12	Study of improved cook stove	1

References:

1. G.D. Rai. Non-Conventional Energy Sources, Kh Publishers, New Delhi.
2. N. S. Rathore. A.K. Kurchania, N.L. Panwar. (2007). Non Conventional Energy Sources, Himanshu Publications.
3. N.S. Rathore. A. K. Kurchania, N.L. Panwar. (2007). Renewable Energy, Theory and Practice, Himanshu Publications.
4. K.C. Khandelwal. & S.S. Mandi. (1990). Biogas Technology.

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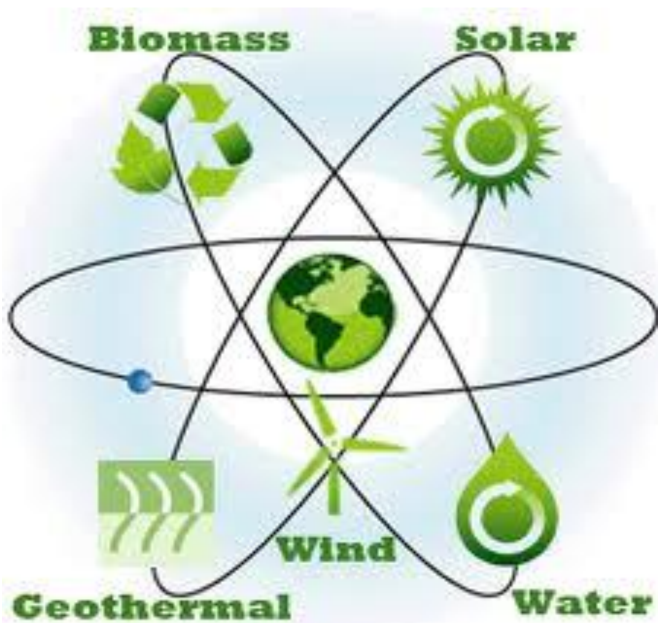
Lect.-1
Classification of energy sources, contribution of these sources in agricultural sector.



By
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Energy:

Energy is defined via work, i.e capacity of doing work.

the SI (Standard International) unit for **energy** is the same as the unit of work – the joule (J),

named in honor of James Prescott Joule.

1 joule is .equal to 1 Newton- metre. (**N·m)**

One Newton is the force needed to accelerate one kilogram of mass at the rate of one metre per second squared in the direction of the applied force.

$F = m \cdot a$ *or* $N = 1\ kg \cdot 1\ m/s^2$

- The energy unit used for electricity, is the kilowatt- hour(kWh);

One kWh is equivalent to 3.6×10^6 J (3600 kJ or 3.6 MJ).

In Food industry the unit of energy is calorie.

1 calorie = 4.184 J

Basically energy can be classified into two types:

Potential Energy and Kinetic Energy

Potential Energy

Potential energy is stored energy and the energy of position (gravitational). It exists in various forms.

Kinetic Energy

Kinetic energy is energy in motion- the motion of waves, electrons, atoms, molecules and substances. It exists in various forms.

Various Forms of Energy

(i) Chemical Energy

Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

(ii) Nuclear Energy

Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. The nucleus of a uranium atom is an example of nuclear energy.

It is not a renewable energy source, but because it is a technology not based on fossil fuels many people think nuclear power plants could play an important role in reducing carbon emissions and battling climate change.

(iii) Stored Mechanical Energy

Stored mechanical energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

(iv) Gravitational Energy

Gravitational energy is the energy of place or position. Water in a reservoir behind a hydropower dam is an example of gravitational energy. When the water is released to spin turbines, it becomes rotational energy.

(v) Radiant Energy

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

(vi) Thermal Energy

Thermal energy (or heat) is the internal energy in substances- the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

(vii) Electrical Energy

Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

(viii) Energy in Motion

The movement of objects or substances from one place to another is motion. Wind and hydropower are examples of motion.

(ix) Sound Energy

Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

(x) Light Energy

Light energy is a type of wave motion. That is, light is a form of energy caused by light waves. It enables us to see, as objects are only visible when they reflect light into our eyes.

Classification of Energy Resources on the basis of availability:

Primary energy resources:

1. Fossil fuels such as coal natural gas etc.
2. Nuclear fuels such as Uranium, Thorium etc.
3. Hydro energy
4. Solar energy
5. Wind energy
6. Geothermal energy
7. Ocean energy such as tidal energy, wave energy
8. Hydrogen energy

Secondary energy resources:

1. Petrol, diesel, kerosene oil.
2. CNG and LPG
3. Electrical energy based on coal, diesel gas.

Energy flow Pattern in Present Context

Primary energy sources	:	Gift of nature (Fossil fue,l Falling water & Solar energy etc.)
Energy conversion Processes	:	Oil Refineries, Power Plants, Solar Collector etc.
Secondary Energy	:	Refined oil, Electricity
Transmission & Distribution	:	Railway, Pipelines, Transmission Lines
Final Energy	:	At the consumer house
Energy utilization Equipment & Devices	:	Stove, IC Engine, Furnace

End use Activities

- Domestic
- Agriculture
- Transport
- Industry

Classification of Energy Sources

Energy sources can be classified on the basis of three features:

(a) Conventional and Non Conventional Energy sources.

(b) Renewable and Non Renewable Energy sources.

(c) Commercial and Non Commercial Energy sources.

Conventional and Non Conventional Energy sources.

- Based on conventionality in deriving energy, energy sources can be classified as conventional (coal, oil, hydro, nuclear, etc.) and non - conventional (solar, wind, tidal, geothermal, biogas, etc.) sources.
- Fossil fuels(coal, oil and petroleum products, natural gas) are conventional energy sources.
- Fossil fuels are formed by the decomposition of the remains of dead plants and animals buried under the earth long ago.
- Hydro power is also conventional source of energy. The watercourses created by precipitation of rain and snows and flowing from higher level to a lower level can be used for generation of electricity.

Flowing water → Turbine → Generator → Electricity

Potential energy to kinetic energy – Mechanical energy to electrical energy

Hydro Electric Energy

Hydro power is the cleanest, cheapest & best source of electricity generation. It falls under the conventional energy resource. Energy is derived from fast flowing water. Hydropower converts power of the falling water to electric power which can be transmitted to long distances through wires & cables. It can be stored for future use also. Hydropower is generated by using hydraulic machine, called turbines. Now high dams are built to obtain a substantial amount of hydrostatic pressure.

It has the main advantage over all the other forms of alternative energy production , that is, its greater reliability as compared to the other forms of alternative energy sources.

Coal:

- Normally found under the crest of earth trapped in rocks.
- Mostly (about 71%) Used in thermal power plant as fuel.
- Depending upon the carbon contents of coal these are classified as;

(i)Peat- 60% carbon

(ii) Lignite – (soft coal) 70% carbon

(iii) Bituminous- (household coal) 80% carbon

(iv) Anthracite- (Hard coal) -90% carbon

Crude Petroleum can be heated at various temperatures to get following useful products:

(i) Petroleum gas – LPG (Below 40^0C)

(ii) Petrol- 40 to 170^0C

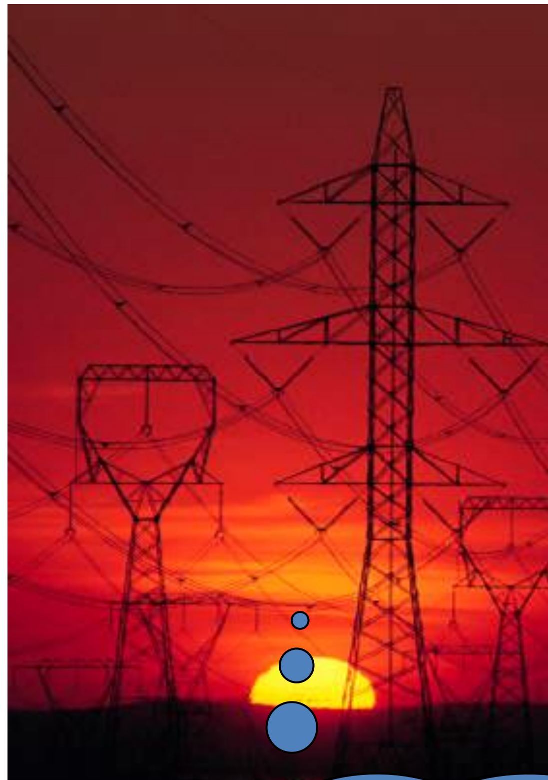
(iii) Kerosene- 170 to 250^0C

(iv) Diesel – 250-350 ^{0}C

(v) Lubricating oil, paraffin wax – above 400 ^{0}C

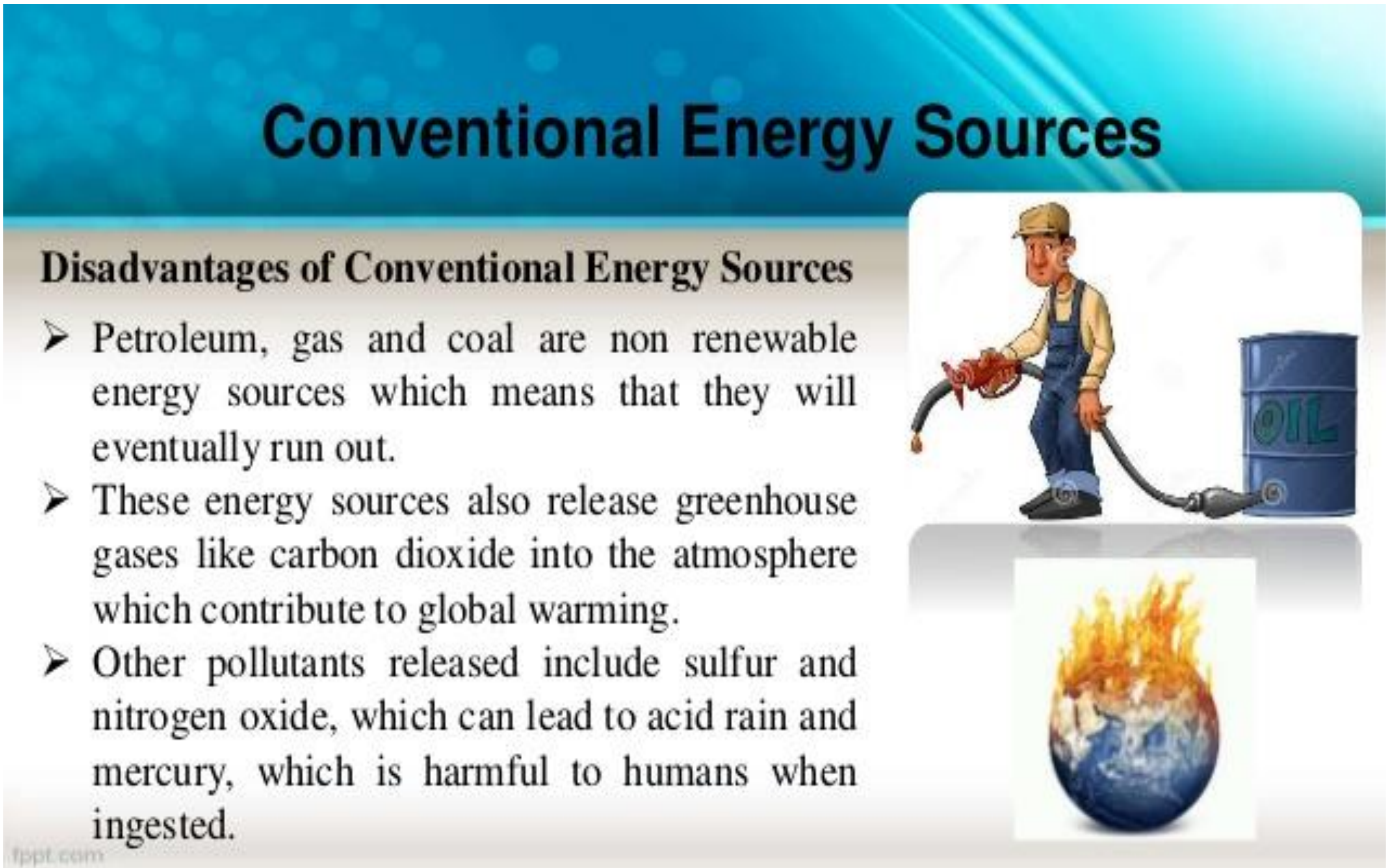
Natural gas- it consists of about 95% methane, and rest ethane and propane.

Burning of Fossil Fuels



Pollution from coal, natural gas, and oil

The conventional sources can produce energy irrespective of weather conditions.



Non conventional energy sources:

These sources are obtained from the earth atmosphere and have no shortage as far as their quantum is concerned.

- Solar
- Wind
- Biomass
- Tidal
- Geothermal
- Ocean energy.

Commercial and Non Commercial Energy sources.

On the nature of their transaction, the energy sources can be classified as commercial and noncommercial sources of energy .

All energy resources, particularly the commercial ones, are natural. Coal, oil and nuclear sources constitute commercial sources,

While firewood, biomass and animal dung constitute non- commercial sources.

Non Renewable and Renewable Sources of Energy Sources

Non Renewable Energy Sources:

These energy sources are nature gifted resources being accumulated in nature for a very long time and can't be replaced if exhausted. Once these natural resources are used up, they are gone forever, hence called non- renewable.

Example: coal, petroleum, natural gas, thermal power, hydro power and nuclear power are the main conventional sources of energy.

Uranium is a non-renewable source, but it is not a fossil fuel.
Uranium is converted to a fuel and used in nuclear power plants.

Renewable Energy Sources

Energy sources, which are continuously and freely produced in the nature and are not exhaustible, are known as the renewable sources of energy.

Renewable energy is captured from an energy resource that is replaced rapidly by a natural process.

Example: solar energy, biomass and wood energy, geo thermal energy, wind energy, tidal energy and ocean energy.

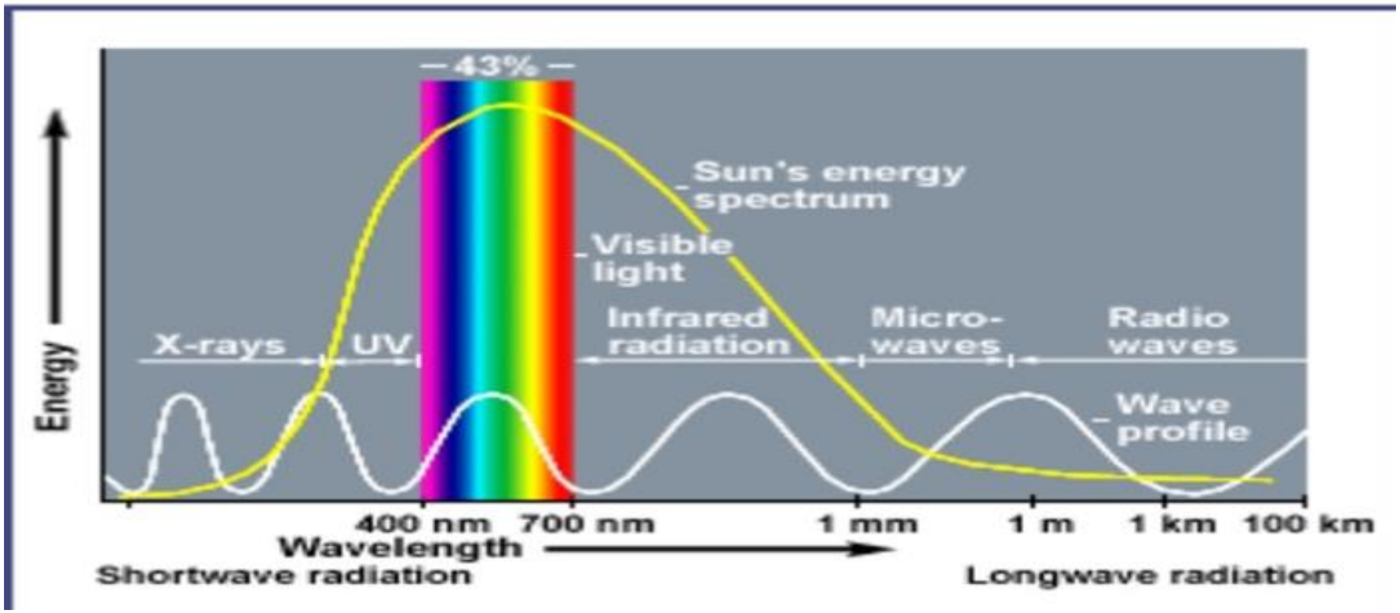
But main attention has to be directed to the following sources of renewable namely, a) solar photovoltaic, b) wind, and c) hydrogen fuel cell.

Renewable energy

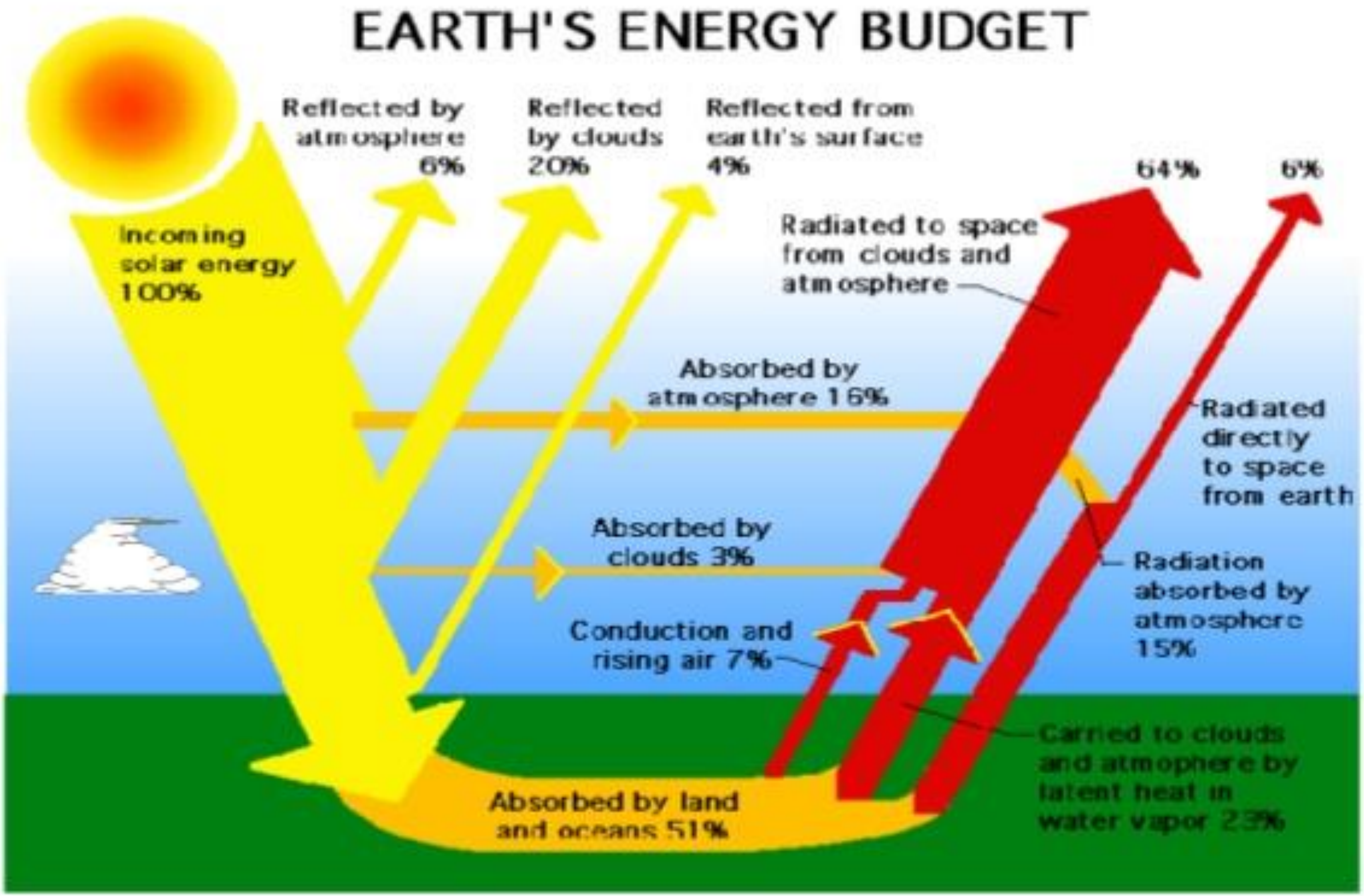
- **Renewable energy** is energy that is collected from renewable sources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy often provides energy in four important areas:
- Electricity generation,
- Air and water heating/cooling,
- Transportation and
- Rural (off grid) energy services.

Solar Energy

Solar energy is the energy received from the sun. This energy is in the form of solar radiation, which may be used directly for thermal applications like drying, heating etc. and can also be used to produce electricity by using solar PV cells.



Solar Power


EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Use of solar energy

Thermal mode and photovoltaic mode

(A) In domestic sector

- Cooking
- Water heating
- Lightening
- Operating electrical appliances
- Solar distillation
- Drying

(B) In Agriculture sector

- Pumping of irrigation water
- Drying of farm produce
- Winnowing
- Soil solarisation

USAGE OF SOLAR POWER

Agricultural Usage:

Agriculture seeks to optimize the capture of solar energy in order to optimize the productivity of plants. Sunlight is generally considered a plentiful resource, the exceptions highlight the importance of solar energy to agriculture.

Greenhouses convert solar light to heat, enabling year-round production and the growth c specialty crops and other plants not naturally suited to the local climate.

Drying

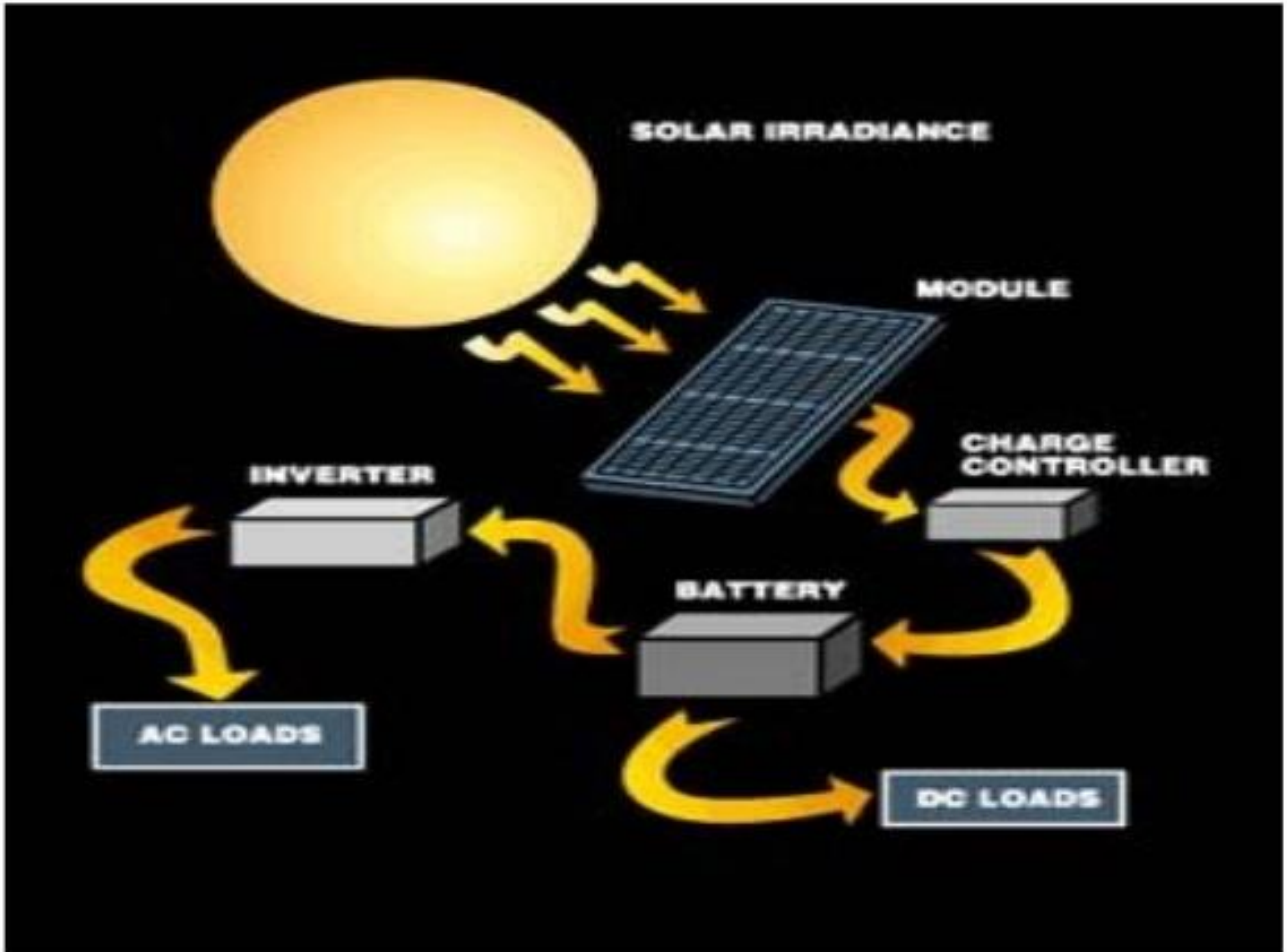
- For safe storage
- For off season use of the product
- The important factor is to preserve the nutritive value and the colour

Protection from birds, no effect of rain, wind storm etc.

Solar dryers

Solar steam generator and steam engine that operates with a high efficiency for pumping water

Solar PV pump for irrigation



Electricity generation from solar energy

Photovoltaic pumping system specifications

Motor pump/ Configuration	**Output (m^3.day)**	**Head (m)**	**Solar Array (Wp)**
Submerged borehole motor pump	40 25	20 20	1200 800
Surface motor/ submerged pump	60	7	840
Reciprocating positive displacement pump	6	100	1200
Floating motor/pumpset	100 10	3 3	530 85
Surface suction pump	40	4	350

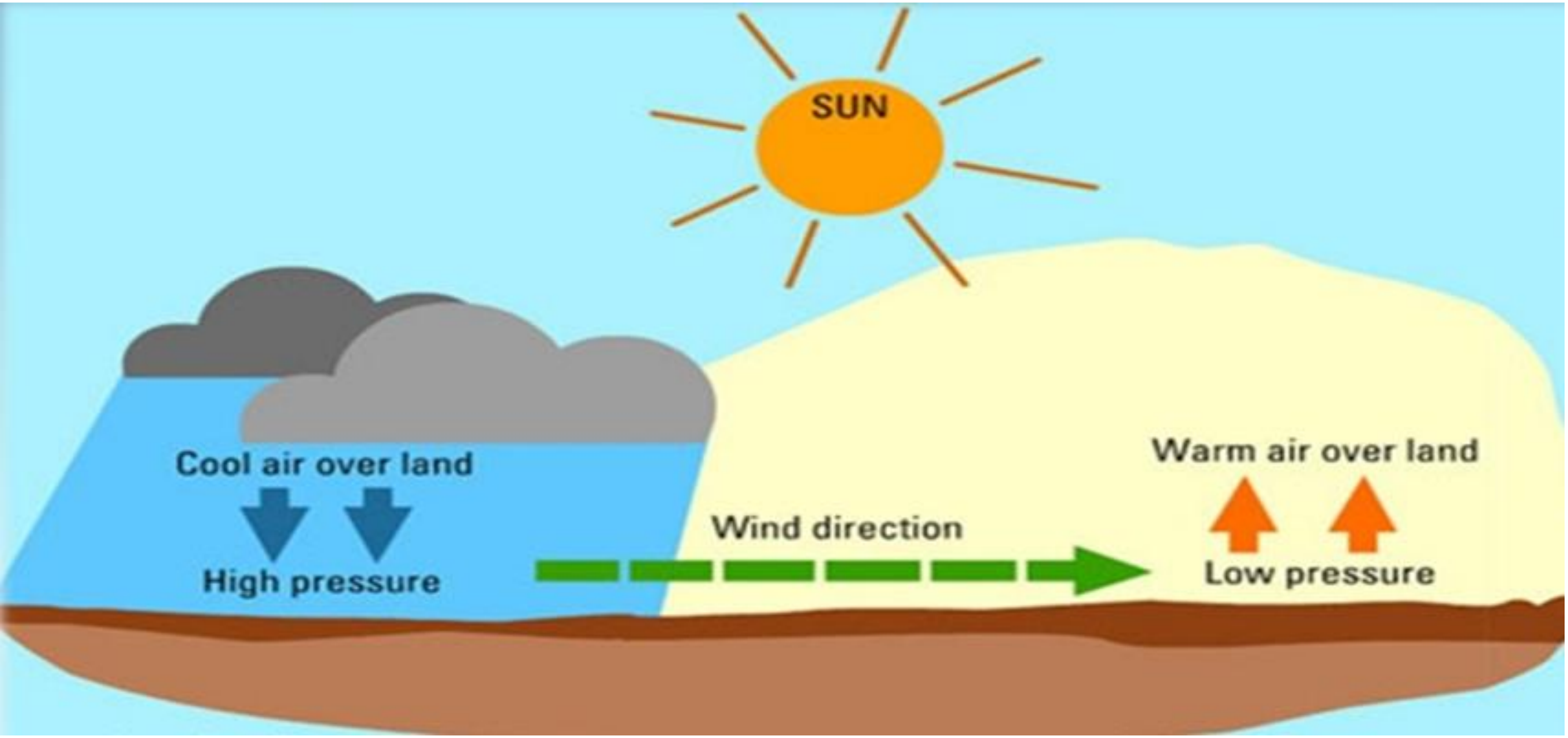
View of SOLAR PHOTOVOLTAICS pump with Sun tracker for 900 Wp SPV Panel in Operation

Wind 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, bodies of water, and vegetative cover.

This wind flow or energy in wind motion, can be harnessed by windmills for pumping, grinding etc. or by modern wind turbines to generate electricity.

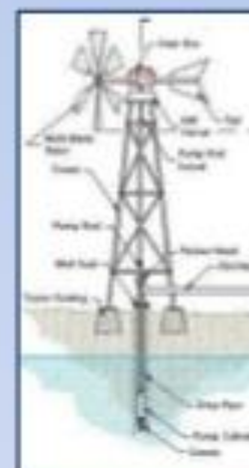


This behaviour of warm gases or liquids moving upward and being replaced by cooler particles is called Convection. The energy moving during convection is called convectional current.

The wind energy is kinetic energy from the wind.

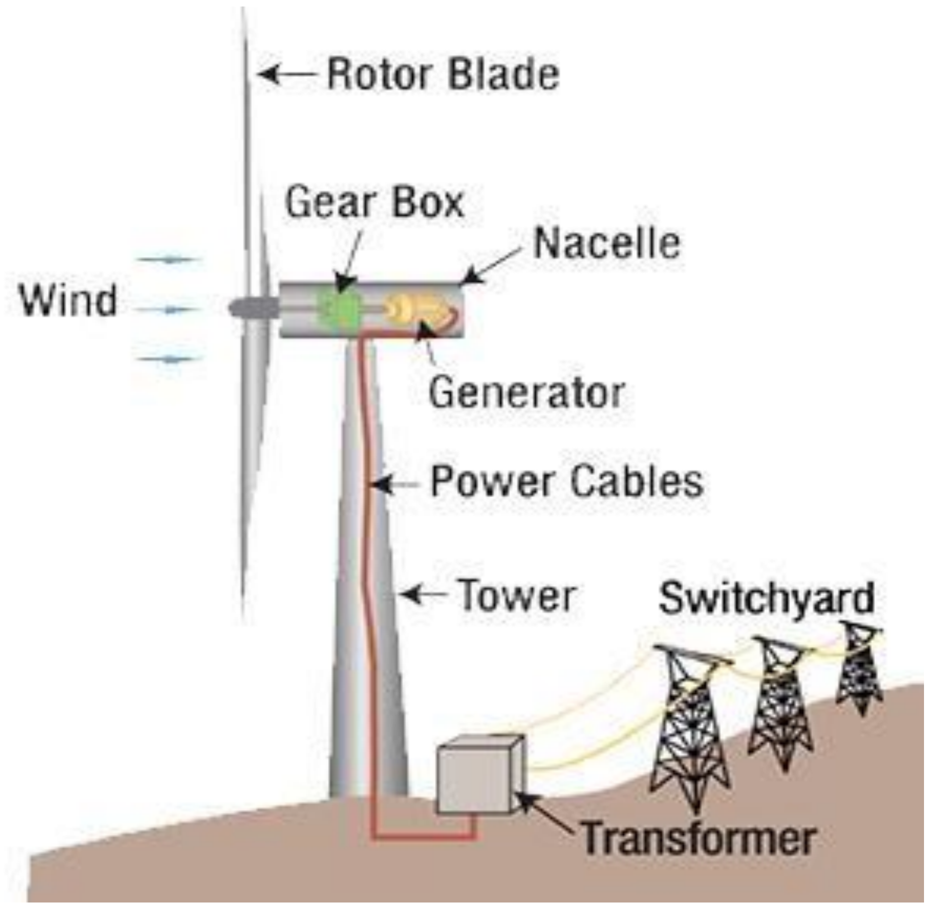
Wind turbines: how do they work? (1)

- Wind turbines convert the **kinetic energy** in the wind into mechanical power.
- This **mechanical power** can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into **electricity**.
- <u>A wind turbine works the opposite of a fan.</u>
- Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.



Wind turbine

The wind turbines use the kinetic energy of the wind and convert that energy into mechanical energy, which in turn can be converted into electricity by means of a generator.



The new windmills, also known as wind turbines, appeared in Denmark as early as 1890.

Power in the Wind (W/m2)

- The power in the wind is:

$$\text{Power} = \tfrac{1}{2}\,\rho\,A\,V^3$$

$$= 1/2 \times \text{air density} \times \text{swept rotor area} \times (\text{wind speed})^3$$

ρ

A

V^3

Density = P/(RxT)

P – pressure (Pa)
R – specific gas constant (287 J/kgK)
T – air temperature (K)

Area = πr^2

Instantaneous Speed
(not mean speed)

kg/m^3	m^2	m/s

- Using the density of air at sea level:

Power = $0.6125\,AV^3$ (metric)

Types of wind machines

Fan Mill Horizontal Axis

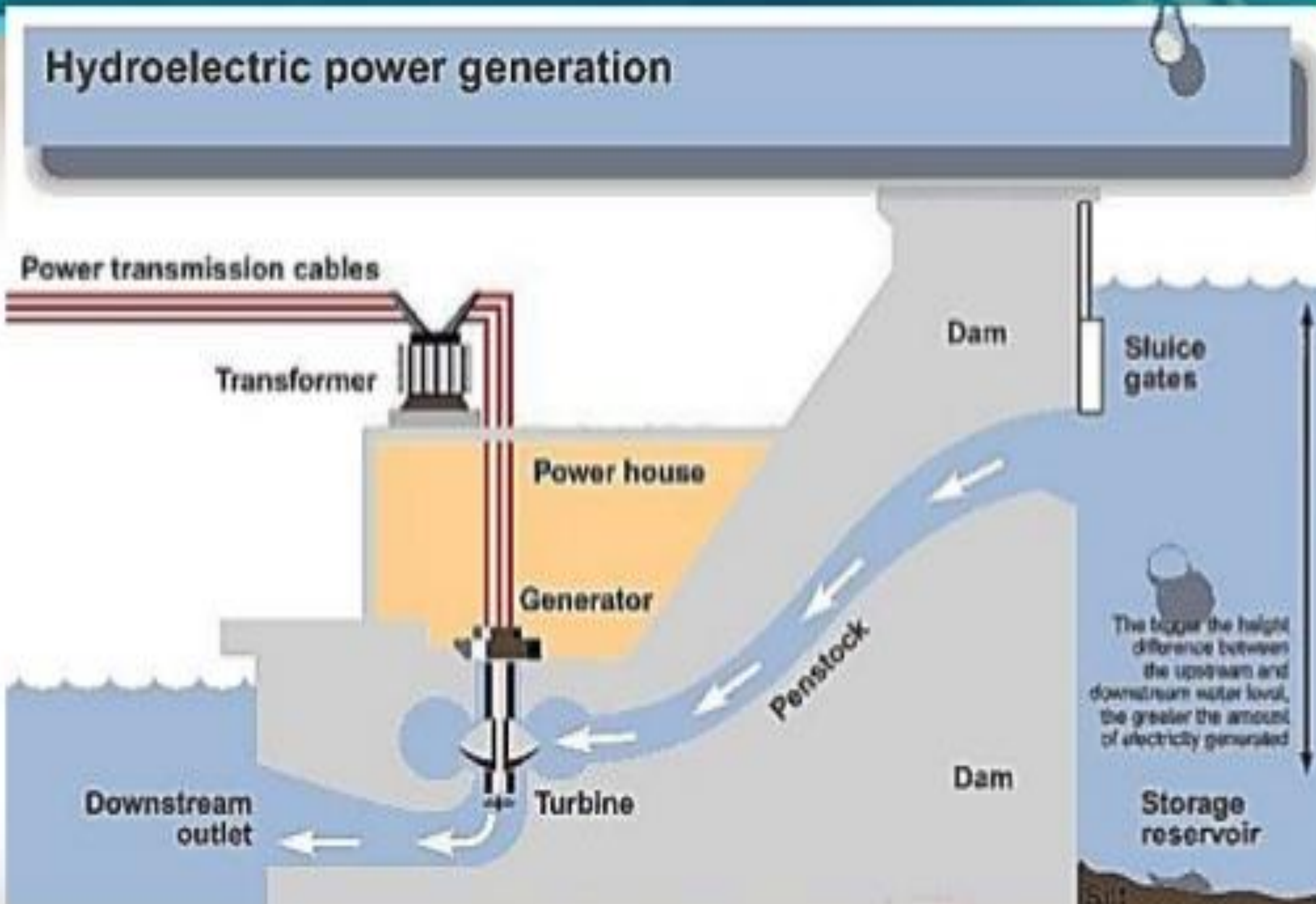
Darrieus Vertical Axis

Hydropower

Harvesting energy from water is possible due to the gravitational potential energy stored in water. As water flows from a high potential energy (high ground) to lower potential energy (lower ground), the potential energy difference thereby created can be partially converted into kinetic, and in this case electric energy through the use of a generator.

There are essentially two major designs in use that utilize water to produce electricity: the hydroelectric dam, and the pumped-storage plant.

Hydropower


Hydroelectric power generation
Power transmission cables
Transformer
Power house
Generator
Turbine
Downstream outlet
Penstock
Dam
Dam
Sluice gates
The bigger the height difference between the upstream and downstream water level, the greater the amount of electricity generated
Storage reservoir

Principle :

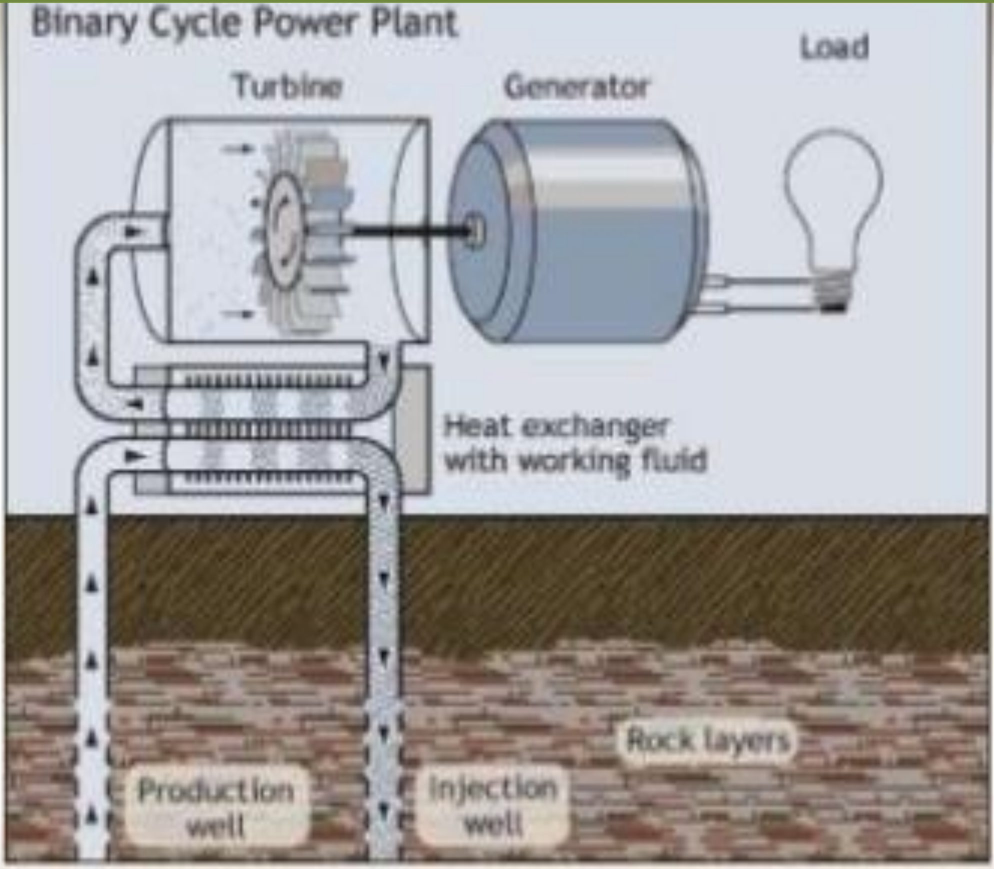
The force of the water being released from the reservoir through the penstock of the dam spins the blades of a turbine. The turbine is connected to the generator that produces electricity. After passing through the turbine, the water reenters the river on the downstream side of the dam.

A pumped-storage plant is very similar to the hydroelectric dam, the main difference being that the pumped-storage plant uses two reservoirs, one being considerably higher than the other. The advantage of this design is that during periods of low demand for electricity, such as nights and weekends, energy is stored by reversing the turbines and pumping water from the lower to the upper reservoir. The stored water can later be released to turn the turbines and generate electricity as it flows back into the lower reservoir.

Geothermal energy

It is one of the only renewable energy sources not dependent on the Sun. Instead, it relies on heat produced under the surface of the Earth.

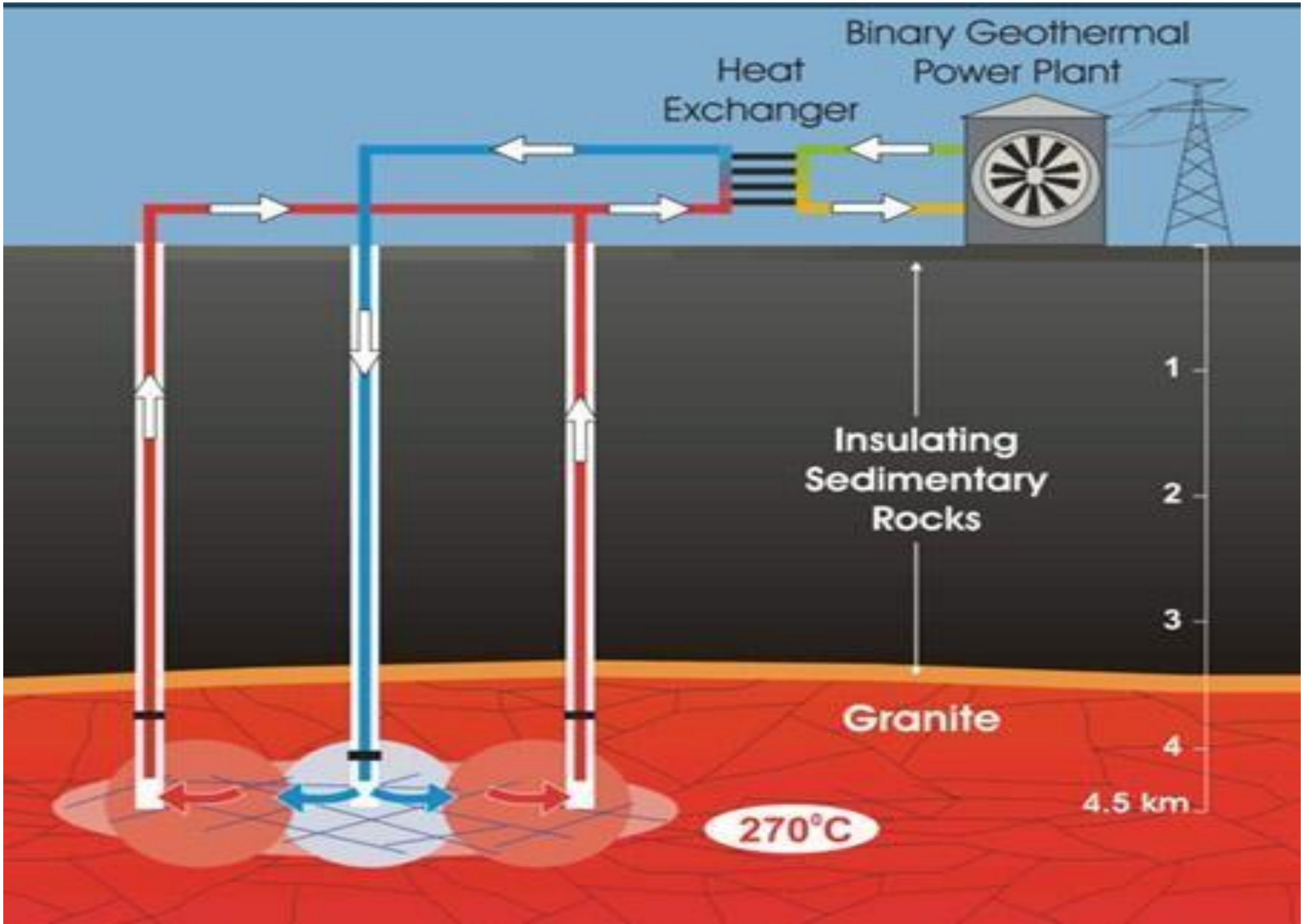
- Geothermal energy is energy obtained by tapping the heat of the earth itself, both from kilometers deep into the Earth's crust in volcanically active locations of the globe or from shallow depths, as in geothermal heat pumps in most locations of the planet. It is expensive to build a power station but operating costs are low resulting in low energy costs for suitable sites. Ultimately, this energy derives from heat in the Earth's core.



Geothermal energy

- Three types of power plants are used to generate power from geothermal energy: dry steam, flash, and binary.
- Dry steam plants take steam out of fractures in the ground and use it to directly drive a turbine that spins a generator.
- Flash plants take hot water, usually at temperatures over 200 °C, out of the ground, and allows it to boil as it rises to the surface then separates the steam phase in steam/water separators and then runs the steam through a turbine.
- In binary plants, the hot water flows through heat exchangers, boiling an organic fluid that spins the turbine. The condensed steam and remaining geothermal fluid from all three types of plants are injected back into the hot rock to pick up more heat.
- The geothermal energy from the core of the Earth is closer to the surface in some areas than in others. Where hot underground steam or water can be tapped and brought to the surface it may be used to generate electricity.

Binary Geothermal Power Plant



Problems with Geothermal energy use

Some problems that geothermal energy faces are depletion of both water and heat in geothermal areas.

- The first problem has been partially addressed by re-injecting water into reservoirs, thus sustaining the plant's ability to operate.
- Water re-injection can cause small earthquakes, which raises the question of whether the plants should be liable for the damages caused.

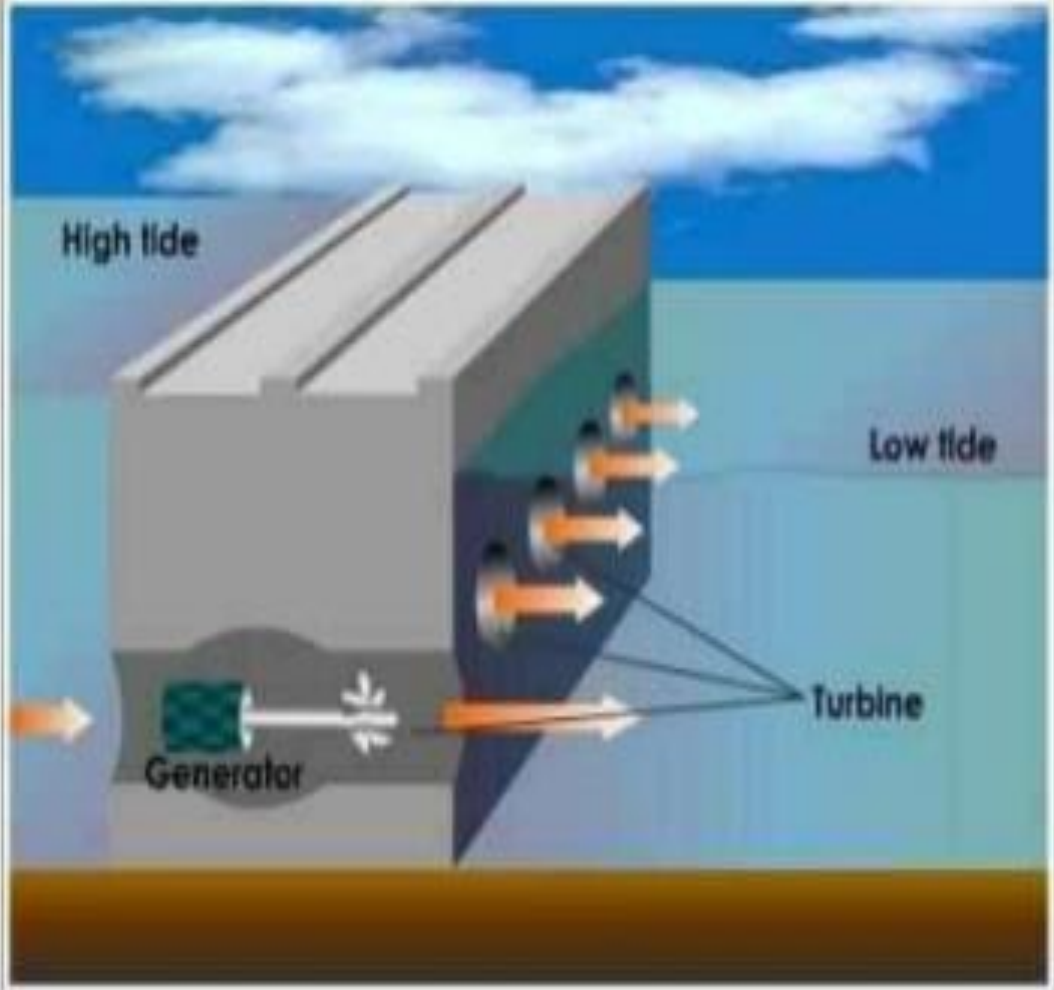
Ocean Energy

Nearly seventy percent of the Earth's surface is covered by oceans, which have the potential to supply humans with an enormous amount of renewable energy. Humans have exploited the vast energy potential of Earth's oceans by taking advantage of wave movement, tides, ocean currents, and ocean thermal energy.

Wave farm: This technology is based on the principle of rolling waves flowing through joints in a large cylindrical pipe, which pushes high pressure oil through hydraulic motors to generate electricity- which is in turn fed to an onshore grid through an underwater cable. Thus wave energy can be converted to electricity. One square kilometer of ocean interspersed with the devices would produce about 30 MW of electricity, which could power 20,000 homes.

Tidal Energy

- This is another unlimited and inexhaustible source of energy. The Gulfs of Kutch is preferably suited to build up electricity from the energy produced by high and lofty tides entering into slender creeks.



Ebb generation

Ebb generation means, at high tide, water flows in through openings (gates) in the barrage, or dam up to the normal level, spinning turbines to generate electricity. The water is retained behind the barrage until low tide, when it flows out again, once again spinning the turbines and generating electricity.

The predictability of tides makes tidal power a reliable energy source, though it can only produce electricity at certain times of day: during high and low tides.

BIOMASS ENERGY

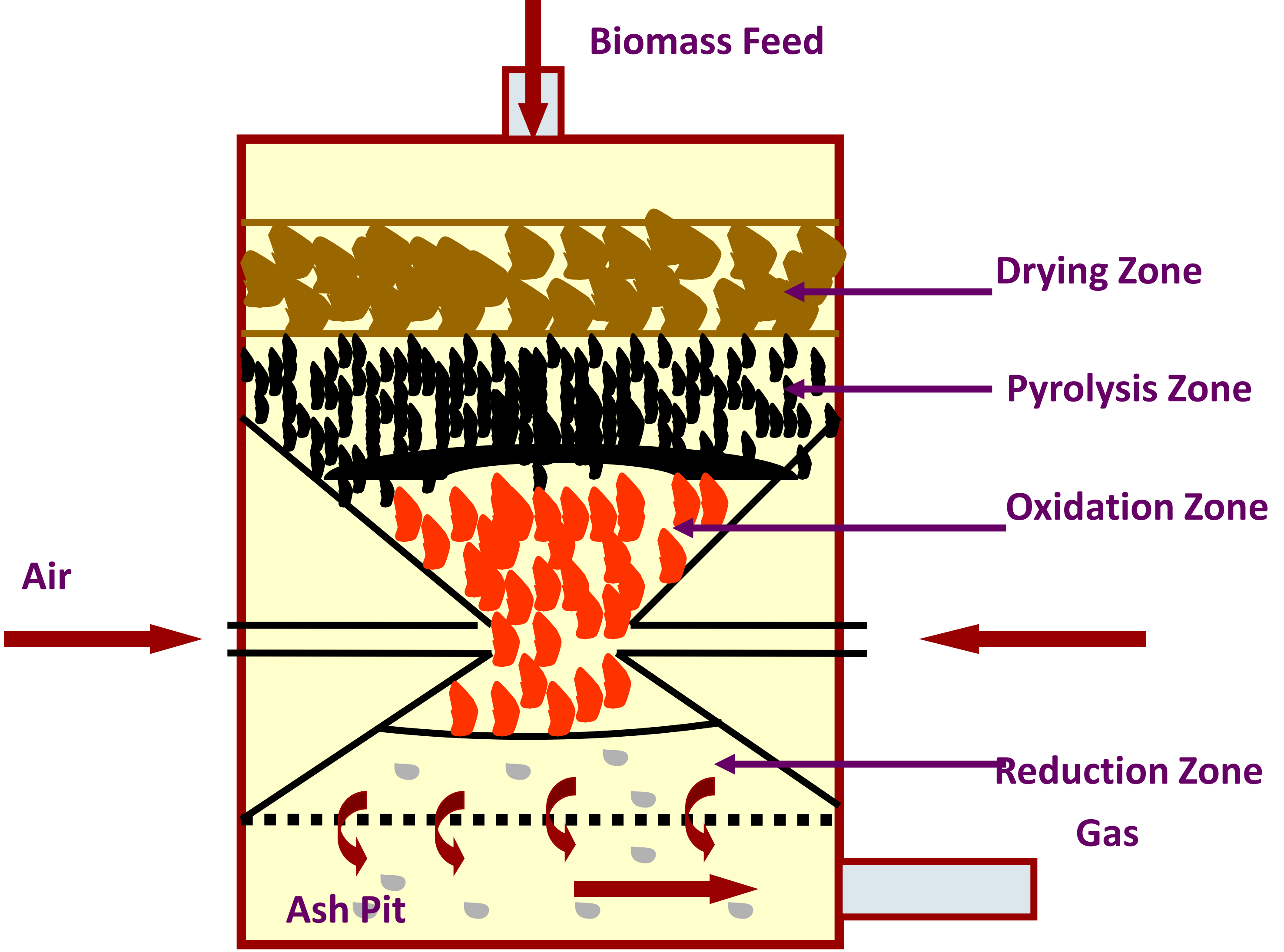
Biomass, a renewable energy source, is biological material derived from living, or recently living organisms, such as wood, waste, and alcohol fuels.

Biomass

Biomass can be converted into fuels through a number of different processes, including solid fuel combustion, digestion, pyrolysis, and fermentation and catalyzed reactions.

Electricity is generated in many places through solid fuel combustion.

- **Pyrolysis** creates a product much like charcoal, with double the energy density of the original biomass, making the fuel highly transportable and more efficient.
- The most widely used alternative fuel, ethanol, is created through fermentation of organic materials.



Biomass wastes based Gasifier for thermal and power generation

Ethanol

Ethanol, also known as ethyl alcohol or grain alcohol, is a colorless, clear liquid. The chemical formula is **CH_3CH_2OH.** Fuel-quality ethanol goes through more processes than do alcoholic beverages, in order to make it unfit for human consumption and to increase the purity so as to avoid separation when mixed with gasoline.

- Ethanol is not used by itself to fuel vehicles. Instead, it's mixed with gasoline. The two most common blends are E10 and E85. The number refers to the percentage of ethanol in the blend. E10 is a blend of ten percent ethanol and ninety percent gasoline. E85, the most mainstream alternative fuel, is eighty-five percent ethanol and fifteen percent gasoline.

- Using ethanol increases the octane rating and decreases the amount of damaging emissions associated with fuel consumption. It is for this second reason that ethanol use is so strongly recommended.
- Increase in use of ethanol as fuel will benefit farmers economically. The majority of ethanol used today comes from corn.
- The variety of other feedstock that can be used today includes barley, wheat, cornstalks, rice straw, sugarcane bagasse, pulpwood, switch grass and even municipal solid waste.

Biogas Production from Organic Waste

- Biogas is produced when bacteria degrade organic matter in the absence of air.
- Biogas contains around 55-65% of methane, 30-40% of carbon dioxide and small quantities of hydrogen, nitrogen, carbon monoxide, oxygen and hydrogen sulphide.
- The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ: at around 55% methane content).
- The biogas can effectively be utilized for generation of power through a biogas based power generation system after dewatering and cleaning of the gas.
- The slurry produced in the process provides valuable organic manure for farming.

FAMILY SIZE BIOGAS PLANT

Advantages of Renewable Energy

Renewable Energy	Non-renewable Energy
Continuous supply.	Limited supply.
Can be replenished within a short period time.	It takes a longer time (millions of years) to be replenished.
Most of the resources are fairly non-polluting and available locally.	Cause pollution and global warming.

Disadvantages of Renewable energy sources

A common disadvantage to all is that it is difficult to produce the large quantities of electricity their counterpart the fossil fuels are able to. Since they are also new technologies, the cost of initiating them is high.

- wind : turbines are expensive. Wind doesn't blow all the time, so they have to be part of a larger plan.
- Solar :panels are expensive Not all climates are suitable for solar panels.
- waves : different technologies are being tried around the world. Scientists are still waiting for the killer product.
- tides : barrages (dams) across river mouths are expensive to build and disrupt shipping. Smaller turbines are cheaper and easier to install.

Disadvantages of Renewable energy sources

- Rivers : Dams are expensive to build and disrupt the environment. They have also caused earthquakes.
- Geothermal : Difficult to drill two or three kilometers down into the earth.
- Biofuel : Often uses crop lands and crops (like corn) to produce the bio-alcohol. This means that more land has to be cleared to grow crops, or there is not enough food, or that food becomes more expensive.

- Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). India was the first country in the world to set up a ministry of non-conventional energy resources, in the early 1980s.
- Solar Energy Corporation of India is responsible for the development of solar energy industry in India.
- Hydroelectricity is administered separately by the Ministry of Power and not included in MNRE targets.

Contribution of Energy Sources in Agriculture Sector

In agriculture sector the following operations are generally performed:

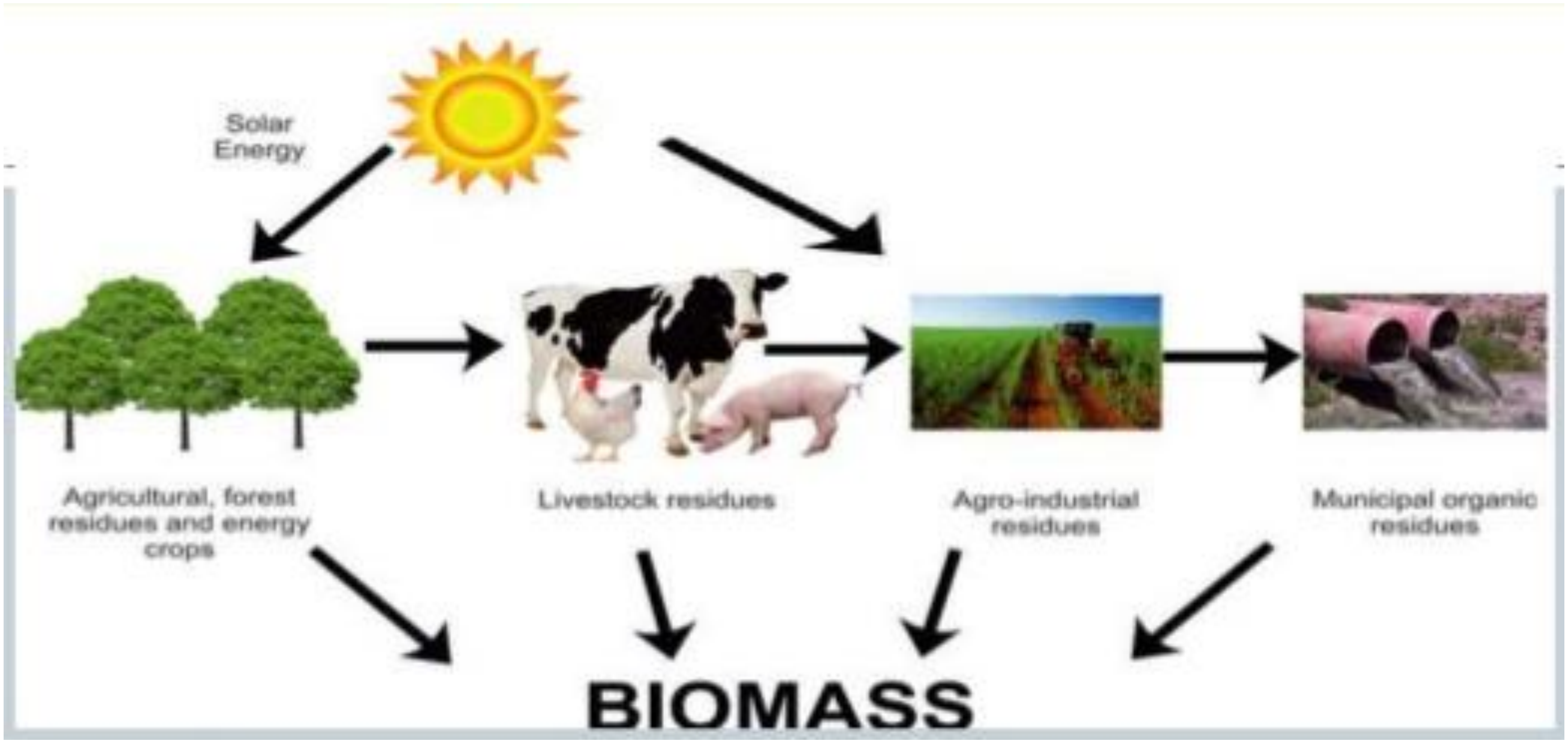
1. Land preparation
2. Sowing or transplanting
3. Water pumping
4. Weeding
5. Spraying & dusting
6. Harvesting
7. Drying
8. Transportation
9. Processing of products
10. Packaging
11. Long time storage in cold stores.

For all these activities, energy is required which can be obtained by different energy sources like diesel, electricity, biomass, cattle dung , solar and wind along with the power of human and animals .

Thank You

Lect.-2

Familiarization with biomass utilization for biofuel production and their applications



Utilization of Biomass

Technology	Energy services provided
Biogas	• Cooking • Heating • Electricity (local pumping, milling, lighting, and possible distribution via utility grid
Producer gas	• Electricity (local pumping, milling, lighting, and possible distribution via utility grid) • Heating
Ethanol / Bio-diesel	• Vehicle transportation • Cooking
Boiler + Steam turbine	• Electricity (for industrial processing) • Heating process heat
Biofuel + Gas turbine	• Electricity (for industrial processing) • Heating process heat

Properties of Biomass

Physical Properties

Following are important for solid fuels for combustion / thermal processing:

- **Moisture Content**
- **Particle Size and Size distribution**
- **Bulk Density & Specific gravity**
- **Higher Heating/Calorific Value**

TABLE Typical proximate analysis of sugar-cane bagasse at 20% moisture

Component	Mass % w.b.
Moisture	20.00
Volatile	65.24
Fixed carbon	12.11
Ash	2.65
High heat value (MJ/kg) (dry basis)	19.04

Chemical composition of biomass

- Total Ash %,
- Solvent soluble %,
- Water Soluble %,
- Lignin %,
- Cellulose %,
- Hemi-cellulose %

- Wood is grouped as either hardwood or softwood.
- Softwoods have 40–45% cellulose, 24–37% hemicellulose and 25–30% lignin.
- Hardwoods contain approximately 40–50% cellulose and 22–40% hemicellulose.

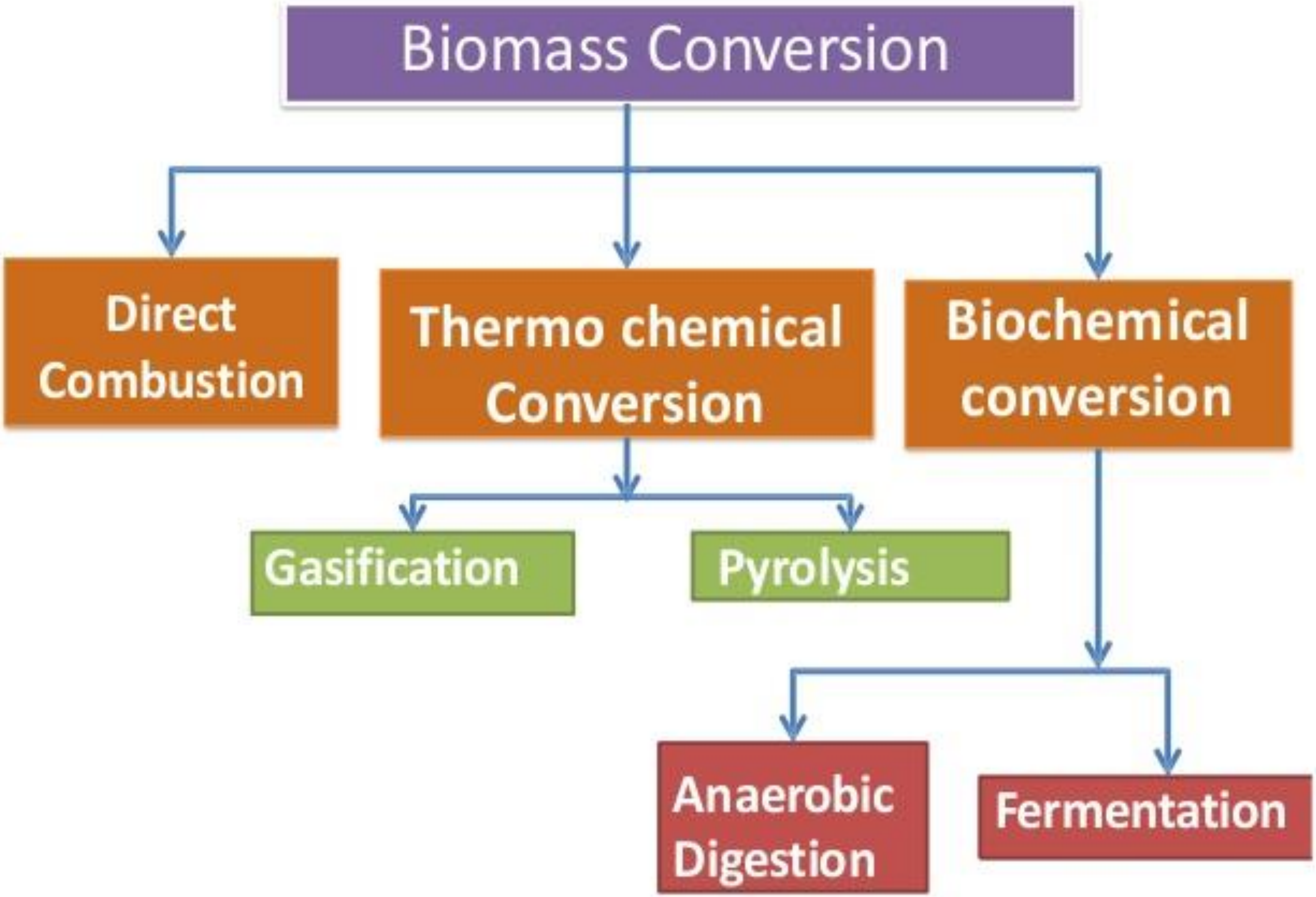
Properties of Biomass

Elemental Composition

- Carbon
- Hydrogen
- Oxygen
- Nitrogen
- Sulphur

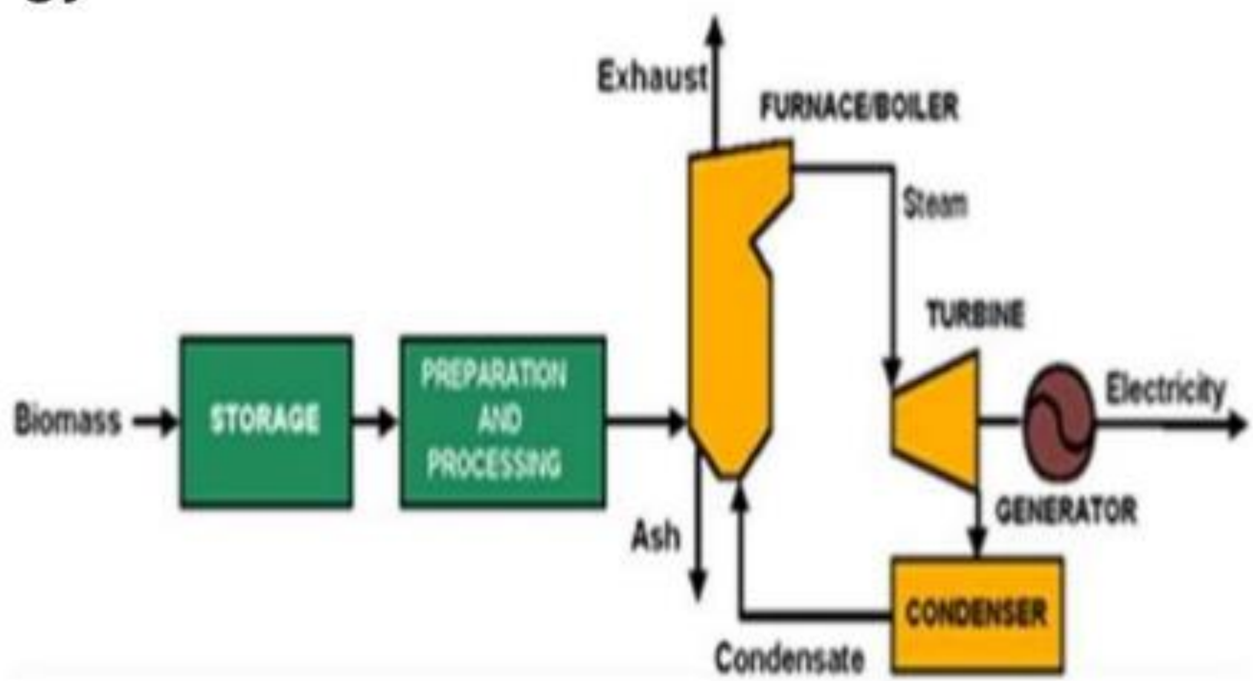
TABLE Typical ultimate analysis of sugar-cane bagasse

Component	Mass %, d.b.
C	49.66
H	5.71
O	41.08
N	0.21
S	0.03
Ash	3.31


Biomass Conversion
Direct Combustion
Thermo chemical Conversion
Biochemical conversion
Gasification
Pyrolysis
Anaerobic Digestion
Fermentation

Direct Combustion

In a direct combustion system, biomass is burned in a **combustor** or **furnace** to generate hot gas, which is fed into a boiler to generate **steam**, which is expanded through a steam **turbine** or steam engine to produce **mechanical** or **electrical energy**.



Direct Combustion

- The direct combustion of biomass in **presence** of **oxygen/air** to produce heat and by products is called direct combustion.

- The complete combustion of biomass into ash is called incineration.

- This heat energy in the product gases or in the form of steam can be used for various applications like space heating or cooling, power generation process heating in industries or any other application.

Thermo-Chemical Conversion

The thermo chemical reaction can convert the organic biomass into more valuable and convenient form of products as gaseous and liquid fuels,residue and by-products etc.

These processes can be carried out in following ways:

1) Gasification
2) Pyrolysis

Pyrolysis

It is the heating of biomass in a closed vessel at temperatures in the range 500°c-700°C in **absence** of **O_2/air** or with steam. It produces solid, liquid and gases.

The pyrolysis process can use all type of organic materials including plastic and rubber

Gasification- takes place by heating the biomass with **limited oxygen / Air** (deficient O2 and Air) to produce low heating value gas or by reacting it with **steam** & **oxygen** at **high pressure** & **temperature** to produce medium heating value gas like H_2,CO,CH_4,N_2

Biochemical Conversion

In biochemical processes the **bacteria and micro organisms** are used to transform the raw biomass into useful energy like methane and ethane gas. Following organic treatments are given to the biomass:

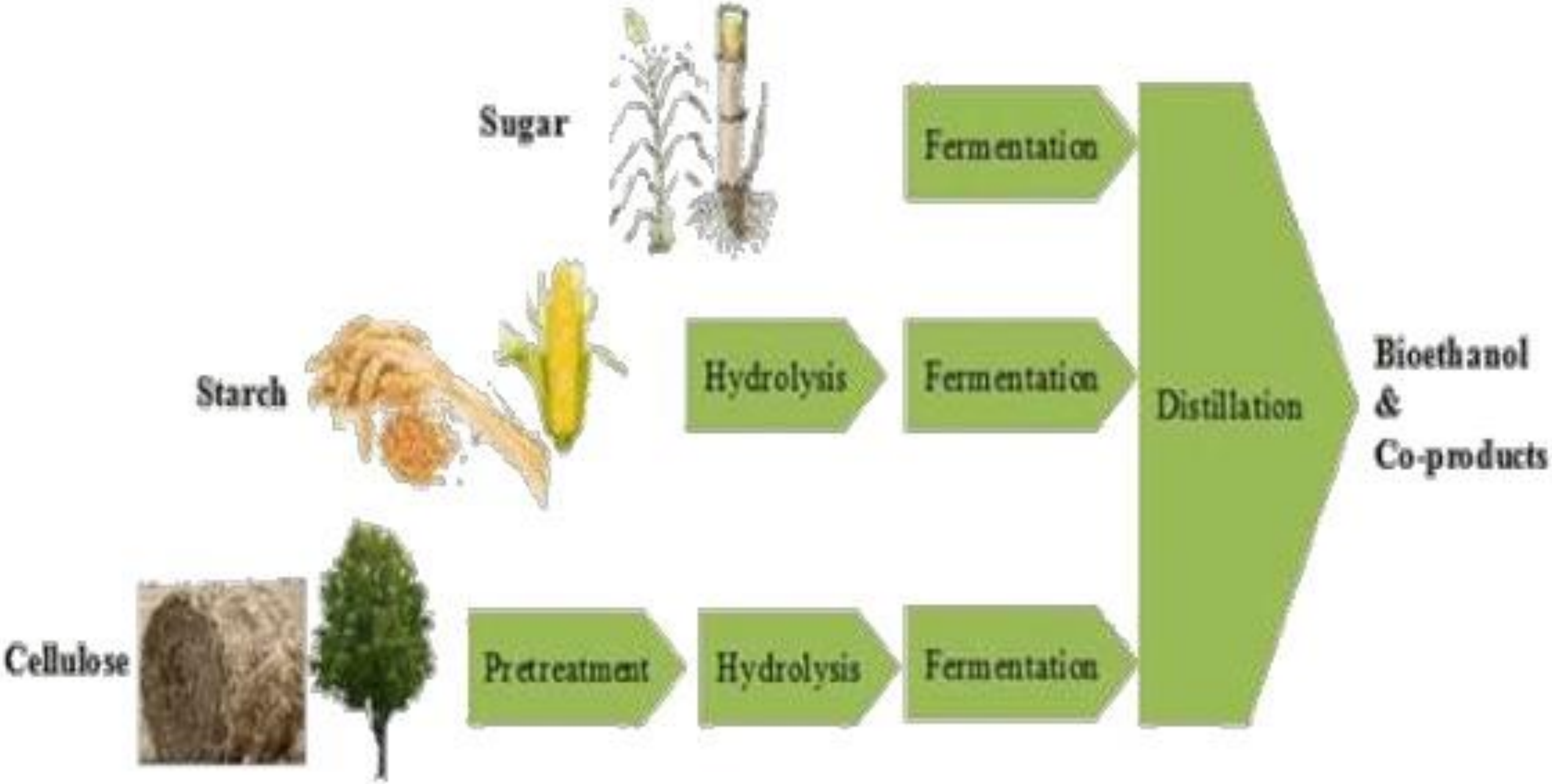
1) Fermentation of biomass (Aerobic digestion)
2) Anaerobic digestion of biomass

Fermentation

Fermentation is a process of decomposition of complex molecules of organic compound under the influence of micro-organism(**ferment**) such as **yeast**, bacteria, enzymes etc.

The example of fermentation process is the conversion of grains and sugar crops into ethanol and CO_2 in presence of yeast.

Fermentation



Biofuel

Any fuel that is derived from biomass—that is, plant or algae material or animal waste. Since such feedstock material can be replenished readily, bio-fuel is considered to be a source of renewable energy.

The two most common types of biofuels in use today are ethanol and biodiesel.

Ethanol

- Ethanol is a alcohol fuel made from the sugars found in grains such as corn, sorghum, and wheat, as well as potato skins, rice, sugarcane, sugar beets etc. by fermentation.
- It is used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions.
- The most common blend of ethanol is E10 (10% ethanol, 90% gasoline).
- Some vehicles, called flexible fuel vehicles, are designed to run on E85 (a gasoline-ethanol blend containing 51%–83% ethanol).
- Most ethanol is made from plant starches and sugars.
- The common method for converting biomass into ethanol is called fermentation. During fermentation, microorganisms (e.g., bacteria and yeast) metabolize plant sugars and produce ethanol.

Characteristics of bio-fuels

- Kinematic viscosity
- Density
- Calorific value
- Melt or pour point
- Cloud point
- Flash point
- Cetane number
- Carbon residue
- Ash percentage
- Sulphur percentage

Kinetic Viscosity:

- Viscosity represents flow characteristics of fluids. Fuel atomization is also affected by fuel viscosity.
- Fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion, increased exhaust smoke and emissions.

Density:

- It's the weight per unit volume.
- Oils that are denser contain more energy.
- For example, petrol and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per litre. Biodiesel is generally denser than diesel fuel with sample values rangingbetween 877 kg/m3 to 884 kg/m^3 compared with diesel at 835 kg/m^3. Thus, density of the final product depends mostly on the feedstock used.

Melt point or Pour point :

- In case where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.

Cloud point:

- The temperature at which an oil starts to solidify is known as the cloud point.
- While operating an engine at temperatures below an oil's cloud point, heating will be necessary in order to avoid waxing of the fuel.

Flash point

- The flash point temperature of fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of fuel.
- The flash point determines the flammability of the material. Neat biodiesel has a flash point (150°C) well above the flash point of petroleum based diesel fuel (±70°C).

Cetane number

- Fuels with low Cetane Numbers will result in difficult starting, noise and exhaust smoke.
- In general, diesel engines will operate better on fuels with Cetane Numbers above 50.
- Diesel fuel usually has a cetane rating between 45 and 50 while vegetable oil is 35 to 45. Biodiesel is usually have in between 50 to 60.

Carbon residue:

- This indicates the tendency of fuel to form carbon deposits in an engine.
- An important indicator of the quality of biodiesel is the carbon residue, which corresponds to the content of glycerides, free fatty acids, soaps, polymers and remaining catalyst.

Ash Percentage:

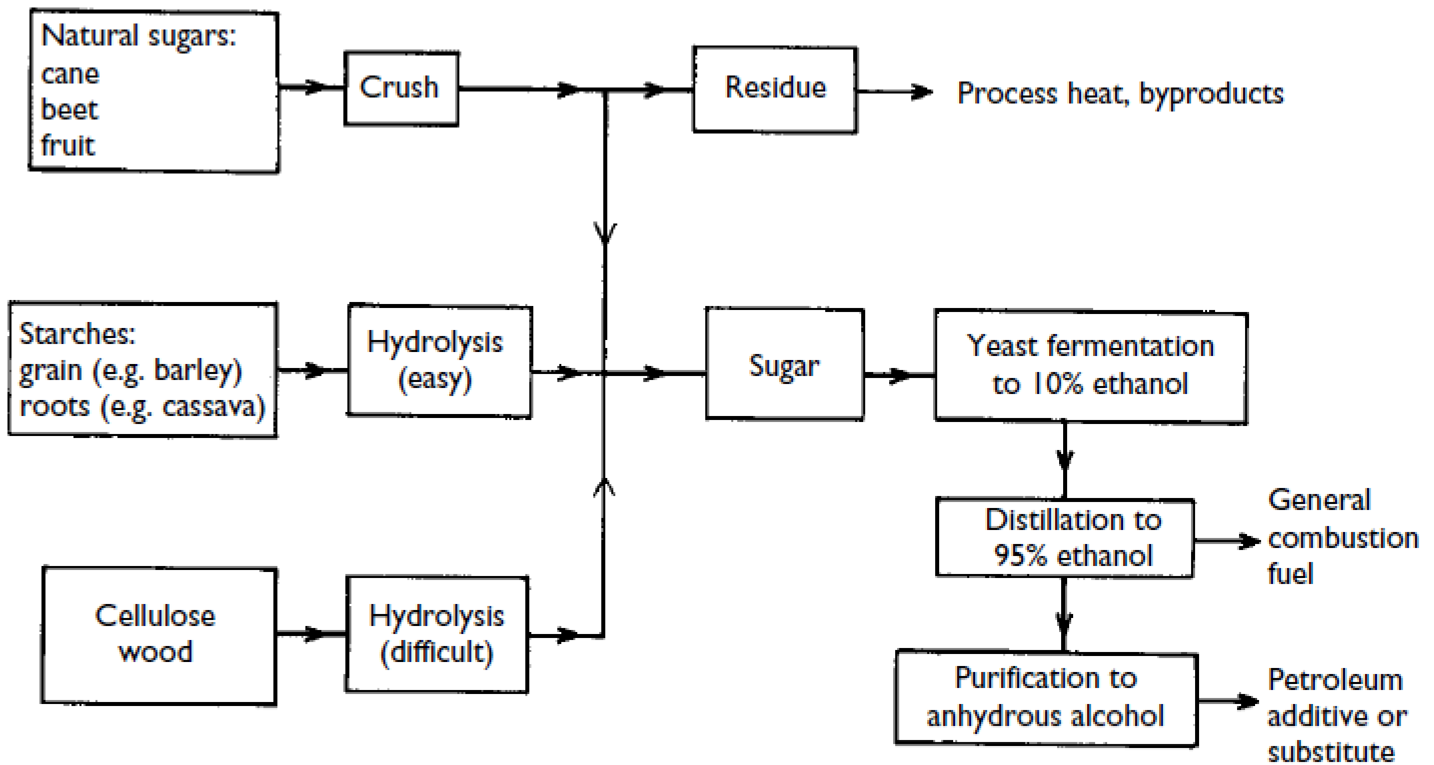
- Ash is a measure of the amount of metals contained in the fuel.
- High concentrations of these materials can cause injector tip plugging, combustion deposits and injection system wear. The ash content is important for the heating value, as heating value decreases with increasing ash content.

Sulphur percentage: The percentage by weight, of sulphur in the fuel.

- First use vegetable oil and animal fat based biodiesel has less than 15 ppm sulphur.

Production of Ethanol

Ethanol, C_2H_5OH, is produced naturally by certain micro-organisms from sugars under acidic conditions, i.e. pH 4 to 5.



Directly from Sugarcane

Usually commercial sucrose is removed from the cane juices, and the remaining molasses used for the alcohol production process (These molasses themselves have about 55% sugar content. But if the molasses have little commercial value, then ethanol production from molasses has favourable commercial possibilities, especially if the cane residue (bagasse) is available to provide process heat. In this case the major reaction is the conversion of sucrose to ethanol:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{yeast}} 4C_2H_5OH + 4CO_2$$

In practice the yield is limited by other reactions and the increase in mass of yeast. Commercial yields are about 80% of those predicted . The fermentation reactions for other sugars, e.g. glucose, $C_6H_{12}O_6$, are very similar.

The feedstock used in this process is corn stover. The main compounds are (on dry basis, wt.) cellulose (37.4%), hemicellulose (21.1%) and lignin (18.0%). The modeling starts just after the washing of the feedstock which step induces an increase of the feedstock moisture. Three reaction steps follow:

1.Hydrolysis : the feedstock is heated (190°C) at high pressure (12.1 atm) with an acid catalyst (H2SO4). Most of the hemicellulose is converted to xylose.
2. Saccharification : this is an enzymatic reaction that converts the cellulose into glucose.

3. Fermentation : most of the glucose and xylose are converted to ethanol and carbon dioxide.

Ethanol fuel use

Liquid fuels are of great importance because of their ease of handling and controllable combustion in engines. Anhydrous ethanol is a liquid

with a flash point of 130 C and an ignition temperature of 423 C, and so has the characteristics of a commercial liquid fuel, being used

as a direct substitute or additive for petrol (gasoline), and is used in three ways.

1. As 95% (hydrous) ethanol, used directly in modified and dedicated spark-ignition engines;

2. Mixed with the fossil petroleum in dry conditions to produce *gasohol*, as used in unmodified spark-ignition engines, perhaps retuned;

3. as an emulsion with diesel fuel for diesel compression engines (this may be called *diesohol*, but is not common).

In general such *bioethanol* fuel has the proportion of ethanol indicated as EX, where X is the percentage of ethanol, e.g. E10 has 10% ethanol and 90% fossil petroleum. Gasohol for unmodified engines is usually between E10 and E15, and larger proportions of ethanol require engine modification to some extent.

	Litres of ethanol per tonne of crop	*Litres of ethanol per hectare per year*
Sugarcane	70	5200
Cassava	180	2160
Sweet sorghum	86	3010
Sweet potato	125	1875
Corn (maize)	370	2800
Wood	160	3200

BIODIESEL

- Biodiesel is a liquid fuel produced from renewable sources, such as new and used vegetable oils and animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel.
- Biodiesel is nontoxic and biodegradable and is produced by combining alcohol with vegetable oil, animal fat, or recycled cooking grease.
- Like petroleum-derived diesel, biodiesel is used to fuel compression-ignition (diesel) engines.
- Biodiesel can be blended with diesel in any percentage, including B100 (pure biodiesel) and, the most common blend, B20 (a blend containing 20% biodiesel and 80% diesel).

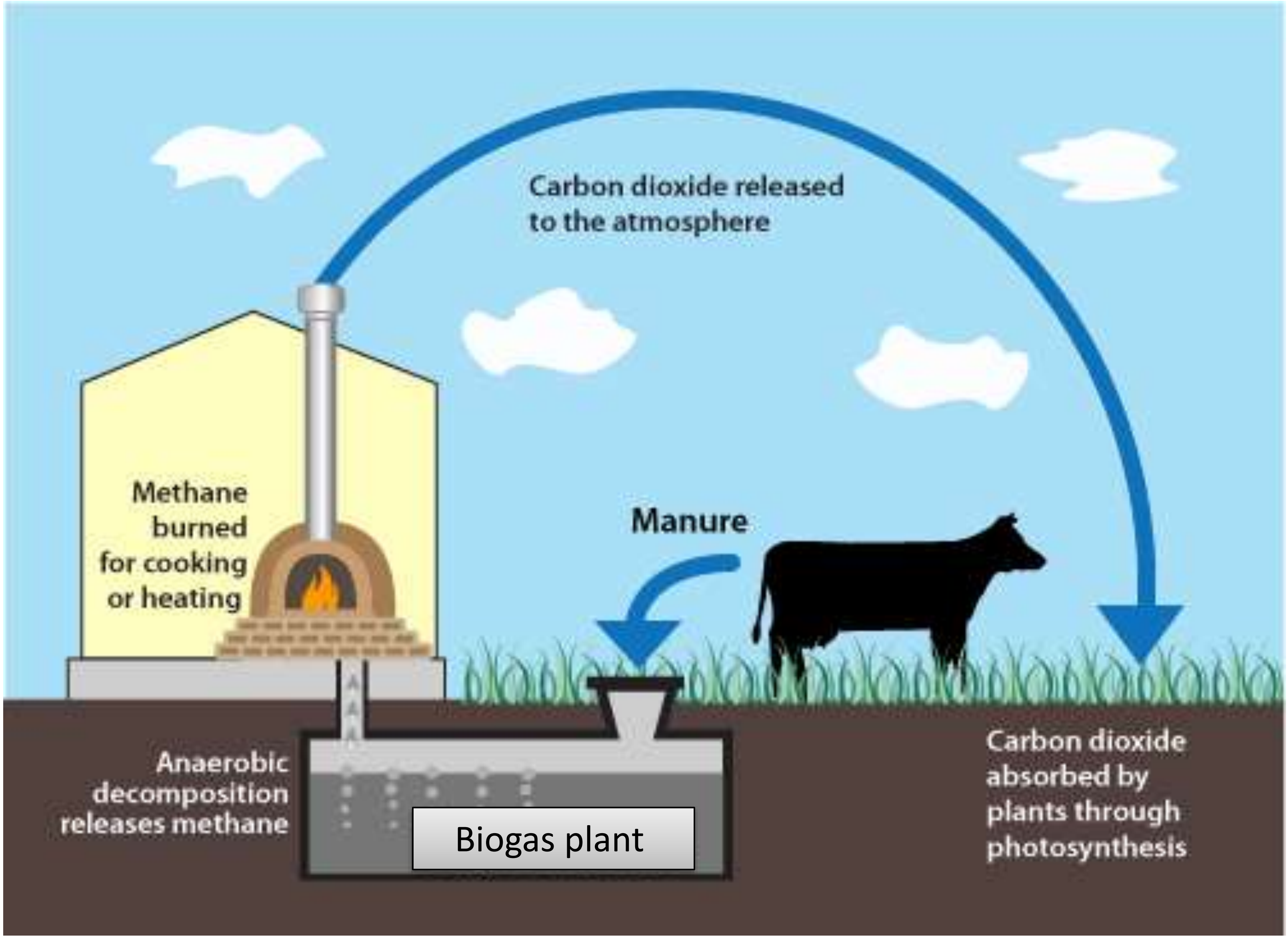
Lect.-3
Familiarization with different types of biogas plants.

- Biogas is a mixture of gases produced by the breakdown of organic matter in the absence of oxygen (an aerobically) and presence of moisture.

- The biogas so obtained is a mixture of methane (CH_4) : 55-65% and Carbon dioxide (CO_2) : 30- 40%. It also contains traces of Nitrogen, Hydrogen, carbon monoxide, oxygen, hydrogen sulphide and water.

- The calorific value of biogas is 4713 kcal/ m^3.

- The calorific value of dung cake is 2093 kcal/kg and the thermal efficiency of burning them in stove is about 11%.
- The calorific value of firewood is 4978 kcal/kg and the thermal efficiency of burning them in stove is about 17.3%.
- So biogas is an efficient fuel for cooking.
- The biogas plant was first installed in 1941 at IARI New Delhi.



BIOGAS AND ENVIRONMENT

Raw materials required

- Forms of biomass listed below may be used along with water.
- Animal dung
- Poultry wastes
- Plant wastes (Husk, grass, weeds etc.)
- Human excreta
- Industrial wastes(Saw dust, wastes from food processing industries)
- Domestic wastes (Vegetable peels, waste food materials)

VIGYAN ASHRAM
RURAL DEVELOPMENT EDUCATION SYSTEM

What is important
Ratio of water & Nutrients

- Ratio
  - 1 water :1 solid waste
- Nutrients
  - carbon (C) and nitrogen (N)
    - N= provide nutrients for the growth and multiplication of the anaerobic organisms
    - Experiment with different types of solid waste!

Advantages:

a) The technology is very suitable for rural areas.

b) Biogas is locally generated and can be easily distributed for domestic use.

c) Biogas reduces the rural poor from dependence on traditional fuel sources, which lead to deforestation.

d) The use of biogas in village helps in improving the sanitary condition and checks environmental pollution.

e) The by-products like nitrogen rich manure can be used with advantage.

f) Biogas reduces the drudgery of women and lowers incidence of eye and lung diseases.

Classification of biogas plants:

BIOGAS PLANT

- Batch Type Plant
- Continuous type plant
  - Floating Gas Holder Biogas Plant
  - Fixed Dome Biogas Plant

BATCH TYPE BIOGAS PLANT

a) Batch type biogas plants are appropriate where daily supplies of raw waste materials are difficult to be obtained.

b) Batch type plant is charged at 50-60 day intervals.

c) Once charged, it starts supplying the gas after 8-10 days and continuous to do so for about 40-50 days till the process of digestion is completed. Afterwards it is emptied and recharged.

d) Gas production in batch type is uneven.

e) Several digesters occupy more space.

f) This type of plants require large volume of digester, therefore, initial cost becomes high.

g) Such plants are installed in European countries.

h) Does not suit the conditions in Indian rural areas

CONTINOUS TYPE BIOGASS PLANT

- In continuous type biogas plant, the supply of the gas is continuous and the digester is fed with biomass regularly.
- Plant operates continuously and is stopped only for maintenance or for sludge removal.
- The gas produced is stored in the plant or in a separate gas holder.

- Hydraulic Retention Time:
  The number of days the feed material is required to remain in the digester for the release of its gas (about 80-90%). It is based on temerature zones of the country .
  HRT is 30 days for Average ambient temp. More than 20 degree C.
  40 days for 15-20 degree C and 55 days for temp. less than 15 degree C. For Rajasthan 40 days HRT is recommended.

- Scum: The thin dry layer often formed at the top of the slurry is known as scum.

Fix dome type biogas plants

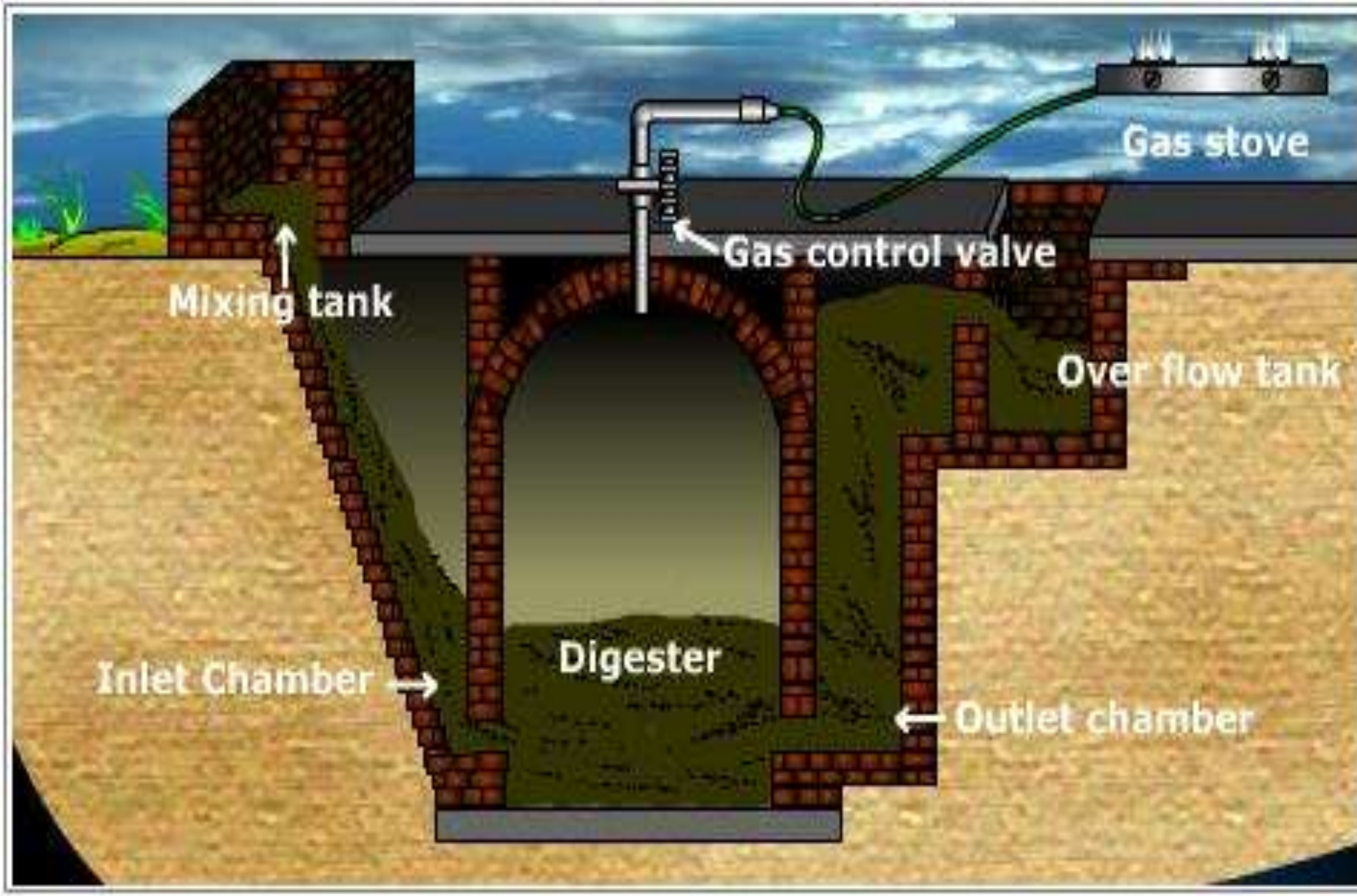
(i) Janata Biogas plant:

It was developed by PRAD (Planning Research and Action Division) in 1978.

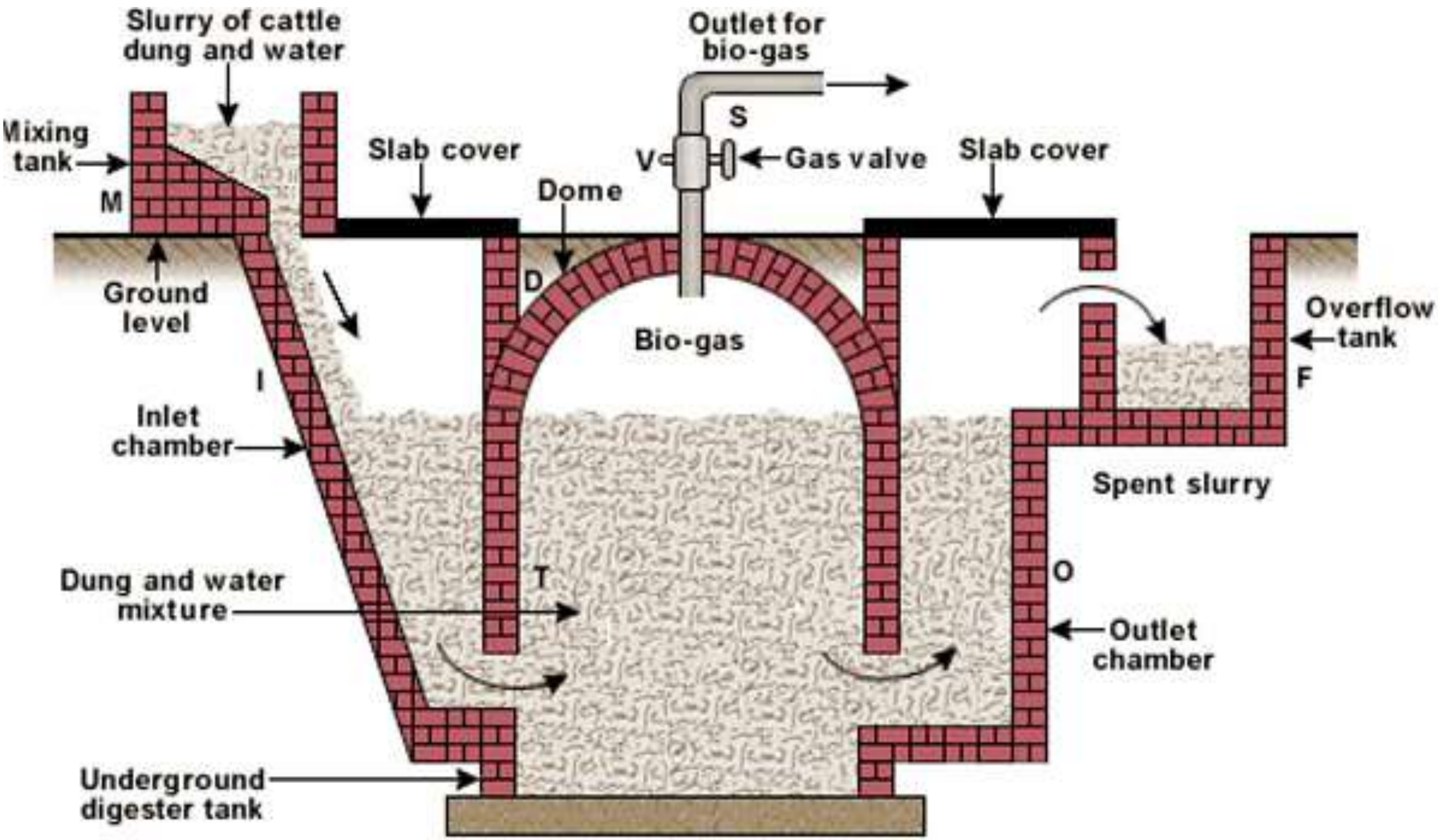
(ii) Deenbandhu biogas plant:

It is modification and advance version of Janata biogas plant. Action for Food Production (AFPRO) developed it in 1984.

Janta Type Biogas plant



JANATA MODEL



Construction of Janata biogas plant

The Janata biogas plant is a brick and cement structure having the following five sections:

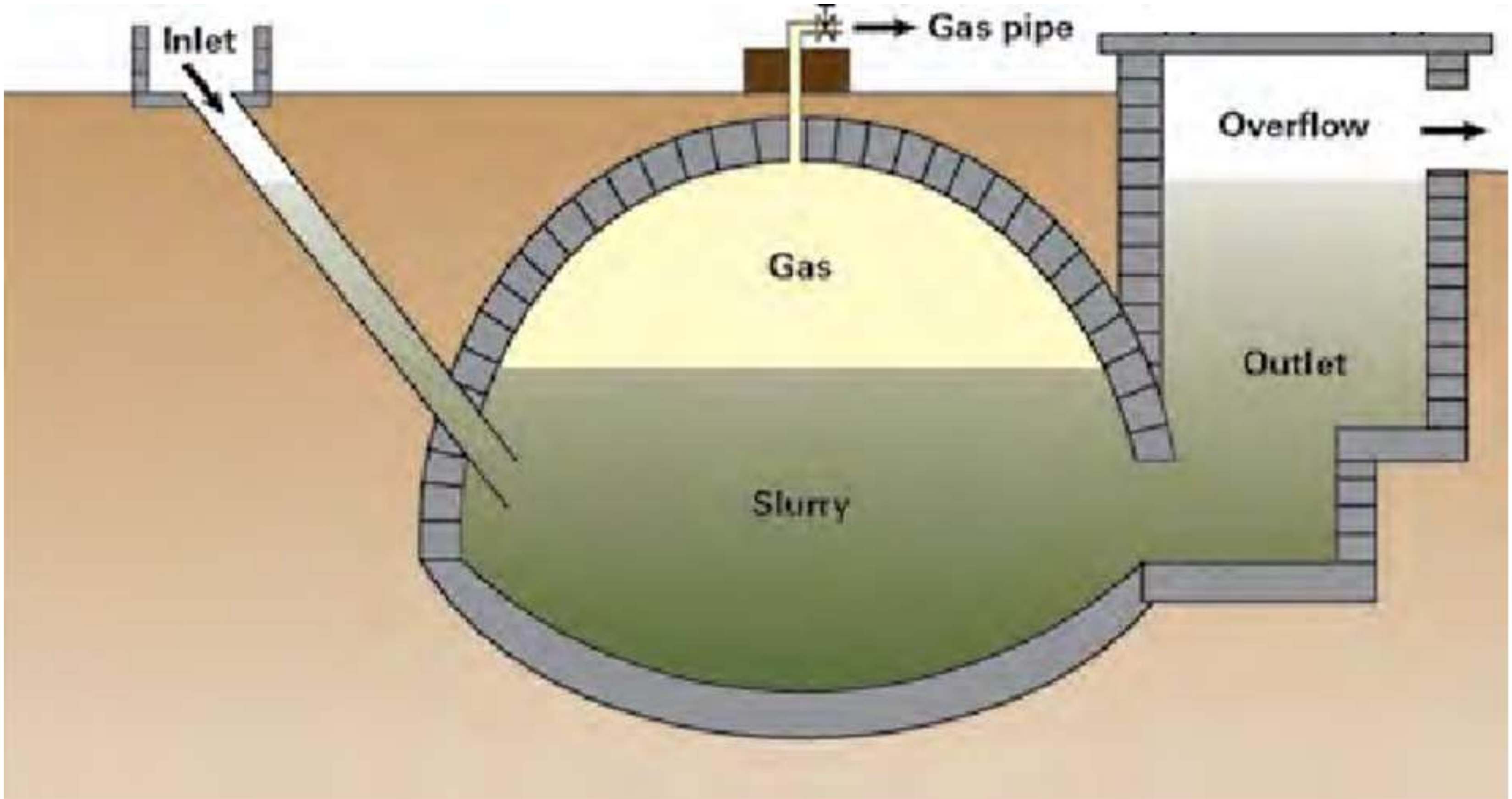
1. Mixing tank: above the ground level.
2. Inlet tank: The mixing tank opens underground into a sloping inlet chamber.
3. Digester: The inlet chamber opens from below into the digester which is a huge tank with a dome like ceiling.
4. Gas outlet: The ceiling of the digester has an outlet with a valve for the supply of biogas.
5. Outlet tank: The digester opens from below into an outlet chamber. The outlet chamber opens from the top into a small over flow tank.

Working of Fixed Dome type Biogas Plant

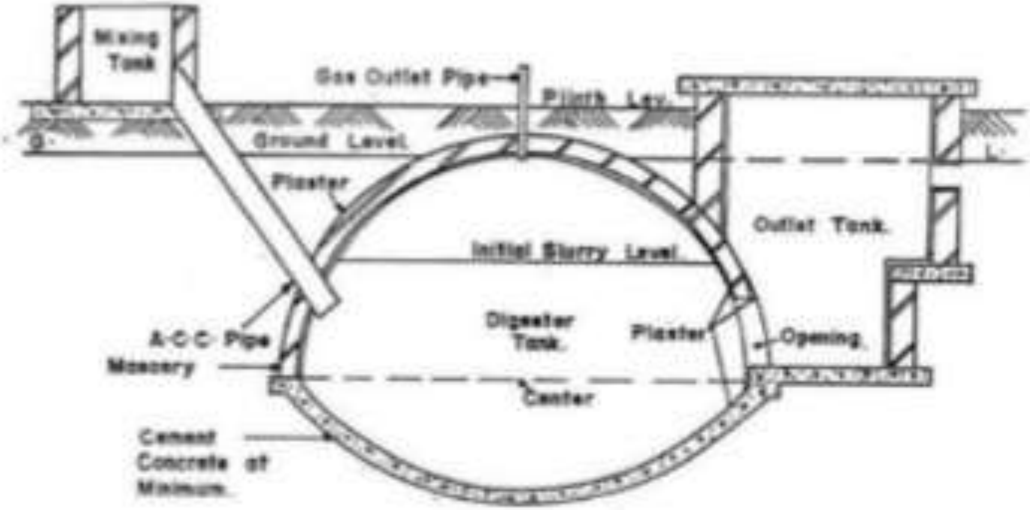
- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the slurry.
- The slurry is fed into the digester through the inlet chamber.
- Initially the digester is filled with the slurry, the further introduction of slurry is stopped and the plant is left unused for some days.
- During these days, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.
- As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.

- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
- From the outlet chamber, the spent slurry overflows into the overflow tank.
- The spent slurry is manually removed from the overflow tank and used as manure for plants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas is required.
- To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry.

Deenbandhu Biogas Plant



❑ Deenbandhu



- The biogas plant has a hemispherical fixed dome type biogas plant.
- The plant like two saucers kept on each other face to face.
- Working principle is same as janta model
- Low cost biogas plant

Components of Deenbandhu biogas plant:

1. Foundation: The foundation of the plant is bowl shaped with a collar around the circumference. The construction of the digester dome is done on this collar.
2. Dome Digester: The dome of the digester is divided in 2 parts.

The bottom part is called digester. The mixture of dung and water decomposes in this part and produces gas due to bacterial activity. Gas storage : The upper part of the digester dome is called gas storage. The gas produced by the bacterial activity is stored in this place.

3.Mixing tank: Slurry after proper mixing is allowed from this tank to inlet pipe.

4..Gas outlet pipe: A nipple is fitted on the top of the dome, which is connected to a GI pipe.

5.. Inlet pipe: The pipe through which fresh dung and water enters the plant is called Inlet pipe. This pipe is connected to a small tank for mixing dung and water. gas reaches the kitchen through this pipe.

6.Outlet tank: The portion of the plant where the slurry accumulates after coming out of the digester is called outlet tank. It is in two parts. The first bottom part is small and rectangular, which is connected to the dome opening, the other part of outlet tank is also rectangular but of big size having a overflow outlet.

Dome construction


Deenbandhu biogas plant


Deenbandhu biogas plant

Types of floating gas holder type biogas plants

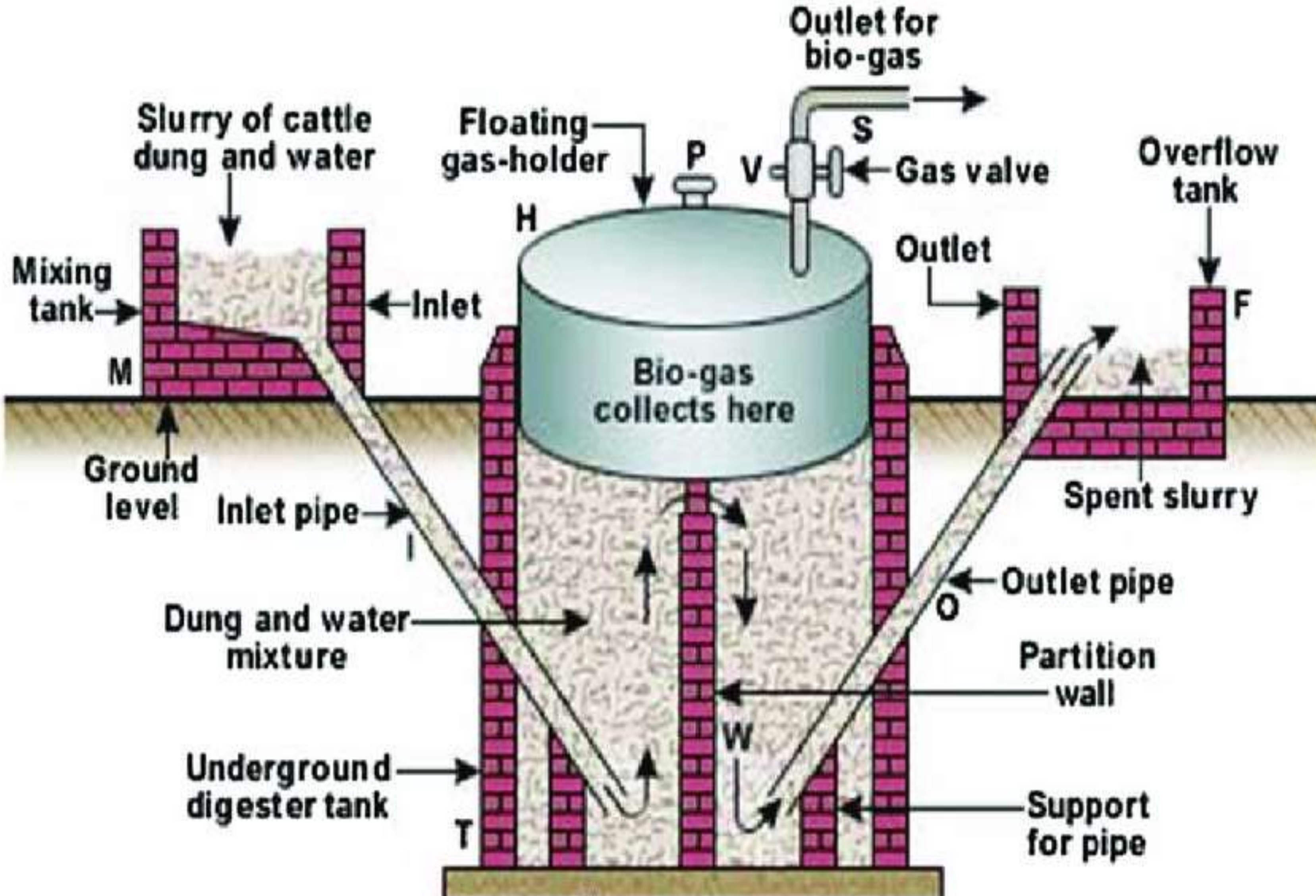
a) KVIC model with a cylindrical digester.
b) Pragati model with a hemisphere digester.
c) Ganesh model made of angular steel, bamboos and plastic foil.
d) Floating drum plant made of pre-fabricated reinforced concrete compound units.
e) Floating drum plant made of fiber glass reinforced polyester.

In 1956, Jashu Bhai J Patel from India designed the first floating drum biogas plant, popularly called Gobar gas plant.

KVIC biogas plant

In the year1961 Khadi and Village Industries Commission (KVIC) patented this design.

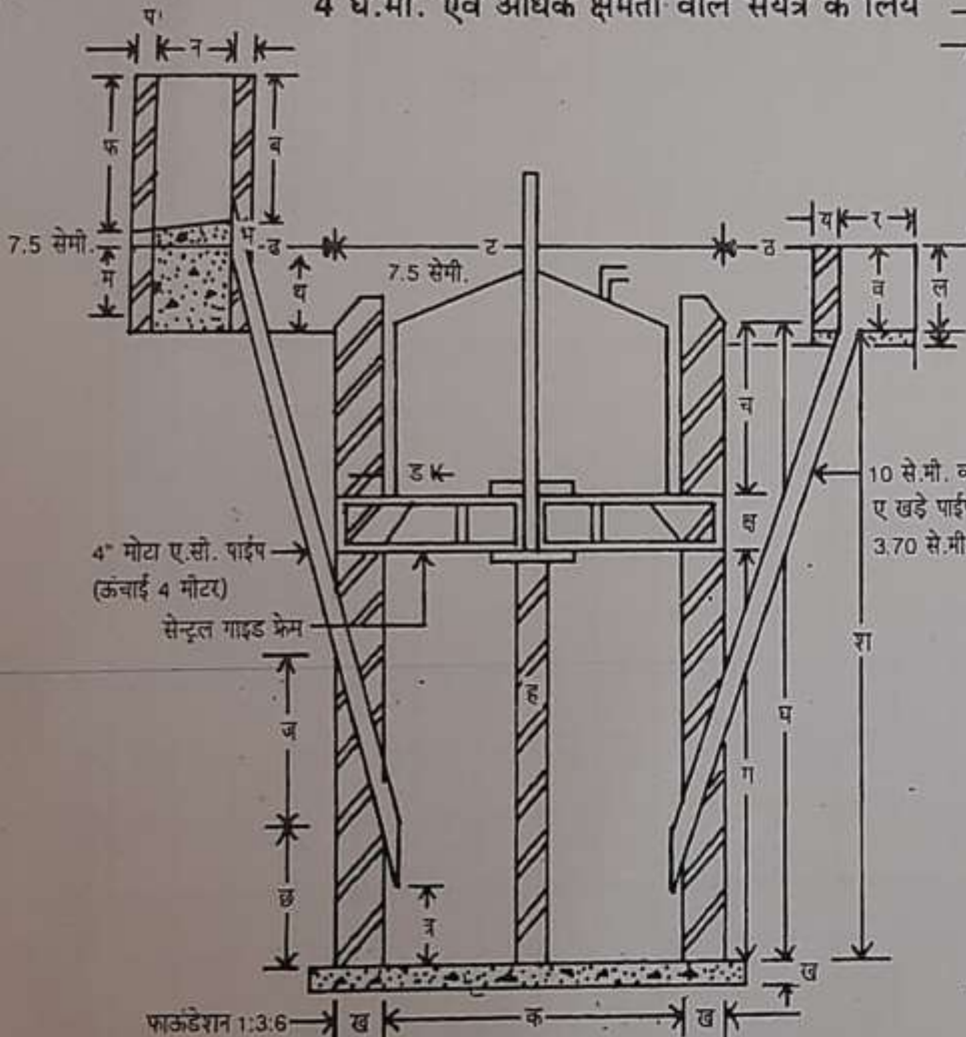
KVIC MODEL



Outlet for bio-gas
Slurry of cattle dung and water
Floating gas-holder
P
V
S
Gas valve
Overflow tank
H
Mixing tank
Inlet
Outlet
F
M
Bio-gas collects here
Ground level
Inlet pipe
I
Spent slurry
Outlet pipe
O
Dung and water mixture
Partition wall
W
Underground digester tank
T
Support for pipe

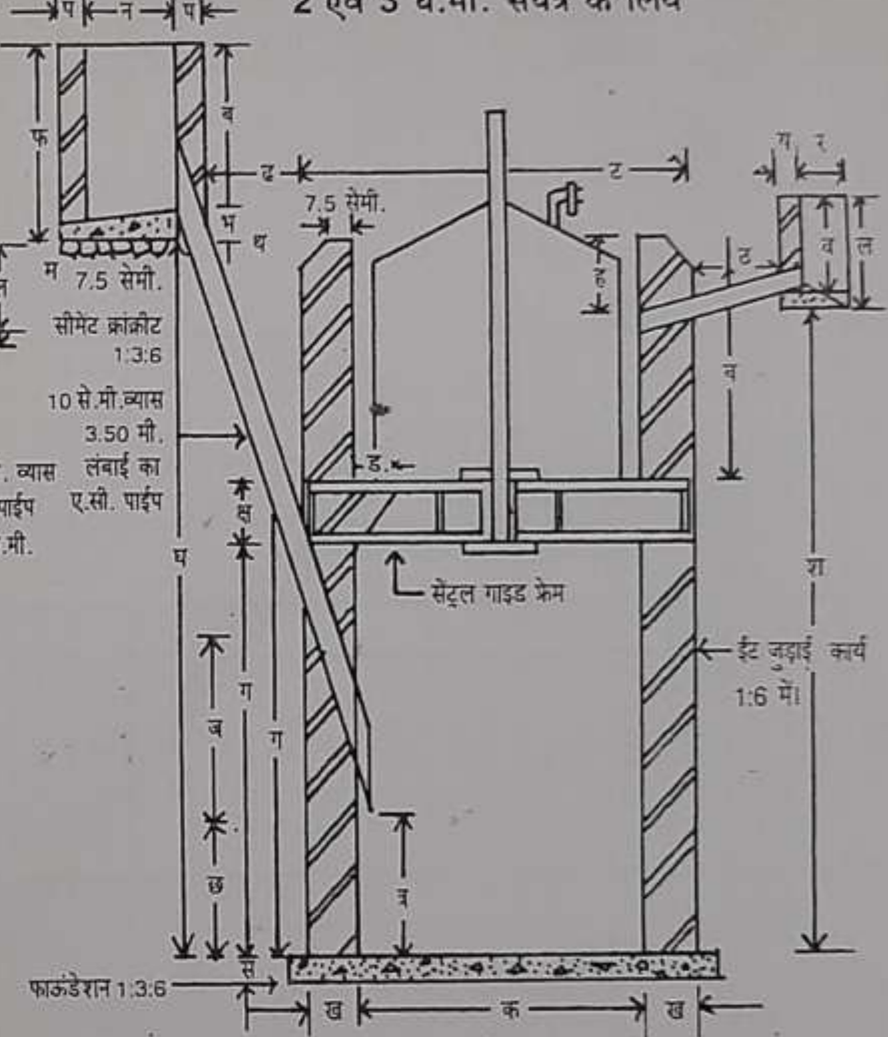
के.वी.आई.सी. मॉडल

4 घ.मी. एवं अधिक क्षमता वाले संयंत्र के लिये



के.वी.आई.सी. मॉडल

2 एवं 3 घ.मी. संयंत्र के लिये



Construction of KVIC biogas plant:

The floating gas holder type of biogas plant has the following chambers/ sections:

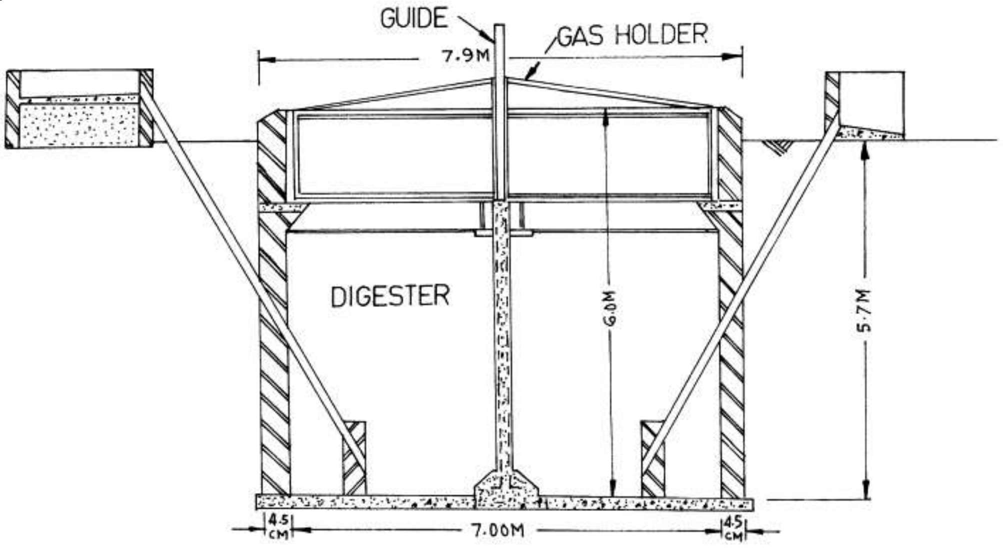
- Mixing Tank - present above the ground level.
- Digester tank - Deep underground well-like structure. If the capacity of plant is more than 3 cum then the digester is divided into two chambers by a partition wall in between.
- It has two long cement pipes (i) Inlet pipe opening into the inlet chamber for introduction of slurry and (ii) Outlet pipe opening into the overflow tank for removal of spent slurry.

- Gas holder - an inverted steel drum resting above the digester. The drum can move up and down i.e., float over the digester.
- Guide Frame – It is an iron structure which helps in upward and downward movement of the gas holder.
- Gas outlet- The gas holder has an outlet at the top which is provided with a valve and connected to gas stove.
- Slurry outlet tank- It is constructed above the ground level over the outlet pipe for the removal of digested slurry.

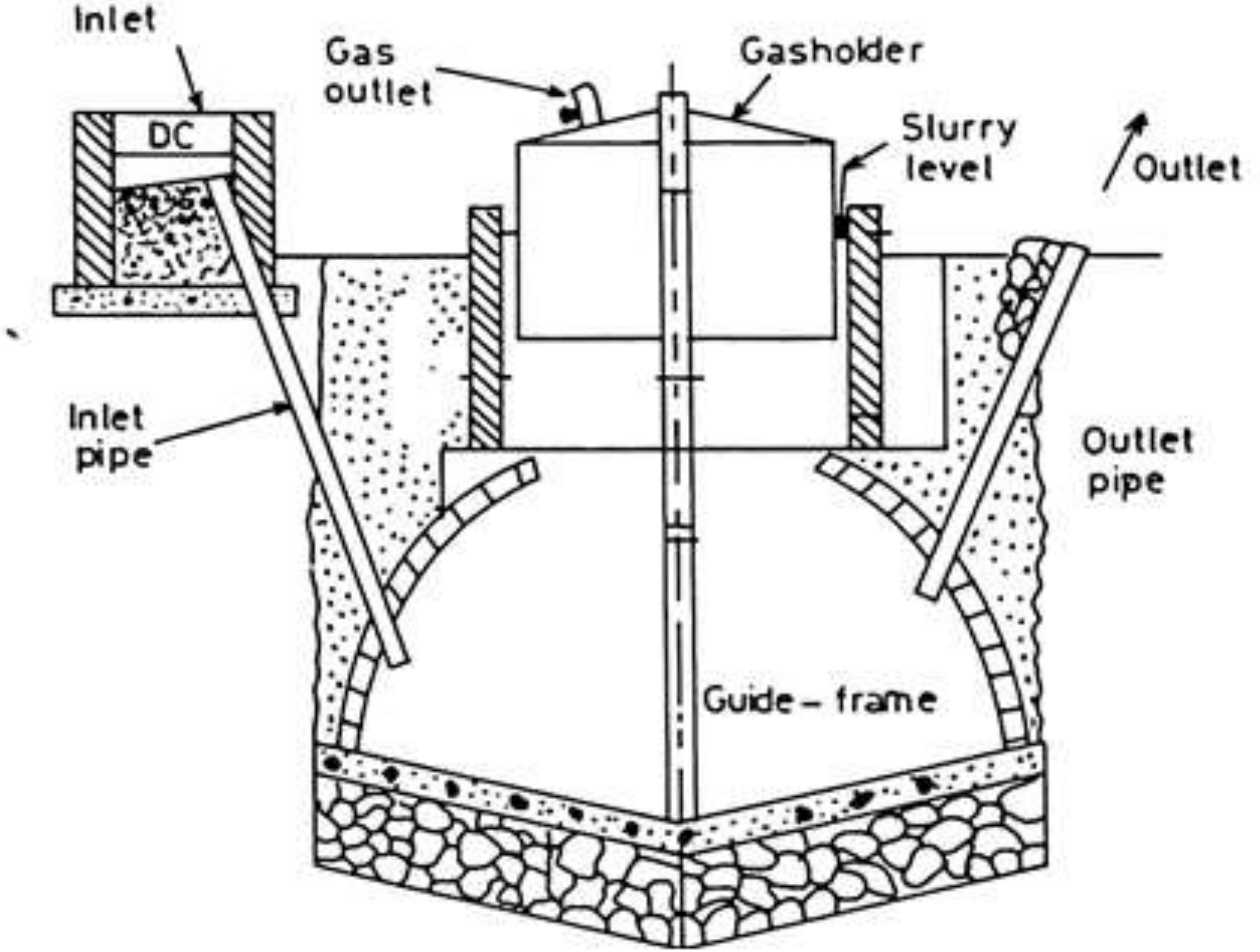
Guide Frame

A floating-drum always requires a guide frame for the following reasons:

- The floating-drum must not touch the outer walls.
- It must not tilt, otherwise the coating will be damaged or it will get stuck.
- It allows the gas drum to be removed for repair

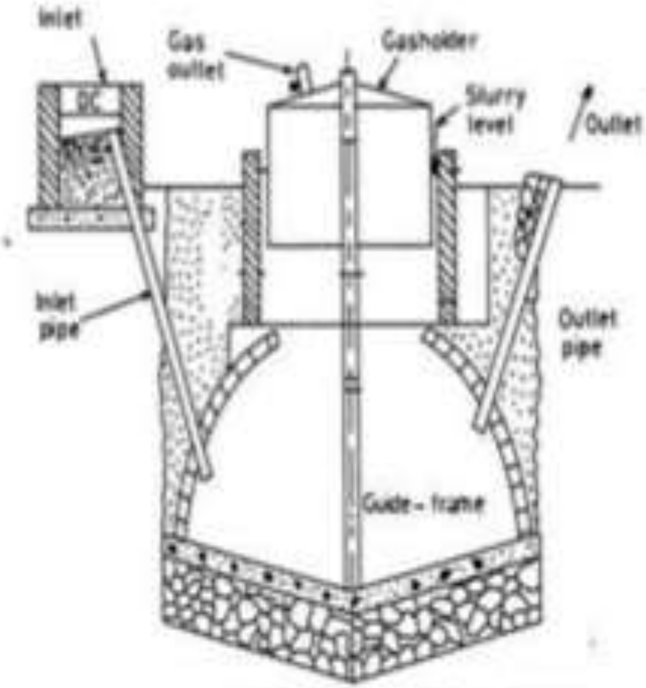


PRAGATI MODEL



PRAGATI biogas plant model

- Developed by united socio-economic development and research programme.
- It is cheaper floating drum biogas plant.
- Depth of pit is less than kvic plant.
- It can be constructed in hilly and high water table areas.
- Cost of this plant is 20% less than kvic plant.

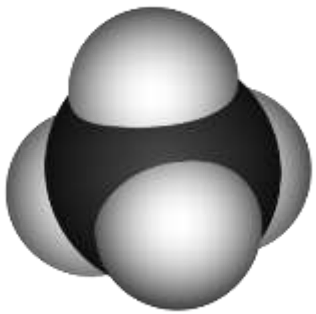


❑ Fixed dome Vs. Floating drum type

Sr.no	particulars	Fixed dome type	Floating drum type
1	initial cost	Less	More
2	Maintenance	Less	More
3	Effect of low temp.	Less	More
4	Pressure	Variable	Constant
5	Life time	More	Less (30 years)
6	Life of gas holder	More	5 to 8 years
7	Locating leakage & repair	Complex	Easy
8	Gas holding drum	Not present	Must
9	Utilization of space	More	Less
10	Efficiency	More	Less
11	Construction skill required	Skilled	moderate

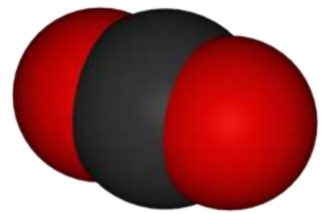
Lect.-4
Biogas production techniques and various uses of biogas.

What is biogas?



CH_4 +

(50-70%)



CO_2

(30-40%)

Hydrogen = 5-10 %
Nitrogen-=1-2 %
Water vapour= 0.3%
Hydrogen sulphide = Traces

Biogas

It is a mixture of gas produced by the microorganisms during the anaerobic fermentation of biodegradable materials.

Anaerobic fermentation is a biochemical process in which particular kinds of bacteria digest biomass in an oxygen-free environment resulting in production of CH_4, CO_2, H_2 and traces of other gases along with decomposed mass.

Properties of biogas

Properties	Range
Net calorific value (MJ/m^3)	20
Air required for combustion (m^3/m^3)	5.7
Ignition temperature (^0C)	700
Density (kg/m^3)	0.94

Microbiology of biogas production:

The biogas production process involves three stages namely:

- Hydrolysis
- Acid formation and
- Methane formation

Hydrolysis

The complex organic molecules like fats, starches and proteins which are water insoluble contained in cellulosic biomass are broken down into simple compounds with the help of enzymes secreted by bacteria.

This stage is also known as polymer breakdown stage (polymer to monomer). The major end product is glucose which is a simple product.

Acid formation

The resultant product (monomers) obtained in hydrolysis stage serve as input for acid formation stage bacteria.

Products produced in previous stage are fermented under anaerobic conditions to form different acids.

The major products produced at the end of this stage are acetic acid, propionic acid, butyric acid and ethanol.

Methane formation:

The acetic acid produced in the previous stages is converted into methane and carbon dioxide by a group of microorganism called "*Methanogens*". In other words, it is process of production of methane by methanogens.

Methanogenesis is sensitive to both high and low pH and occurs between pH 6.5 and pH 8.

Major reactions occurring in this stage is given below:

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

Acetic acid → Methane + Carbon dioxide

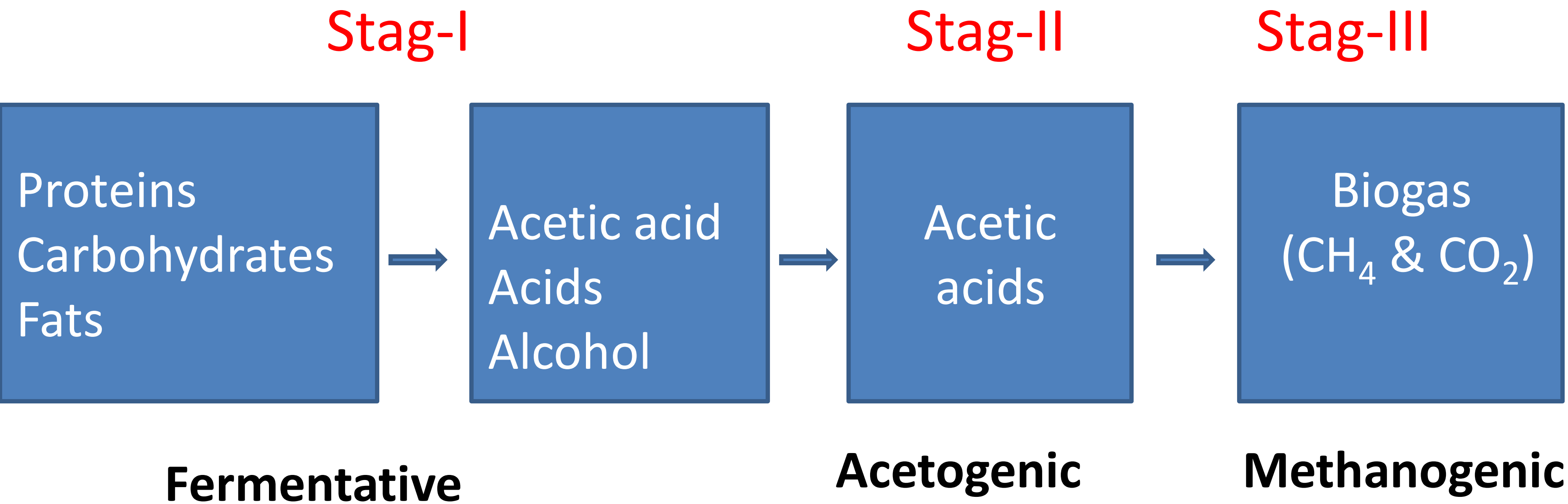
$$2CH_3CH_2OH + CO_2 \longrightarrow CH_4 + 2CH_3COOH$$

Ethanol + Carbon dioxide → Methane + Acetic acid

$$CO_2 + 4\,H_2 \longrightarrow CH_4 + 2\,H_2O$$

Carbon dioxide + Hydrogen → Methane + Water

The process of biogas formation through different stages:



OPERATIONAL PARAMETERS OF A BIOGAS PLANT

Operation of a bio gas plant is affected by a no. of factors:-

A. Temperature

- Methane- forming bacteria works best in temp. ranges 25^{0}-55^{0} C
- Digestion at higher temp. proceeds more rapidly than at lower temp.
- The gas production decreases sharply below 20^{0} C and almost stops at 10^{0} C

B. Pressure

- A minimum pressure of 6-10 cm of water column i.e, 1.2 bar is ideal for proper functioning.
- It should never be allowed to exceed 40-50 cm of water column.
- Excess pressure inhibits leakage in masonry.

C. Solid to moisture ratio in the biomass

- The solid content in the slurry should be maintained between 7.5 to 10 per cent for optimum gas production.
- If water content is too high, the mean slurry temp. and gas production drops.
- If water content is too low, acids accumulate and hinder fermentation process.

D. pH value

- The pH of slurry in the digester should be maintained between 6.8 and 7.2 for optimum gas production and this can be accomplished by maintaining proper feeding rate.
- At higher feeding rate the retention period will be less and undigested slurry may come out.
- So optimum feed rate should be maintained.

F. Carbon to nitrogen ratio

The optimum C/N ratio is 30:1 for maximum microbiological activity.

G. Seeding of biomass with bacteria

- To start and accelerate the fermentation process, a small amount of digested slurry containing a methane forming bacteria is added to the freshly charged plant. This process is known as seeding.
- Seeding helps to accelerate the starting of the digestion process.

H. Mixing or stirring

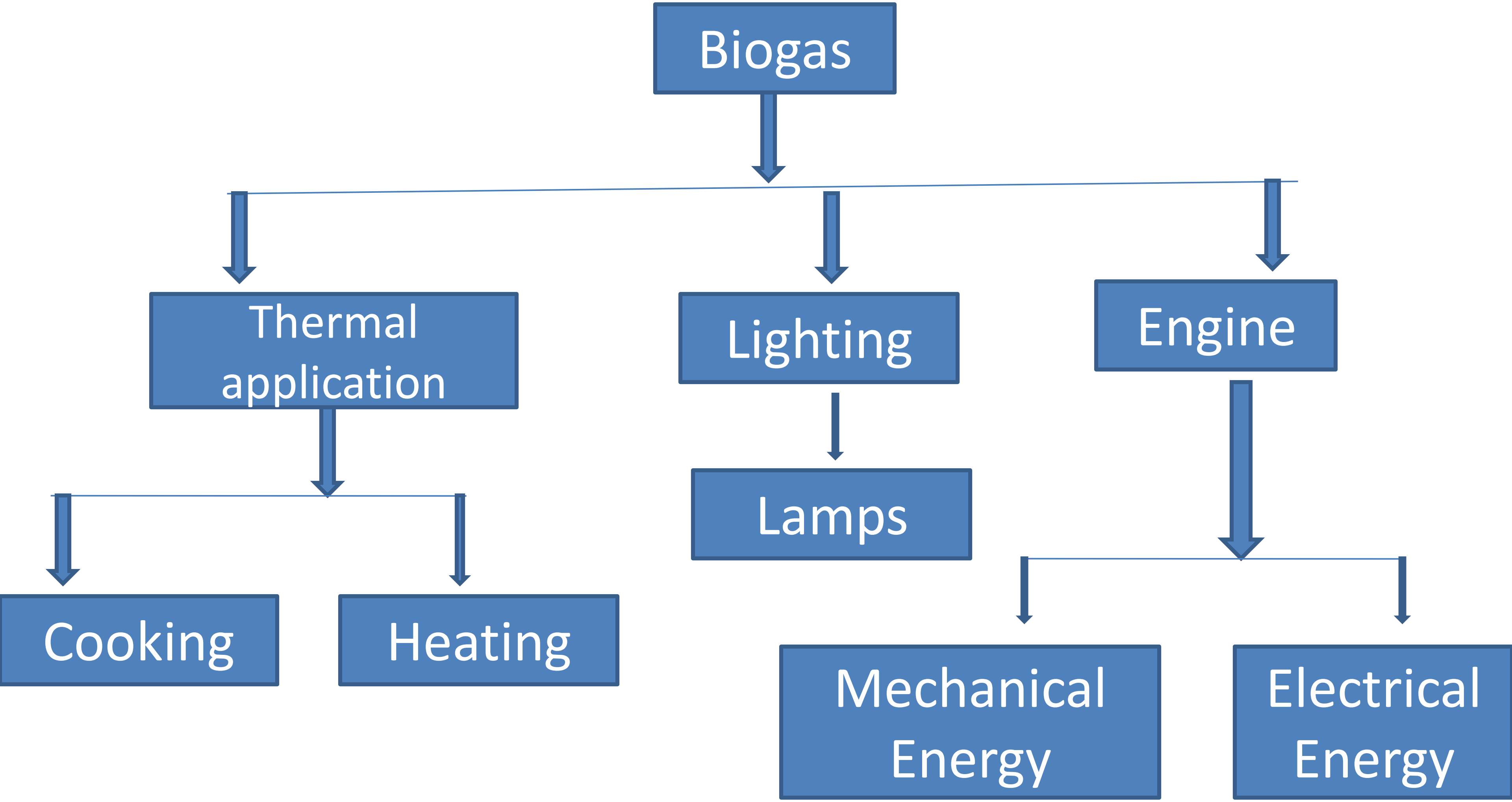
Mixing

- Maintains uniformity in substrate concentration.
- Minimizes formation of scum.
- Prevents the deposition of solids at the bottom.

I. Retention time

- Retention time should be optimum to obtain 70-80% complete digestion.

Flow chart of different applications of biogas.



Uses of biogas

Biogas serves as a suitable alternate fuel for satisfying the energy needs of human society. It can be used for production of power, for cooking,

Cooking:

Biogas is available at low pressures (4 - 8 cm water) so it's stoves are different from LPG stove.

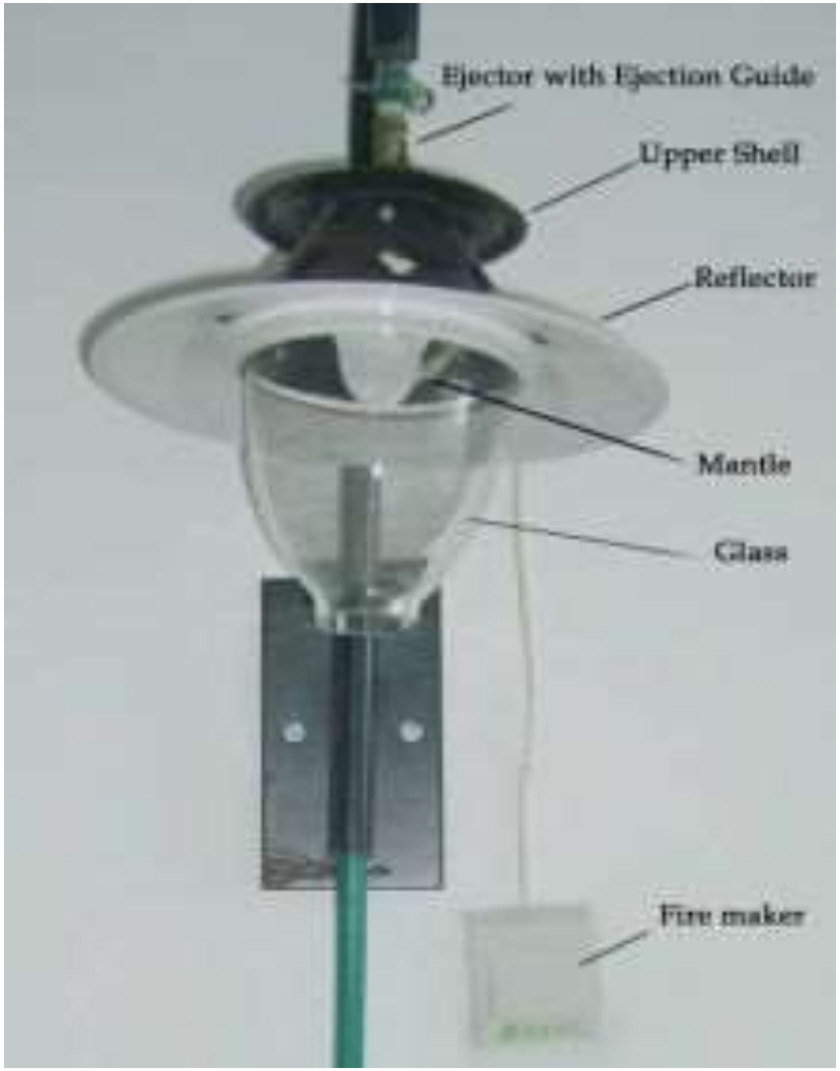
Biogas burns with blue flame and without any soot and odour.

Biogas burner

Lighting

Lighting can be provided by means of a gas mantle, or by generating electricity.

Biogas mantle lamps consume 0.13 cum gas per hour having illumination capacity equivalent to 40 W electric bulbs at 220 volts. This application is predominant in rural and un-electrified areas.


Ejector with Ejection Guide
Upper Shell
Reflector
Mantle
Glass
Fire maker

Biogas as an Engine Fuel

Biogas can be used as a fuel in stationary and mobile engines.

It can be used to operate four stroke diesel and spark ignition engines.

Electricity generation using biogas is a commercially available and proven technology.

When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2 percent otherwise the presence will lead to corrosion of engine parts.

For electricity production, small internal combustion engines with generator can be used to produce electricity.

Biogas Generator

Use of biogas as vehicular fuel

The presence of CO_2 is unsatisfactory.

It lowers the power output from the engine, takes up space in the storage cylinders and

it can cause problems of freezing at valves and metering points, where the compressed gas expands, during running. Therefore CO_2 is to be removed from the raw biogas to prepare it for use as fuel for vehicles and for compression of the gas into high-pressure cylinders, carried by the vehicle.

Uses of bio-digested slurry

The slurry after the digestion will be washed out of the digester which is rich in various plant nutrients such as nitrogen, phosphorous and potash.

Well-fermented biogas slurry improves the physical, chemical and biological properties of the soil resulting qualitative as well as quantitative yield of food crops.

The cow dung slurry after digestion inside the digester comes out with following characteristics and has following advantages:

- When fully digested, effluent is odourless and does not attract insects or flies in the open condition.
- The effluent repels termites whereas raw dung attracts them.
- Effluent used as fertiliser reduces weed growth with about 50%. When FYM is used the undigested weed seeds cause an increased weed growth.
- It has a greater fertilising value than FYM or fresh dung. The form in which nitrogen available can be easily assimilated by the crops.

Numerical

Q1. Design an appropriate size of biogas plant for a family of 6 members owing 2 cows, 2 buffaloes and 2 calves. One candle lamp is used for lighting purpose for 2 hours.

Solution:

Availability of dung: Cow = 2 x10 kg = 20 kg

Buffalo = 2 x 15 kg = 30 kg

Calf = 2 x 5 kg = 10kg

Total available dung = 60 kg

We know that potential gas production of 60 kg per day

= 0.04 x 60 cum = 2.4 cum

Consumption of gas:

Cooking for 6 persons = 0.24 x 6= 1.44 cum/day

Lighting one lamp for 2 hours =0.13 x 2 =0.26 cum/day

Total consumption of gas per day = 1.70 cum/day

Here, potential gas production is 2.4 cum/day, while consumption of gas is 1.70 cum/day. So, plant size will be 2 cum.

Q2. Design a digester of biogas plant from following data:

1. Capacity of plant = 2 cum
2. Diameter to depth ratio = 1.75 : 1
3. Hydraulic Retention time= 50 days
4. Density of slurry = 1020 kg/cum

Solution:

We know that 1 kg of dung produces 0.04 cum gas per day.

Dung requirement for 2 cum capacity plant = 2/0.04 = 50 kg.

Now, volume of daily feed = $\frac{Weight\ of\ (dung + water)}{density\ of\ slurry}$

Or $\frac{50 + 50}{1020}$ = 0.098cum/day

Volume of digester = Retention time x Loading rate per day

= 50 day x 0.098 cum/day = 4.9 cum

But, volume of digester = $\frac{\pi}{4}$ x D^2 x H

Comparing both, $\frac{\pi}{4}$ x D^2 x H = 4.9

Since D = 1.75 H

So, $\frac{\pi}{4}$ x $(1.75H)^2$ x H = 4.9

Or H^3 = 2.036

Therefore, H=1.27 m

And D = 1.75 x 1.27 = 2.22 m

So diameter of digester = 2.22 m and depth = 1.27m

Lect.-5

Biomass Gasification and familiarization with different Gasifiers.

Biomass is combustible organic matter that has been derived from living organisms as a result of the photosynthetic conversion process.

Biomass is source for producing feed, fiber, fertilizer and fuel for mankind and its associates activities.

Bio energy- is energy derived from plants and animal material, such as wood from forest, residues from agricultural and forestry processes and industrial, human and animal wastes. It is in the form of chemical energy stored in the plants and animals and their wastes.

Energy obtained from biomass is a form of Renewable Energy.

Chemical composition of biomass

- The chemical composition of biomass varies among species but a plant consists of 25 % lignin and 75% carbohydrates or sugars.
- The carbohydrate fraction consists of many sugar molecules linked together in long chain polymers. Two larger carbohydrate categories that have significant value are cellulose and hemi-cellulose. The lignin fraction consists of non-sugar type molecules.

Biomass Resources

(i) Agricultural crops: There are many agricultural crops that can be grown specially as energy sources, including sugar cane, maize, wheat, sorghum, sunflower, rapseed and soya beans. The majority of these crops are grown as liquid fuels such as ethanol or biodiesel.

(ii) Ag. Residues: Rice husk, bagasse, coconut husks and shells, groundnut shells, cereal straw, etc.

(iii) Animal waste: The animal waste is also an organic material which has combustible property. The amount of wastes an animal produce depends on the size of animal and the feed. The animal waste is an essential ingredient for fuel production through cakes and anaerobic digestion.

A cow gives 10 kg, buffalo 15 kg and camel about 6 kg of dung per day.

iv) Forest crops: Wood trees which are fast growing and suitable for coppicing are preferred. Forest wastes are also considerable source (residues obtained from thinning, cleaning for logging roads etc.)

v) Industrial wastes: Sawdust, off-cuts of timber, woodchips, and waste product of food processing industries, paper and pulp industries.

Liquid wastes are generated by washing meat, fruit and vegetables, pre cooking meats, poultry and fish cleaning and processing, wine making etc. these can be anaerobically digested to produce biogas.

Biomass conversion technologies

1. Anaerobic digestion: is the decomposition of wet and green biomass through bacterial action in the absence of oxygen to produce biogas.
2. Densification: Briquetting & Pelletising
3. Direct combustion & cogeneration:
4. Pyrolysis
5. Gasification
6. Charcoal production
7. Co-firing
8. Ethanol production

Biomass gasification

- Gasification is a step forward to carbonisation, where end product of carbonisation is finally converted into gaseous mixture of combustible nature.
- Biomass gasification is a process of converting solid biomass fuel into a gaseous combustible fuel gas known as syngas or producer gas through a sequence of thermo-chemical reactions.
- The gas is of a low-heating value fuel, with a calorific value between 1000- 1200 kcal/m^3 Almost 2.5-3.0 m^3 of gas can be obtained through gasification of about 1 kg of air-dried biomass.
- On a dry weight basis heating values range from 17.5 GJ per tonne for various herbaceous crops like wheat straw, sugarcane bagasse to 20 GJ/tonne for wood.

Syngas (synthesis gas):

- Produced by gasification using oxygen and/or steam as gasification agent
- Syngas is a mixture of CO and H_2 - also has CO_2, CH_4, C_2H_4, N_2, H_2O and tar - small amounts of H_2S and Carbonyl sulfide, ammonia, etc. can also be there
- After cleaning, it can be used to produce synthetic natural gas (SNG), H_2, NH_3, Methanol, and synthetic hydrocarbon fuels (synthetic petroleum, synthetic diesel)
- Can be used as fuel in IGCC power plants (integrated gasification combined cycle)
- Called as producer gas if non-combustibles gases (N_2 & CO_2) are significant

C_2H_4 - Ethylene

Fundamental phenomenon of biomass gasification

(a) Evaporation of surface moisture

Surface moisture evaporates from the raw material at the water boiling point (depends on pressure). Inner moisture remains when the raw material is large.

(b) Evaporation of inherent moisture

Following surface moisture evaporation, inherent moisture evaporates at 110-120°C.

(c) **Volatilization**

Thermal decomposition of biomass begins at 200-300°C, and CO, CO_2, H_2 and H_2O are vaporized as gas. Thermal decomposition is a heat generating reaction which is a characteristic phenomenon of biomass.

(d) Volatilization and gasification reaction

The temperature is raised further during volatilization, and the volatile matter of the light weight hydrocarbons is transformed into heavy weight hydrocarbons with a high boiling point.

Subsequently, the heavy weight hydrocarbons reacts with the gasifying agent for conversion to light weight molecule clean gas, although tar and soot can form when diffusion of the gasifying agent is slow and the hydrocarbons condenses.

(e)Char gasification

Following volatilization of the volatile content in the raw material biomass, the fixed carbon and ash become char, and the char is heated to the surrounding temperature. The subsequent reaction with the gasifying agent transforms the carbon into CO and CO_2.

However, in cases where the gasifying agent contains excess steam and the surrounding temperature is over 750°C, a wet gas reaction occurs ($C+H_2O = CO+H_2$) producing gas composed mainly of CO, CO_2 and H_2.

(f)Char residue

The reaction rate of the wet gas reaction is slow, and char residue can easily form. The formation of tar, soot and char tends to reduce efficiency, as well causing equipment trouble.

Biomass Gasification

Different from coal gasification

- Biomass is more reactive and has higher volatile content
- Gasification occurs at lower temperature
- Has lower sulfur content and higher alkali (sodium and potassium) content – can cause slagging and fouling problems
- Product gas requires cleaning to remove tar and other contaminants (alkali compounds)

Smaller particles facilitate faster heat transfer rates and gasification

Smaller particles result in more CH_4, C_2H_4 and CO and lesser CO_2

- Low bulk density fuels present problems in the gasifiers and hence biomass is densified into pellets or briquettes

Slagging (meaning) Scum forming by oxidation at the surface.
Fouling (meaning) Accumulation of unwanted material on soild surface to the detriment of function

Producer gas: produced by gasification using air as gasification agent

Component	Producer gas	Syngas
CO	18-22%	35-40%
Hydrogen	13-19%	20-40%
Methane	1-5%	0-15%
Heavier hydrocarbons	0.2-0.4%	---
Carbon dioxide	9-12%	25-35%
Nitrogen	45-55%	2-5%
Water vapour	4%	Variable
Heating value	4.5 – 6 MJ/Nm3	5.3-12.6 MJ/Nm3

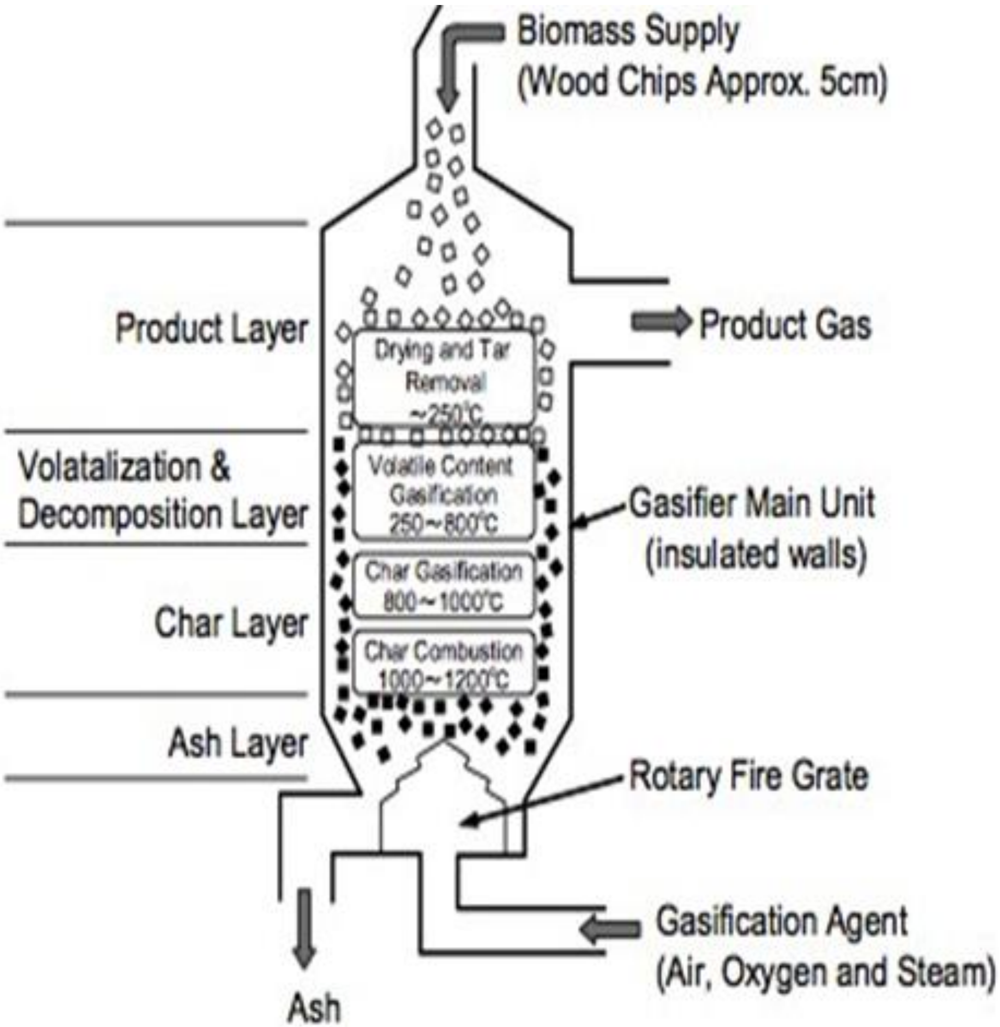
.The ratio between the calorific content of the biomass and that of the product gas (at room temperature) is called cold gas efficiency.

Concept of gasification in gasifier

- Wood chips of about 2.5-5 cm are generally used as the raw material.
- They are supplied from the upper feed port, and layered in the furnace.
- The gasifying agent (air, oxygen, steam or a mixture thereof) is supplied from the bottom in a rising flow (some systems use a descending flow).
- The gasification reaction proceeds from the bottom towards the top.
- From the bottom upward, individual layers are formed due to the changes accompanying gasification of the raw material, in the order of ash, char, volatilized and decomposed material, and product.
- The product gas is obtained at the top.

Concept diagram of a fixed bed gasifier

By weight, gas (wood gas) produced in a gasifier unit contains approximately
20% hydrogen (H_2),
20% carbon monoxide (CO),
and small amounts of methane,
all of which are combustible, plus 50 to 60% nitrogen (N_2).
The nitrogen is not combustible



Chemistry of Gasification

Oxidation

- Supplies the required thermal energy and maintains temperature
- Occurs in the limited or controlled oxygen conditions (1/5 to 1/3rd of the stoichiometric requirement)
- Only char and hydrogen of the syngas are believed to participate in the oxidation reactions

$$C + O_2 \rightarrow CO_2 \text{ (char combustion: - 394 kJ/mol)}$$

$$C + \tfrac{1}{2} O_2 \rightarrow CO \text{ (Partial oxidation of char: - 111 kJ/mol)}$$

$$H_2 + \tfrac{1}{2} O_2 \rightarrow H_2O \text{ (Hydrogen combustion: - 242 kJ/mol)}$$

- Combustion product is a gas mixture of CO, CO_2 and H_2O
- If air is used in the oxidation then the gas mixture will have N_2

Mol (meaning) A mole corresponds to the mass of a substance that contains 6.023x $\mathbf{10^{23}}$ particles of the substance.

Pyrolysis is the basic thermo-chemical process for converting solid biomass to a more useful fuel.

Pyrolysis

- Endothermic reactions take place in the range of 250-700°C – Thermochemical decomposition of the biomass matrix occurs – Chemical bonds are cracked and smaller size molecules are formed – Solid, liquid and gaseous fractions are formed

$$\text{Biomass} \rightarrow H_2 + CO + CO_2 + CH_4 + H_2O + \text{tar} + \text{Char (endothermic)}$$

- Solid fraction is 5-10% for fluidized bed gasifiers and 20-25% for fixed bed gasifiers – Has high carbon content (char) and inert materials of the biomass as ash -
- Liquid fraction (called tars) varies with the type of gasifier – as low as 1% for downdraft gasifiers, 1-5% for bubbling fluidized bed gasifiers and 10-20% for updraft grasifiers – tars include complex organic substances and are condensable at relatively lower temperature (250-350°C)
- Gaseous fraction (pyrolysis gas) is 70-90% - mixture of gases (H_2, CO, CO_2, light hydrocrabons – methane and upto C_3 hydrcarbons;

- Components of product gas that need addressing
  - Tar
  - Particulates (unconverted biomass, ash, char and bed material)
  - Alkali compounds, and nitrogen, sulfur and chlorine containing compounds
  - Water vapour
- Adjustment of the composition of the product gas and/or ratio of H2 to CO and tar removal
  - Water-gas shift reactions
  - Reforming reactions
- Removal of the undesirable constituents (particulates, tar, moisture and carbon dioxide)
  - Cyclone separation
  - Wet scrubbing
  - Wet electrostatic precipitation
  - Barrier filters
- Cooling of the product gas and moisture removal

Reduction

- All products of pyrolysis and oxidation (also of drying) are involved
  - The gas mixture react with char and final syngas is formed

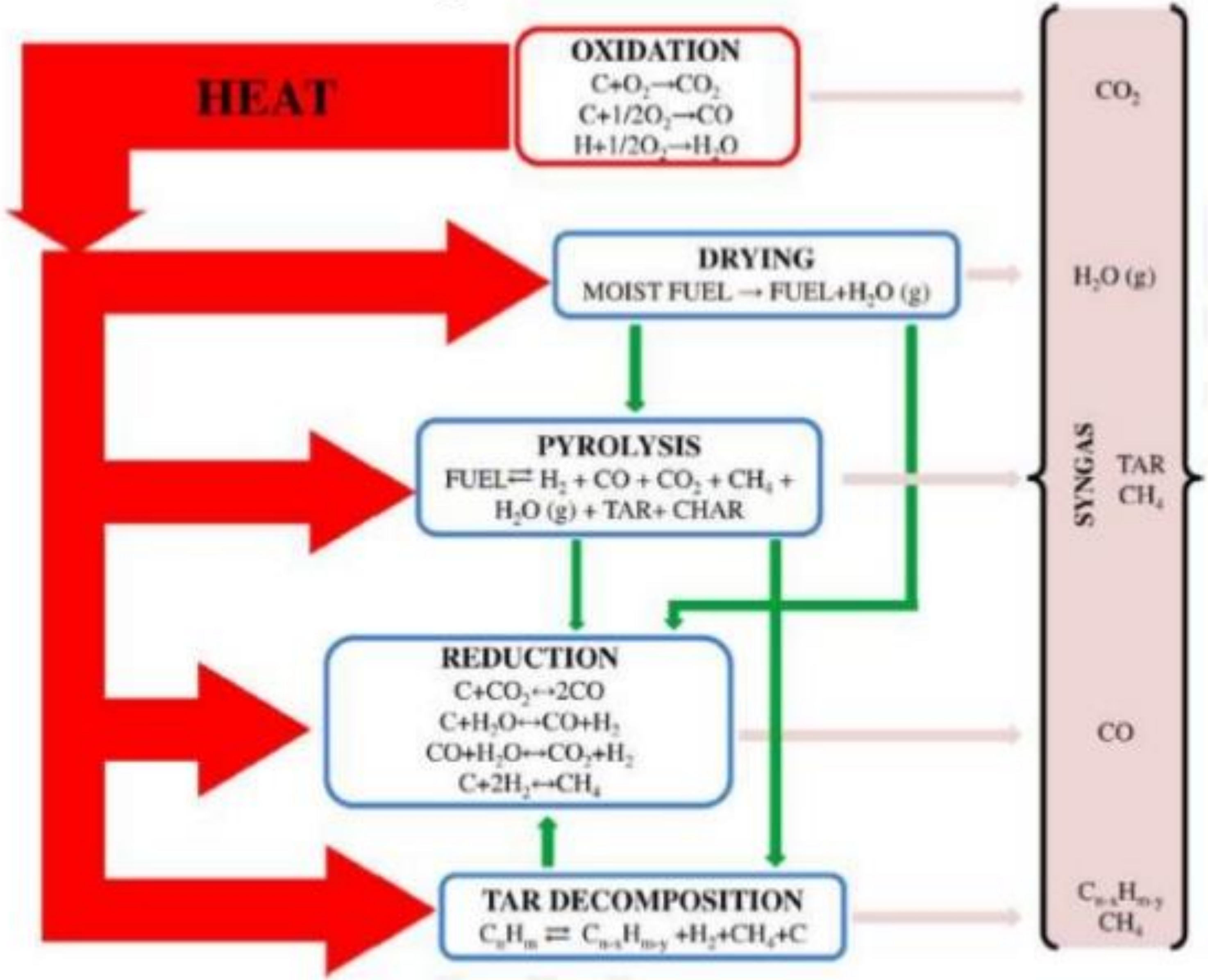
  $C + CO_2 \leftrightarrow 2CO$ (Boudouard reaction: + 172 kJ/mol)

  $C + H_2O \leftrightarrow CO + H_2$ (Char reforming reaction: + 131 kJ/mol)

  $CO + H_2O \leftrightarrow CO_2 + H_2$ (water gas shift reaction: - 41 kJ/mol)

  $C + 2H_2 \leftrightarrow CH_4$ (methanation reaction: - 75 kJ/mol)
- Overall the reduction reactions are endothermic, and the products and the reactants are in chemical equilibrium

Stages of Gasification



Operating Conditions of Gasifiers

Equivalence ratio (ER)

- Ratio of actual air flow to the stoichiometric air flow required for the biomass combustion
- Indicates the extent of partial combustion and controls the gasification temperature (higher the flow greater will be the temperature)
- Increasing ER from 0.2 to 0.45 increased gas yield, but decreased LHV, and the percentages of H_2, CO, CH_4, C_2H_2, and tar
- Effect of ER on the composition of product gas is influenced by temperature and S/B (steam to biomass) ratio

SV: Superficial velocity (m/sec.)

- Air flow rate to the gasifier cross-sectional area (m^3/m^2.sec.)
- Affect residence time of the gasifier – shorter time decreases the extent of biomass conversion

Operating Conditions of Gasifiers

Steam to biomass ratio (S/B ratio):

- Gasification, where steam is used as the gasifying agent, and temperature of gasification is >750-800C (catalysts can however lower the temperature)
- Higher S/B ratio results in higher biomass conversion efficiency

For S/B ratio 0.0-1.35 yields of CH_4, C_2H_4 and CO_2 increase and CO yield decreases

For S/B ratio 1.35 – 2.7 yields of CO and CH_4 decrease and yields of CO_2 and H_2 increase

For S/B ratio >2.7, the gas composition do not change significantly

H/C ratio:

- Ratio of Hydrogen (of biomass, moisture and steam) and Carbon (of biomass)
- Increase of H/C ratio from 1.6 to 2.2 was found increasing H_2 content and LHV of gas, and decreasing tar content

Temperature of the gasifying agent

- Increased temperature is found to increase the gas LHV and to decrease tar and soot content

Temperature profile of gasification

Increasing temperature increases gas yield and overall energy content of the gas (increase of H2 % is mainly responsible)

Temperature profile of gasification

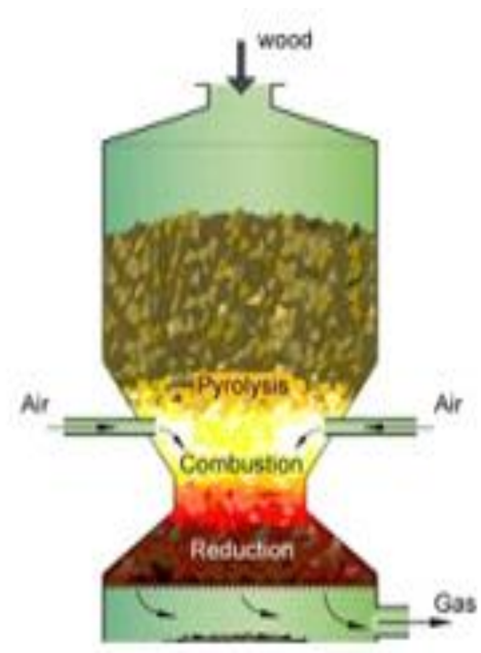
- At >750-800C, H_2 production increases but CH4 production decreases
- At >850-900C, steam reforming and Boudouard reactions predominate and increase the CO content

  $CH_4 + H_2O \rightleftharpoons CO + 3\ H_2$ (strongly endothermic: +206 kJ/mole)

  $C + CO_2 \leftrightarrow 2CO$ (Boudouard reaction; predominates at >850-900C)
- High temperatures favour destruction and reforming of tar
- With air as gasifying agent H2 and CO content of gas increases with temperature from 700 to 900C and CH4 and CO2 decreases

Gasification

- Gasification is a form of pyrolysis, carried out with more air, and at high temperatures in order to optimize the gas production. The resulting gas is producer gas (a mixture of CO, CO_2, H_2, CH_4 and N_2).



Biomass that can be used…

Very wide variety of feedstock can be used with simple processing in terms of sizing and moisture reduction to less than 20%, bulk density of above 100 kgs/m^3 & free flowing nature.

Rice husk (as is basis & no need to briquette)	Agri-residues like Cotton / Soyabean / Mustard stalks, Corn Cobs	Shells of Arecanut, Almond, Cashewnut, Groundnut, Coconut
Waste Wood, Wood chips, Plywood & Saw mill wastes	Branches & Twigs	Bamboo pieces & Pine needles
Sugarcane bagasse & Sugarcane trash (briquetted)	Wild bushes and weeds like Prosopis Juliflora, Lantana, Invader Bush etc.	Greening of waste lands though production of sturdy Energy species.

Applications

Power Generation

- Irrigation Pumping
- Village Electrification
- Captive Power *(Industries)*
- Grid-fed Power
- Simultaneous Charcoal and Power Production

Thermal Applications

- Hot Air Generators
- Dryers
- Boilers
- Thermic Fluid Heaters
- Ovens
- Furnaces & Kilns

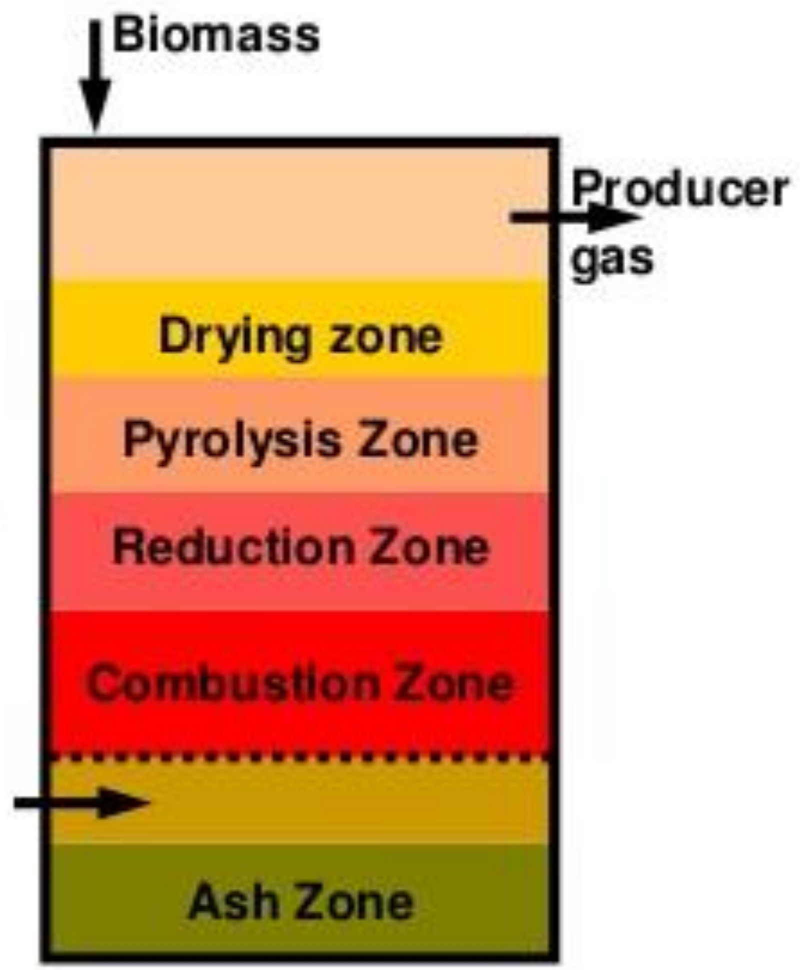
Gasifiers

- Classified according to air blast introduction in the fuel column and producer gas travel in the reactor before the final use.

1. Updraft
2. Downdraft
3. Twin fire
4. Crossdraft
5. Fluidized bed
6. Other

Updraft gasifier

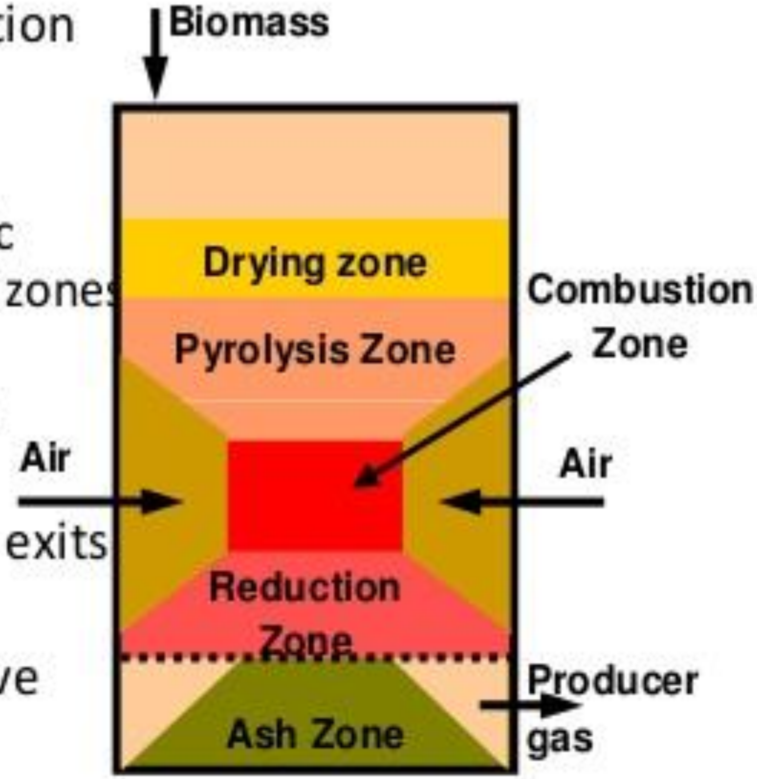
- Disadvantage; Excessive tar amount of tar in raw gas and poor loading capability.



- Biomass feed moves downwards and gasifying agents move upward counter-current to biomass through the fixed bed of biomass
- Ash is removed either as dry ash or as slag (slagging gasifiers - temperatures are greater than the ash fusion temperature)
- Has well defined drying, pyrolysis, reduction and combustion zones
- Excessive tar in the product gas – uncarbonized biomass is gasified (tar is a complex and corrosive mixture of condensed liquid vapours)
- Has higher thermal efficiency
  - Combustion takes place at the gasifier bed bottom and hot gases pass through reduction, pyrolysis and drying zones of the bed
  - Product gas exits from top at lower temp. (500^{0}C)

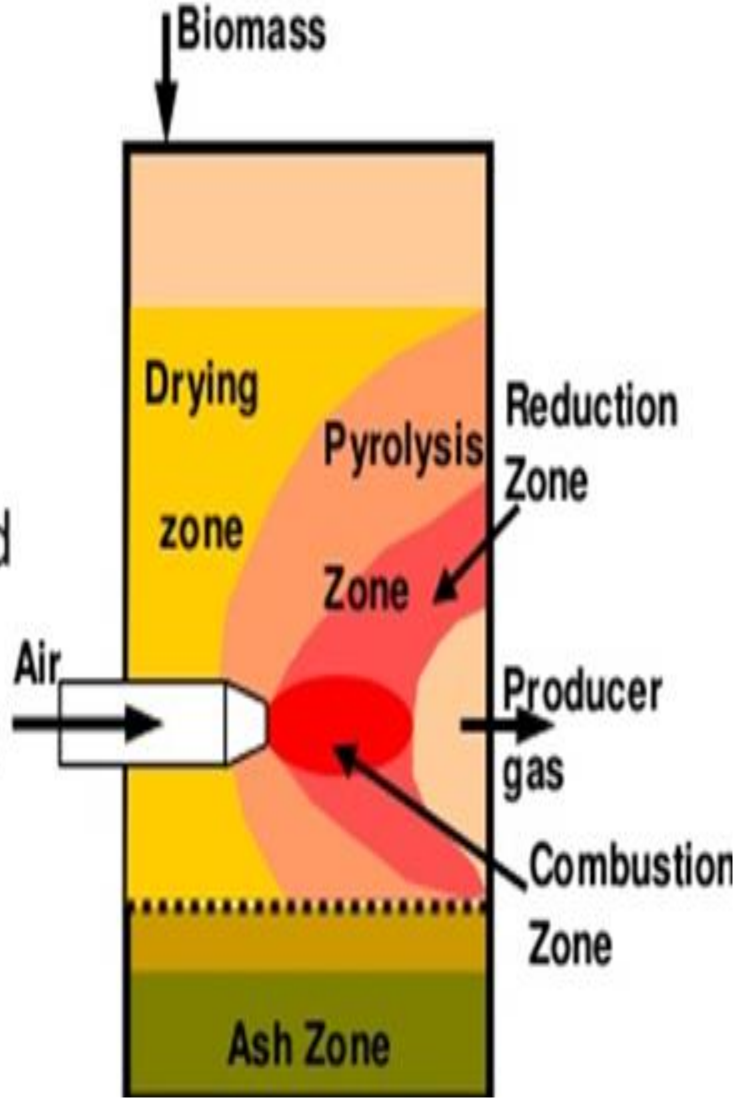
Downdraft fixed bed gasifiers

- Similar to updraft gasifier – but gasification agent flows co-current to fuel (downwards - down draft gasifier)
- Has well defined drying, pyrolysis, combustion and reduction zones
- Tar levels in the product gas are lower
  - Carbonized biomass is gasified and pyrolytic gases pass through combustion - reduction zones
  - Tar constituents of the pyrolytic gas, while passing through combustion and reduction zones, are consumed
- Overall efficiencies are lower - Product gas exits from the bottom at higher temp. (800C)
- Quick startup (20 to 30 minutes) is a positive feature
- High moisture and high ash content in the biomass offer problems
- Preferred over updraft gasifiers for burning the gas in IC engines



Cross draft fixed bed gasifiers

- Ash bin, combustion and reduction zones are separated
- High operating temp., high exit gas temp., high gas velocity and good load following abilities
- Startup is even faster than that of the downdraft gasifier
- Operates well on dry air and dry fuel
- CO_2 reduction is poor



Crossdraft gasifier

- It allows cross movement of fuel and gas. The air is allowed to enter perpendicular to fuel bed and producer gas is generated in the same opposite live.
- This design characteristic limit the type of fuel for operation to low ash fuels such as wood, charcoal and coke.
- The relatively higher temperature in crossdraft gasifier has an obvious effect on gas composition such as high carbon monoxide and low hydrogen and mrthane content when dry fuel such as charcoal is used.

Difference between biomass gasification and coal gasification

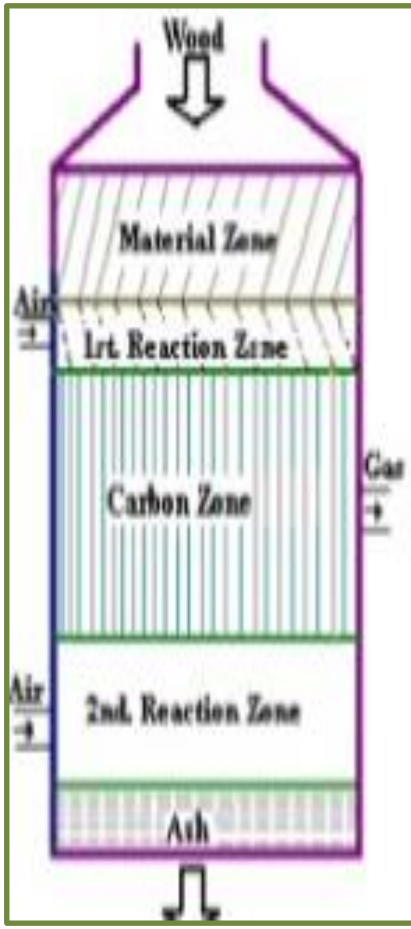
- Biomass is more reactive and has higher volatile content
- Gasification occurs at lower temperature
- Has lower sulfur content and higher alkali (sodium and potassium) content – can cause slagging and fouling problems
- Product gas requires cleaning to remove tar and other contaminants (alkali compounds)

Biomass gasification: Gasifiers

Fixed bed gasifiers	Fluidized bed gasifiers	Other types of gasifiers
Updraft gasifiers	Bubbling fluidized bed gasifier	Entrained flow gasifiers
Down draft gasifiers	Circulating fluidized bed gasifier	Plasma gasifiers
Cross draft gasifiers	Dual fluidized bed gasifier	
Twin fire gasifiers		

Comparison of updraft and downdraft gasifiers

1. Biomass feed moves downwards and gasifying agents move upward counter-current to fuel whereas, incase of downdraft gasifiers, gasifying agents move co-current to fuel.
2. Updraft gasifiers are less sensitive to fuel size and moisture content as compared to downdraft gasifiers.
2. Downdraft gasifiers give relatively cleaner gas (low tar content) and are preferred for engine applications, niche applications demanding cleaner gas.
3. Thermal efficiency is higher in case of updraft gasifier as the hot gas passes through fuel bed and leaves the gasifier at low temperature.
4. Updraft gasifier is suitable for low tar fuel such as charcoal and coke, whereas, downdraft gasifiers are developed to convert high volatile fuel (wood, biomass) to low tar gas.



Twin fire fixed bed biomass gasifiers

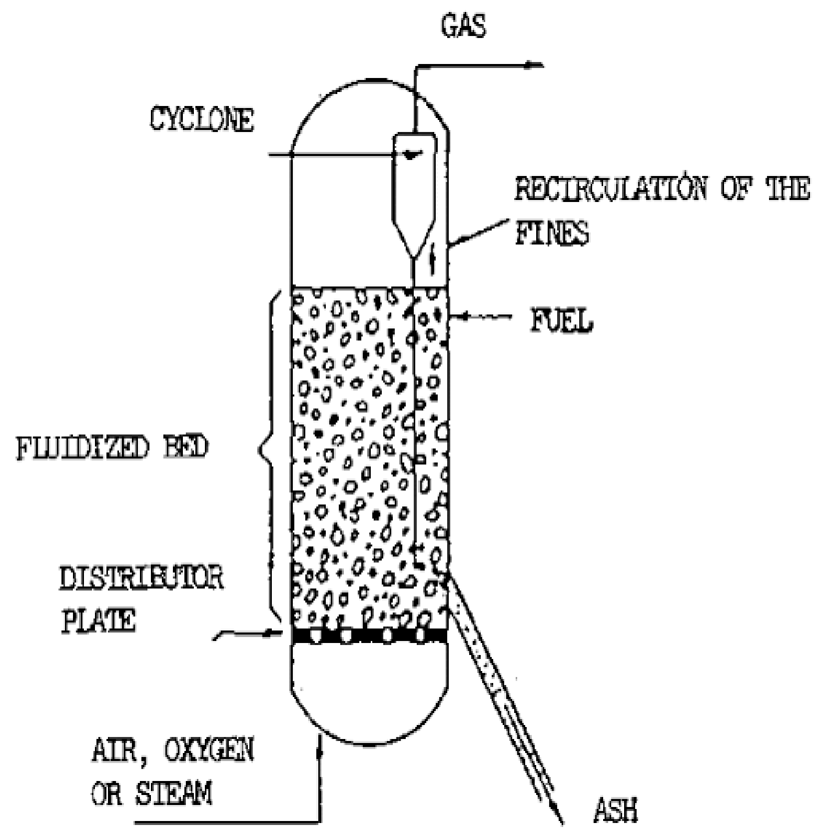
- Has two defined reaction zones
  - Drying, low-temp. Carbonization and cracking of gases occur in (upper) zone-1
  - Gasification of charcoal takes place in (lower) zone-2
- Product gas is fairly clean and its temp. is 460 to 520 °C
- Gasification occurs at -30 mbar pressure
- Advantages of updraft and downdraft gasifiers are combined here

Fluidized bed gasifier

➢In this type of gasifer, air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension.

➢The bed is originally externally heated and the feedstock is introduces as soon as a sufficient high temperature is reached.

➢The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and also instantaneously heated up to the bed temperature.



As a result of this treatment the fuel is pyrolysed very fast.

- Most systems are equipped with an internal cyclone in order to minimize char blow-out as much as possible.
- Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications.

Fluidized bed gasifiers

- Silica or alumina is used as the bed medium
  - These materials have high specific heat and are stable at higher temperatures
- Two types: Dry ash gasifiers and agglomerating gasifiers
  - Biomass is fed from the bottom and ash is removed as dry ash or as defluidized heavy agglomerates
  - Temp. is lower in dry ash gasifiers than in agglomerating gasifiers
- Gasifying/fluidizing agents fluidize the bed - product gas is taken out from top through cyclone separator (for particulate removal)
- Catalysts may be added to the fluidizing agents or to the fluidized medium
- Fluidization enhances heat transfer, and increases reaction rates and conversion efficiencies
  - Throughput is higher than that of fixed bed but lower than that for entrained bed gasifier
- Fluidization tolerates wide variations in fuel types and fuel characteristics – biomass forming corrosive ash can be gasified

Sodium & Potassium content of the biomass are the major contributors to the agglomeration in biomass fired fluidized beds.

Fluidized bed gasifiers

Circulating fluidized bed gasifiers

- Fluidizing agents move the solids and ungasified particles along the product gas
- An attached cyclone separator separates the solids and recirculates back to the gasifier bed

Duel fluidized bed gasifier

- Includes (bubbling/circulating) fluidized bed gasification reactor (fluidized by steam) and circulating fluidized bed combustion reactor (fluidized by air)
- Biomass undergoes endothermic reaction to produce producer gas (H_2, CH_4 and CO; and CO_2 and H_2O) in the gasification reactor
- Combustion reactor is used to heat the bed material and circulate to the gasification reactor (supplies heat for endothermic gasification reactions)
- Combustion of char (in bed material) from gasification reactor occurs in the combustion reactor and heats the bed material
- Cyclones are used in the separation and circulation of bed material

Lect.-6

Concept of briquetting and familiarization with briquetting machines.

A briquette is basically a compressed block of agro-waste and biomass waste that is used as a substitute of non renewable resources of fuel like coal, petrol, etc. The briquette is made from agricultural waste, forestry waste, stalks, wood waste like saw dust, etc. This raw material is passed under various processes to form the final proper shaped briquette. The process consists of crushing, compressing and drying the final end product to increase their life span and efficiency.

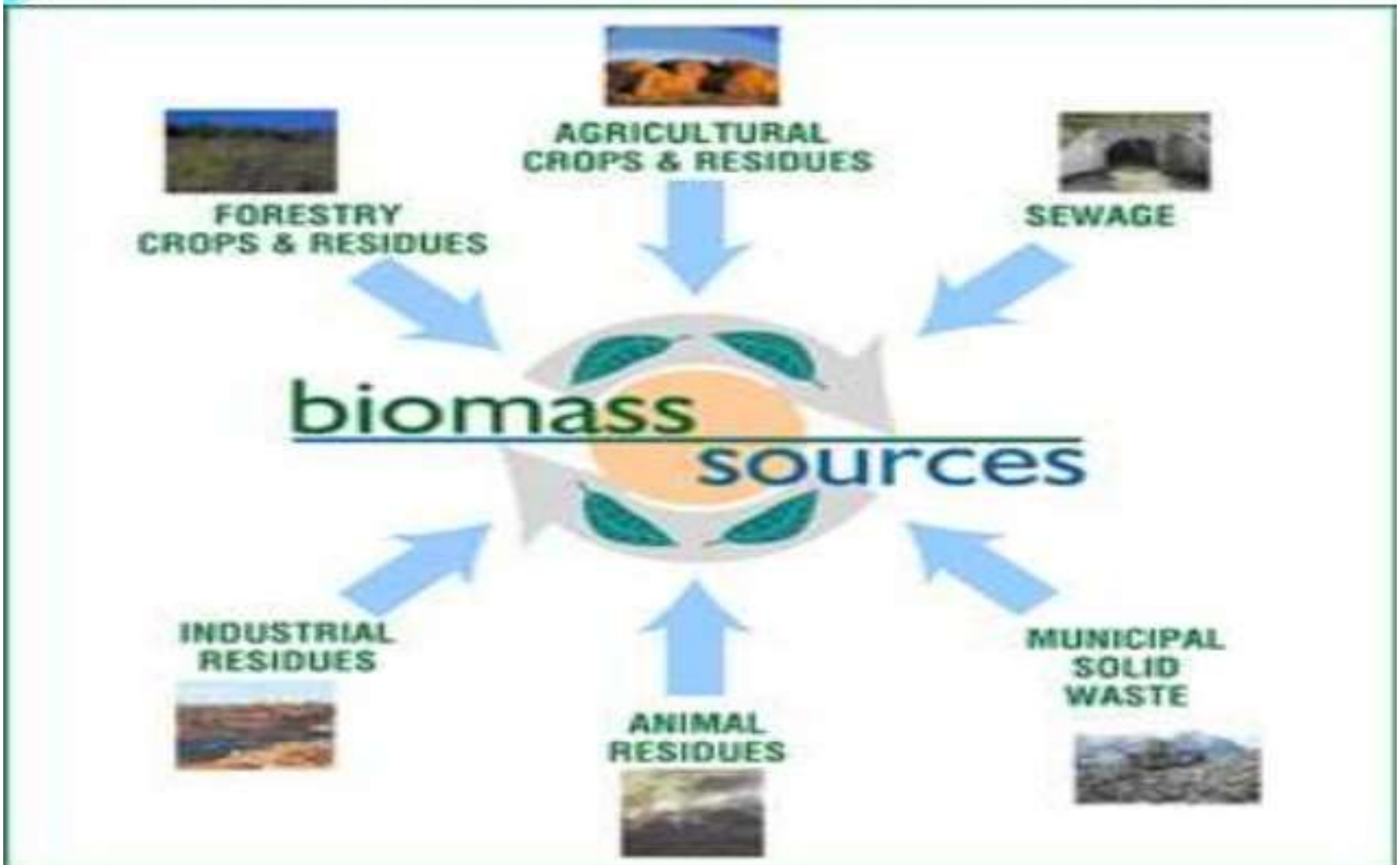
Briquettes

- They are used as a flammable material in brick kilns, paper mills, chemical plants, pharmaceutical units, dyeing houses, food processing units, oil mills etc.

The calorific value of some biomass;
Groundnut shells : 4000 Kcal/kg
Rice husk : 3500 Kcal/kg
Jute waste : 4500 kcal/kg

Kindling : Thin small pieces of wood used for starting a fire.

Raw materials used



Briquetting

- The briquetting process is the conversion of agricultural waste into uniformly shaped briquettes that are easy to use, transport, and store. The idea of briquetting is using materials that are unusable, due to a lack of density, and compressing them into a solid fuel of a convenient shape that can be burned like wood or charcoal.

Advantages

- Renewable in Nature.
- Cost effective fuel for industries.
- Ecofriendly.
- Reduces usage of wood.
- Easy to transport.
- No flying of ashes.
- Constitute burning high efficiency and quality fuel.

Advantages

- **Biomass briquette plant** is made from green waste and industrial waste. So, it is the clean and renewable.
- When the process of making briquette is going on, it does not emit any harmful gases.
- Easy availability of biomass and other raw material.
- From this plant, biomass is converted into useful biomass briquettes. It is also known as white coal.
- Farmers and rural people can earn money by selling their agro waste.

Why briquetting ?

Biomass briquettes helps in the following way:

- Ease of charging the furnace
- Increased calorific value
- improved combustion characteristics
- Reduced entrained particulate emissions, and
- Uniform size and shape.

In addition, furnaces that use other solid fuels can use briquettes also.

Briquetting machine

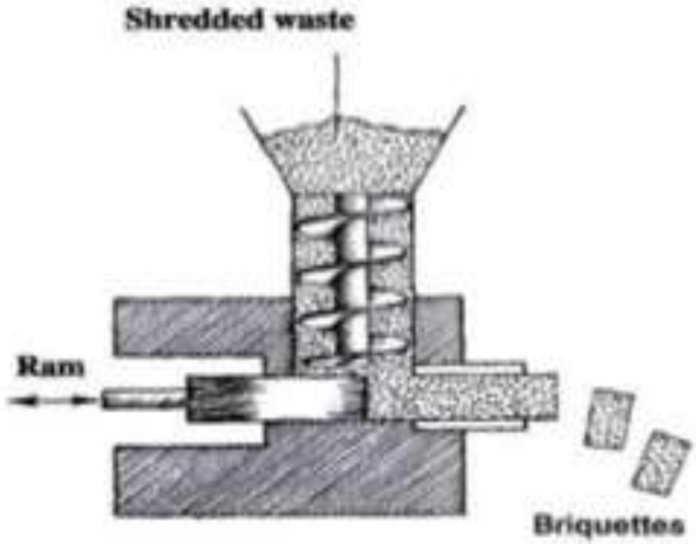
- A briquetting machine is used to turn the waste biomass or powder of biomass product to a regular shape block, which can help to improve the conditions to make them easy for transportation, storage, and more useful for further usage.
- Briquetting always accomplished with the binder as it needs the binding effect to get enough strength for the finished briquette.

How to make briquettes ?

Biomass Briquettes are made from the Agricultural waste, Forest Waste and Industrial Waste.

Densification Process

- Piston press densification
- Screw press densification
- Roll press densification
- Pelletizing
- Low pressure or manual presses

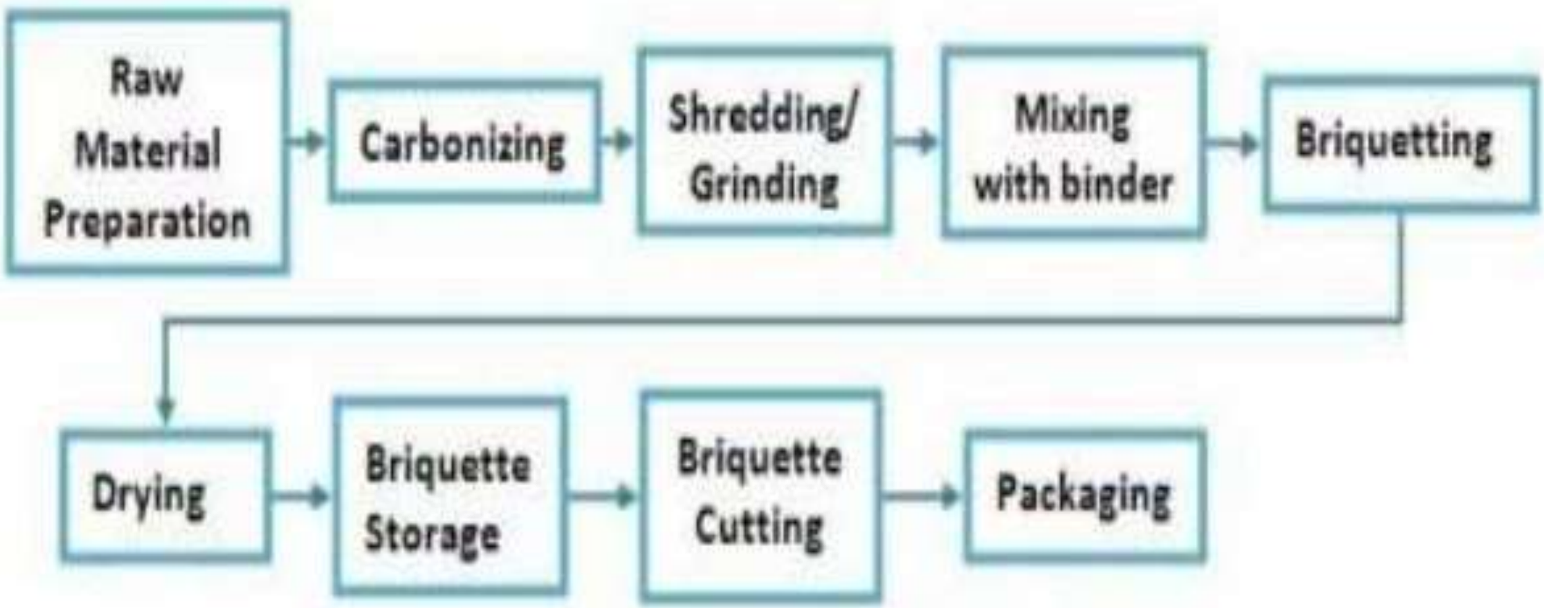


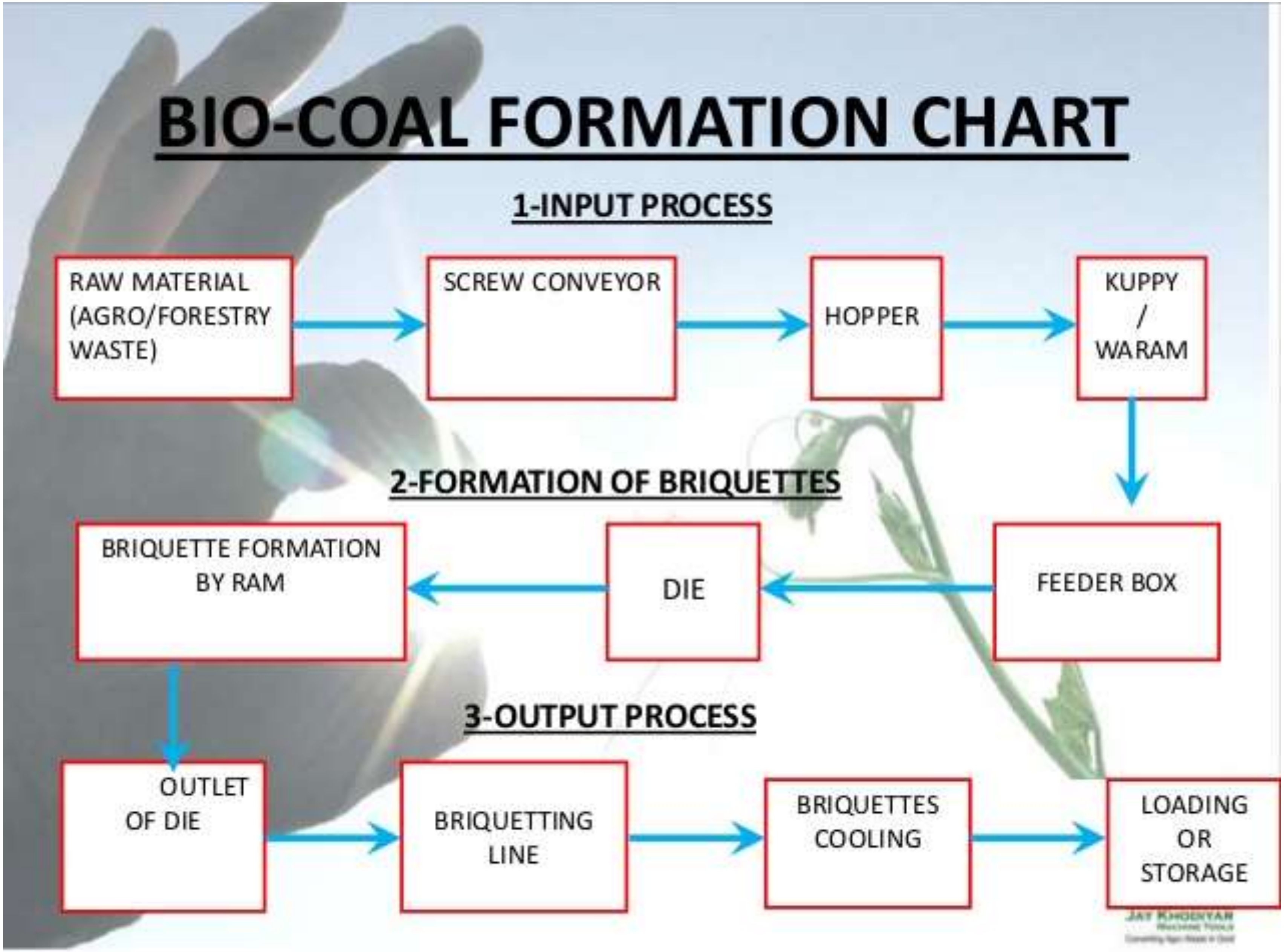
Hammer Mill

A hammer mill is a machine whose purpose is to shred or crush aggregate material into smaller pieces.

Model No:	Hammer Mill
Production capacity	1200 kg/hr
Power Requirement	34 HP
Raw Material Size	01 to 25 mm
Output Product Size	Powder Form

Manufacturing Process




BIO-COAL FORMATION CHART
1-INPUT PROCESS
RAW MATERIAL (AGRO/FORESTRY WASTE)
SCREW CONVEYOR
HOPPER
KUPPY / WARAM
2-FORMATION OF BRIQUETTES
FEEDER BOX
DIE
BRIQUETTE FORMATION BY RAM
3-OUTPUT PROCESS
OUTLET OF DIE
BRIQUETTING LINE
BRIQUETTES COOLING
LOADING OR STORAGE

Renewable White Coal Manufacturing Process

Briquetting machines

- Hand operated press – 5 kg/hr or 25-50 kg/day
- Bullock operated press – Single bullock 100 kg/day
- Power operated press- 400 to 4000 kg/day

  - Piston –ram press type

  - Screw- press type

  -Pellet – press type (10-30 mm size)

Low cost Briquetting machine

Hand operated

Technical specification- of briquetting m/c an example

Model No:	Jumbo 90
Production capacity	1500kg/hr
Moisture Content	10 to 12%
Raw Material Size	Up to 25mm
Finished Product Shape	Cylindrical
Power Requirement	91HP
Biomass Type	Agro residues (cotton salk, groundnut shells, almond shells, coffee husk and other agro residues.

Classification of machines for densification

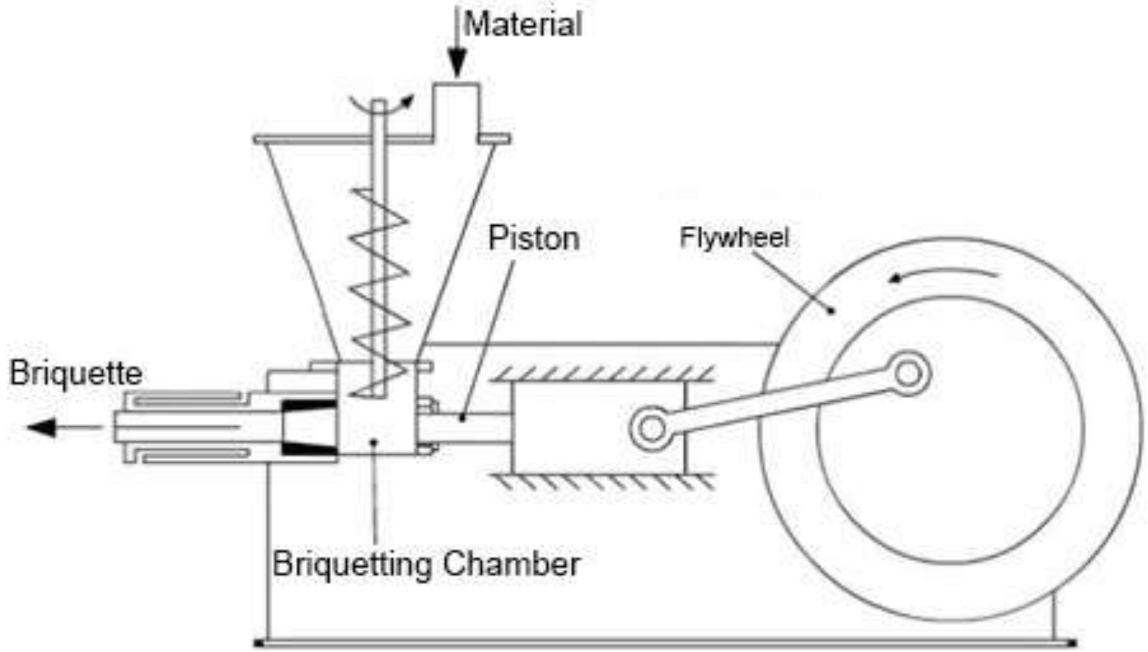
On the basis of pressure, machines are classified in 3 groups

(i) Low pressure (<5 MPa)

(ii) Intermediate pressure (5 -100 MPa)

(iii) High Pressure (> 100MPa)

Piston type



The piston type uses the rotary power of the mechanical device or the thrust of the hydraulic cylinder to reciprocate the piston (or the plunger), and the piston (or plunger) drives the ram to reciprocate in the forming sleeve to generate a pressing force to form the material to briquette.

- A big pressure will be generated as the movement of the flywheel punch the briquette time after time in a short time, it raises the temperature of the raw material.
- As the raw material moves, it fractionates with the inside, another kind of heat – friction heat generates.
- With the action of these two kinds of heat, material raises its own temperature to a high level and melt the lignin. Particle materials then bind together and become strong enough.

PISTON PRESS

- Apart from screw extrusion, a briquette press is a viable and attractive solution.
- It has lower power requirement. Unlike pellet mills (which are used for pelletization), it can handle larger-sized particles and wider moisture contents without the addition of binders.
- Hydraulic or mechanical presses are usually used. The briquettes' densities generally range from 900 to 1300 kg/m3.

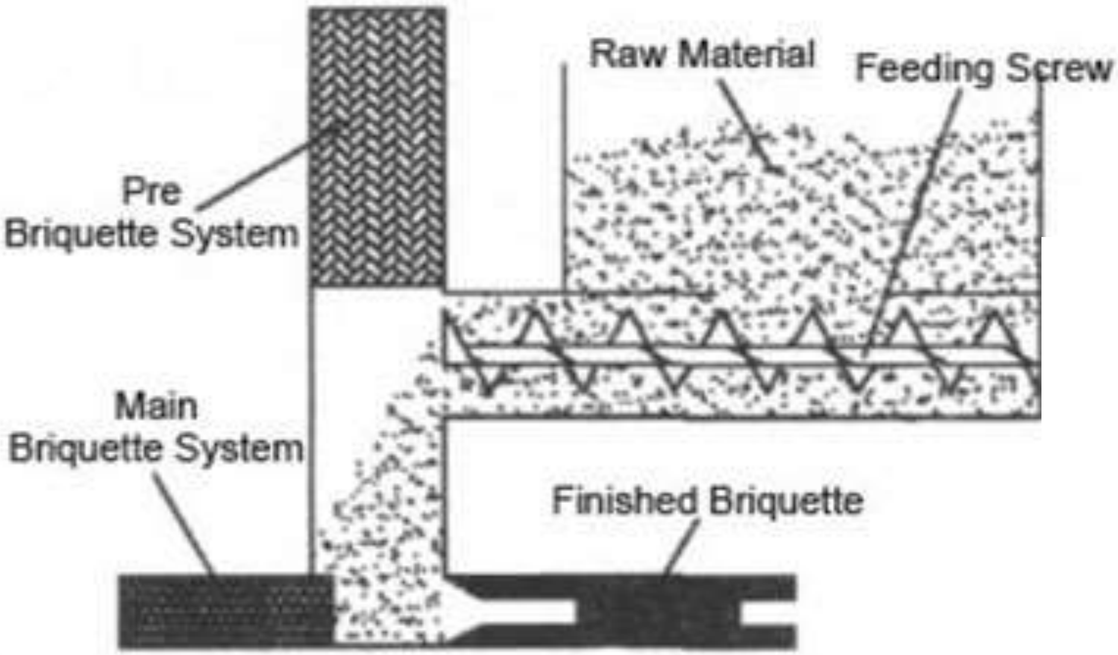
Mechanical piston press

- Mechanical piston presses are typically used for large-scale production, ranging from 200 to 2,500 kg/hr.
- The mechanical press is designed as an eccentric press.
- A continuously rotating eccentric, connected to a plunger, presses the raw material through a conic die.
- The mechanical press is driven by electric motors instead of a hydraulic motor.
- The operating life of a mechanical press is considerably longer than hydraulic presses.
- Generally, a mechanical press gives a better return on investment than a hydraulic press.

Hydraulic piston press

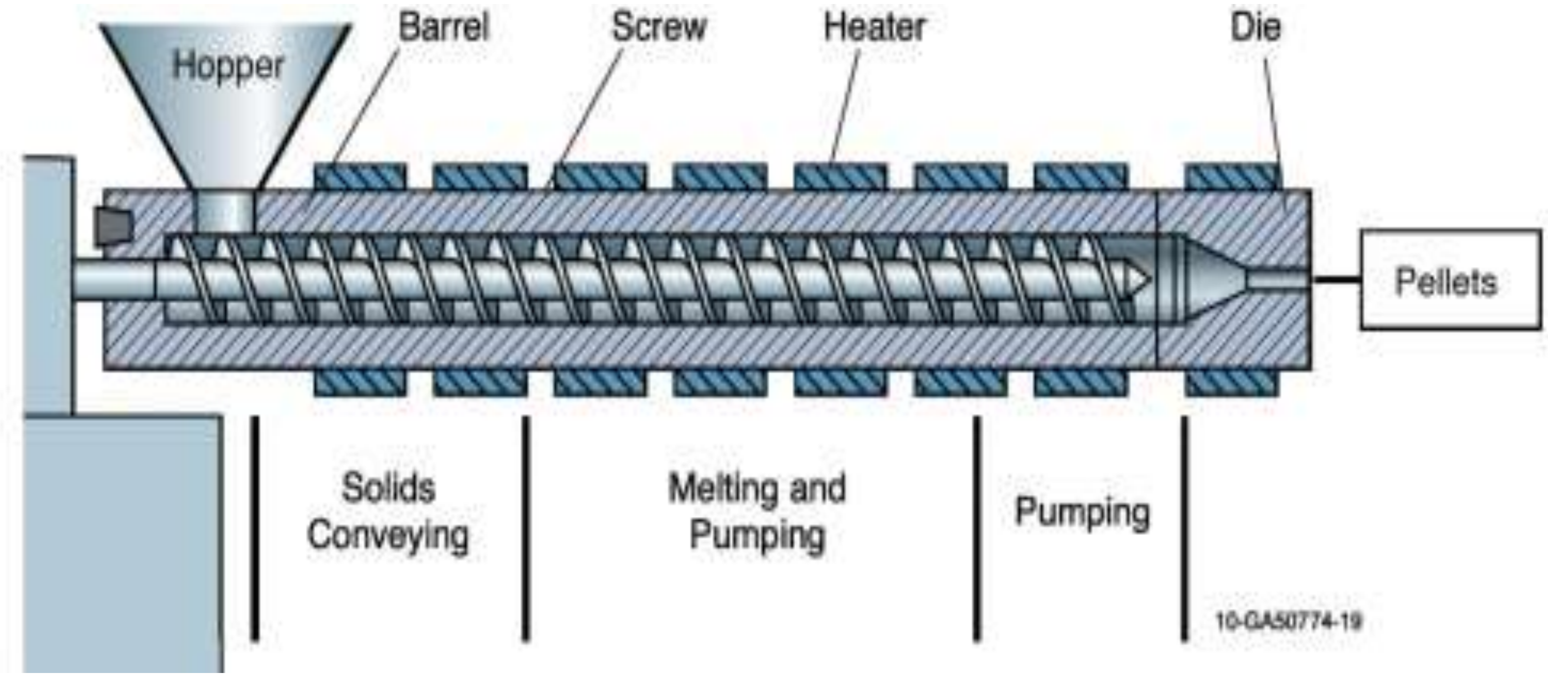
- The energy to the piston is transmitted from an electric motor via a high-pressure hydraulic system.
- The output of a hydraulic press is lower, since the movement of the cylinder is slower compared to mechanical processes.
- The briquettes have a bulk density lower than 1000 kg/m^3 because pressure is limited.
- However, these machines can tolerate higher moisture contents than the usually accepted 15% for mechanical piston presses.

Hydraulic type



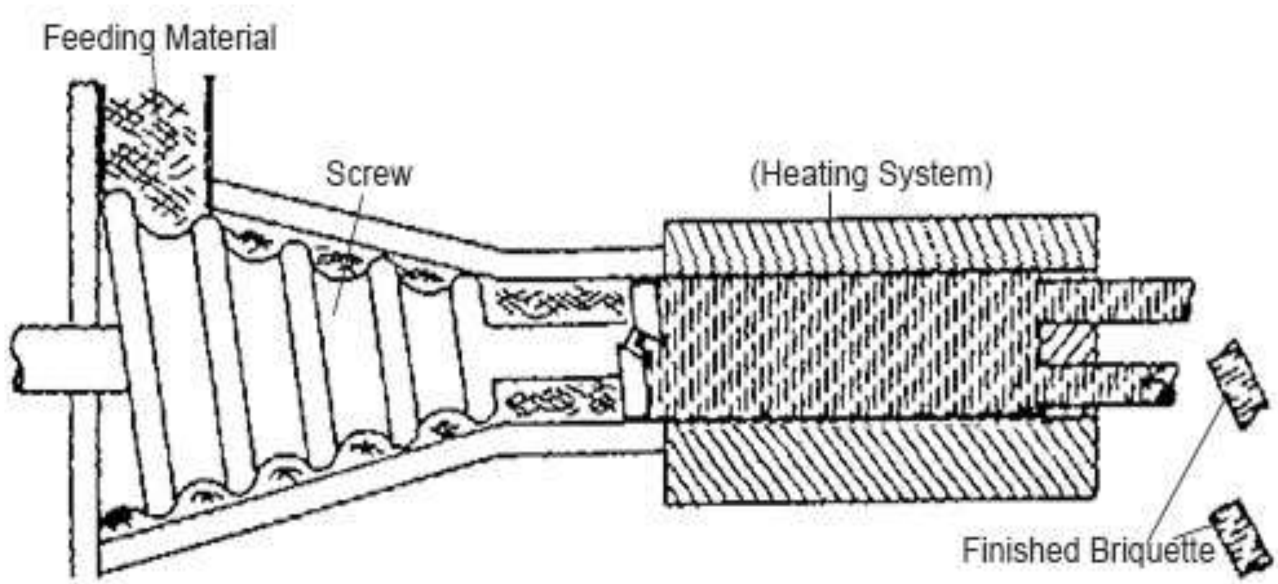
- The briquette working process is in a chamber where materials are fed into, there materials are briquetting under a very high pressure. It causes their plasticity and makes them binding stably together as a block.
- Hydraulic type takes a long pressure keeping time on the briquette, this prevents the short-time material deformation rebound and will cause a special heating for those materials like sawdust for melting its internal lignin, make the briquette with higher strength.

SCREW COMPACTION OR EXTRUSION



The screw type briquette machine uses the auger to press the raw material, it can be equipped with or without the heating system to output briquettes.

SCREW TYPE



- The heating system is a special design for machine using raw materials contain lignin.
- Lignin always can be found on biomass.
- So the heating system is usually used for biomass briquetting.
- For other materials like coal, charcoal, etc. binders are always needed when briquetting with the screw type briquette machine.

- In screw compaction (or screw extrusion), the material is taken in from the feed port, moves through a barrel with the help of a rotating screw, and is finally extruded against a die, which builds a large pressure gradient along with screw.
- The die can be tapered, which further compacts the biomass.
- Along with high pressure, frictional effects increase the temperature of the biomass. The die is also usually heated externally for making the biomass pseudo-plastic for smooth extrusion.

Compaction mechanism

- As the biomass enters through the feed section, and is compacted a little. In the compression zone, formed by a tapering barrel, friction at the barrel wall and between the particles of the biomass, along with a high rotational speed (~ 600 rpm), causes the temperature to increase to 200–250 °C.
- The high temperature and pressure softens the biomass turning it plastic, The particles get pressed against each increasing the intermolecular forces.

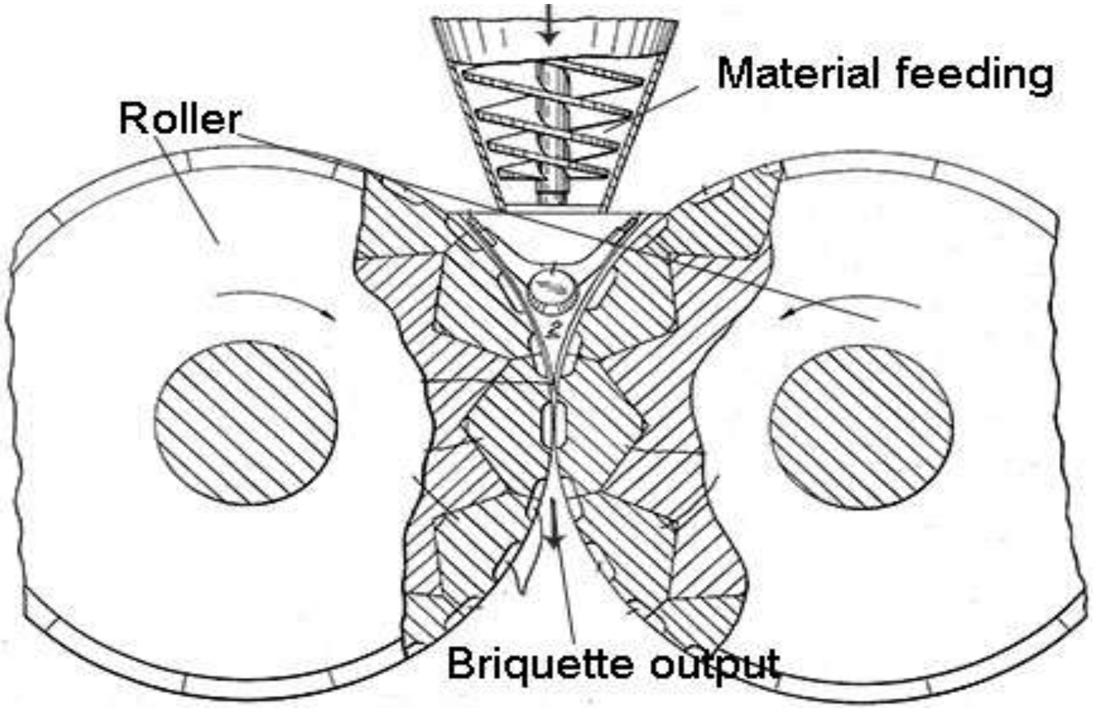
- In this respect, lignin plays an important role by acting as a natural binder.
- At elevated temperatures (>140 °C) and pressure, lignin melts and forms solid bridges between particles.
- Finally, in the tapered die, temperature further increases to 280 °C. Steam gets removed and further compaction takes place. Pressure is transmitted uniformly through the biomass create a uniformly dense briquette.

Roller Type Briquetting m/c

Roller press works with two close rotating rollers at the same speed but with opposite direction.

The two rollers, with the same width and diameter, have holes on the surface.

When they move, the same two holes on the different roller will coincide at the intersection of the midline and the briquette will be pressed there.



Roller Type Briquetting m/c

A normal roller press will use a wedge iron to fix the movable roller as it works on a low pressure.

The hydraulic pump station is also can be used to fix the roller and supplies a much bigger but flexible support to the roller to work stable on big pressure.

Lect. -7
Introduction of Solar Energy, Solar collectors and their applications

Solar energy is radiant light and heat from the Sun that is harnessed using a range of technologies to generate electricity and solar thermal energy It is an essential source of renewable energy.
By photosynthesis, green plants convert solar energy into chemically stored energy, which produces food, wood and the biomass from which fossil fuels are derived.
Solar technologies are characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels

- Active solar techniques use photovoltaics, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs.
- Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun.
- Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand-side technologies.

Sun characteristics:

- The sun is assumed to be a black body with a surface temperature of 5762°K. This is known as the effective temperature of the sun.
- Energy is radiated by the sun as electromagnetic waves of which 99% have wavelength in the range of 0.2 to 4 micron or micrometre.

  (1 micron = 10^{-6} m.)
- Solar energy reaching the top of the earth’s atmosphere consists of about 8 % ultraviolet radiations, 46 % visible light and 46% infrared radiations.

Solar collector

Solar collector is a device that collects and/or concentrates solar radiation from the Sun.

<u>Solar collectors</u>

- Non concentrating type
  - Flat plate collector
  - Evacuated tube collector
- Concentrating type
  - Line focusing collector
  - Point focusing collector

Stationary Collector Types

- 1. Flat plate collectors (FPC);
- 2. Evacuated tube collectors (ETC).
- 3. Stationary compound parabolic collectors (CPC);

Solar energy collectors

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (°C)
Stationary	Flat plate collector (FPC)	Flat	1	30–80
	Evacuated tube collector (ETC)	Flat	1	50–200
	Compound parabolic collector (CPC)	Tubular	1–5	60–240

Non-concentrating type Collectors

- Absorb radiation received on surface
- Both beam &diffused radiation
- No optical concentration method
- No need of solar tracking
- Simple and compact construction
- Fixed on rigid platform- maintanenence free
- High temp cannot be achieved

Non concentrating type collectors may be used for water heating and space heating.

Flat plate Collector

Flat plate collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a black coloured absorber plate. These plates are usually made out of metal that is a good conductor usually copper or aluminum. The sides and bottom of the collector are insulated to minimize heat losses to the surroundings.

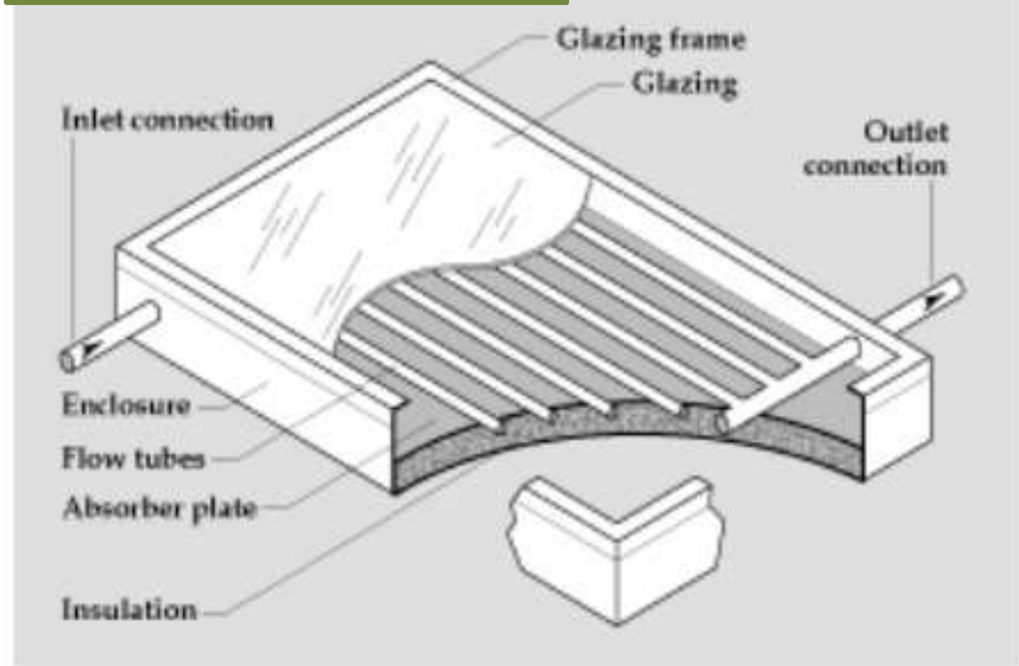
Solar radiation passes through the transparent glazing material and hits the absorber plate. This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate.

Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint.

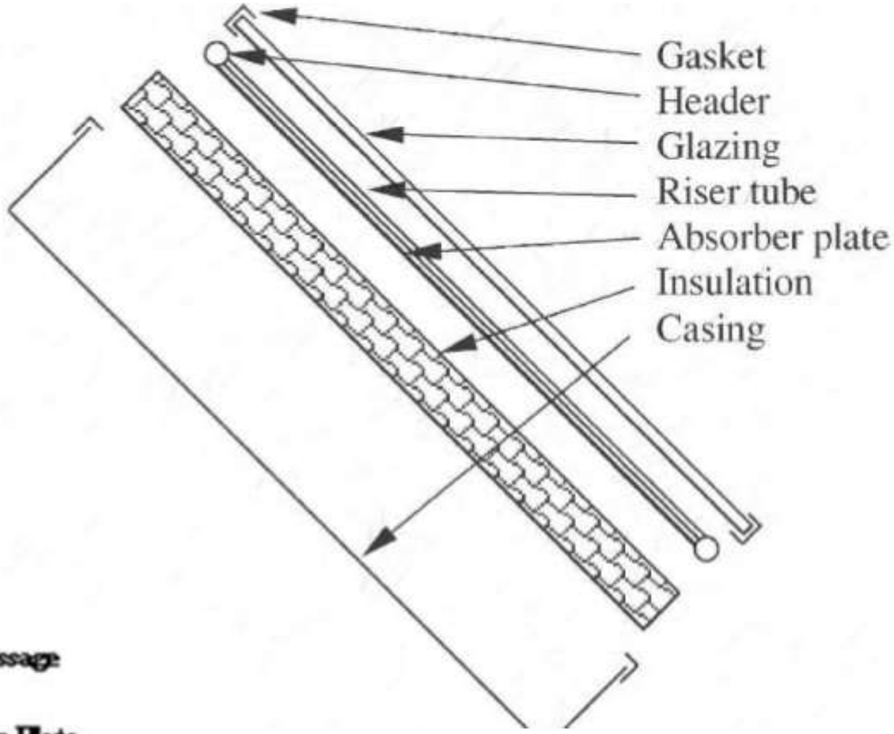
Working Principle of flat plate collector used for water heating

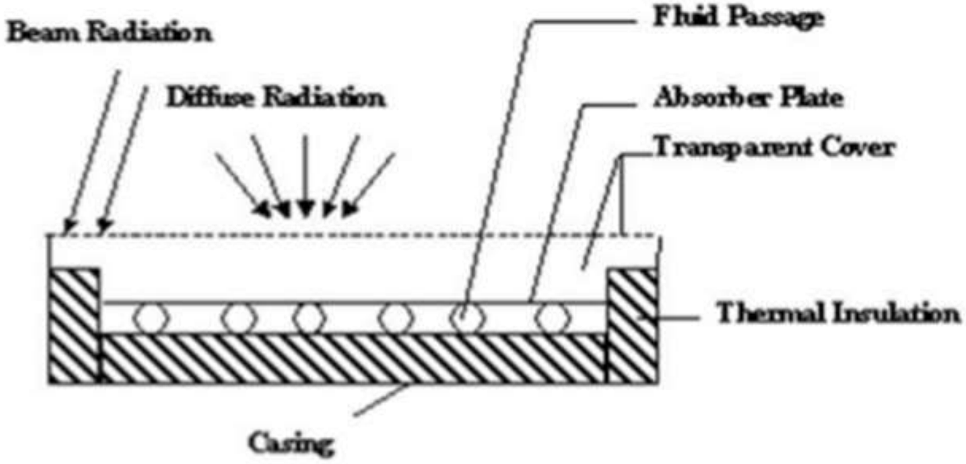
- The flat plate collector mainly consists of a casing, absorber plate, transparent glass covers, insulating material and fluid passage tubes.
- The transparent cover of glass or plastic allows short-wave solar radiation (**Beam, diffuse radiation)** to enter the box and fall on the black plate, but it prevents the long-wave (thermal) radiation emitted by the black plate from being lost.
- **The radiation is absorbed by absorber plate, which is coated with black absorber paint. The fluid tubes, which are connected to absorber plate, absorb the heat and transferred to the water passing through the tubes and gets heated.**

Liquid flat plate collector

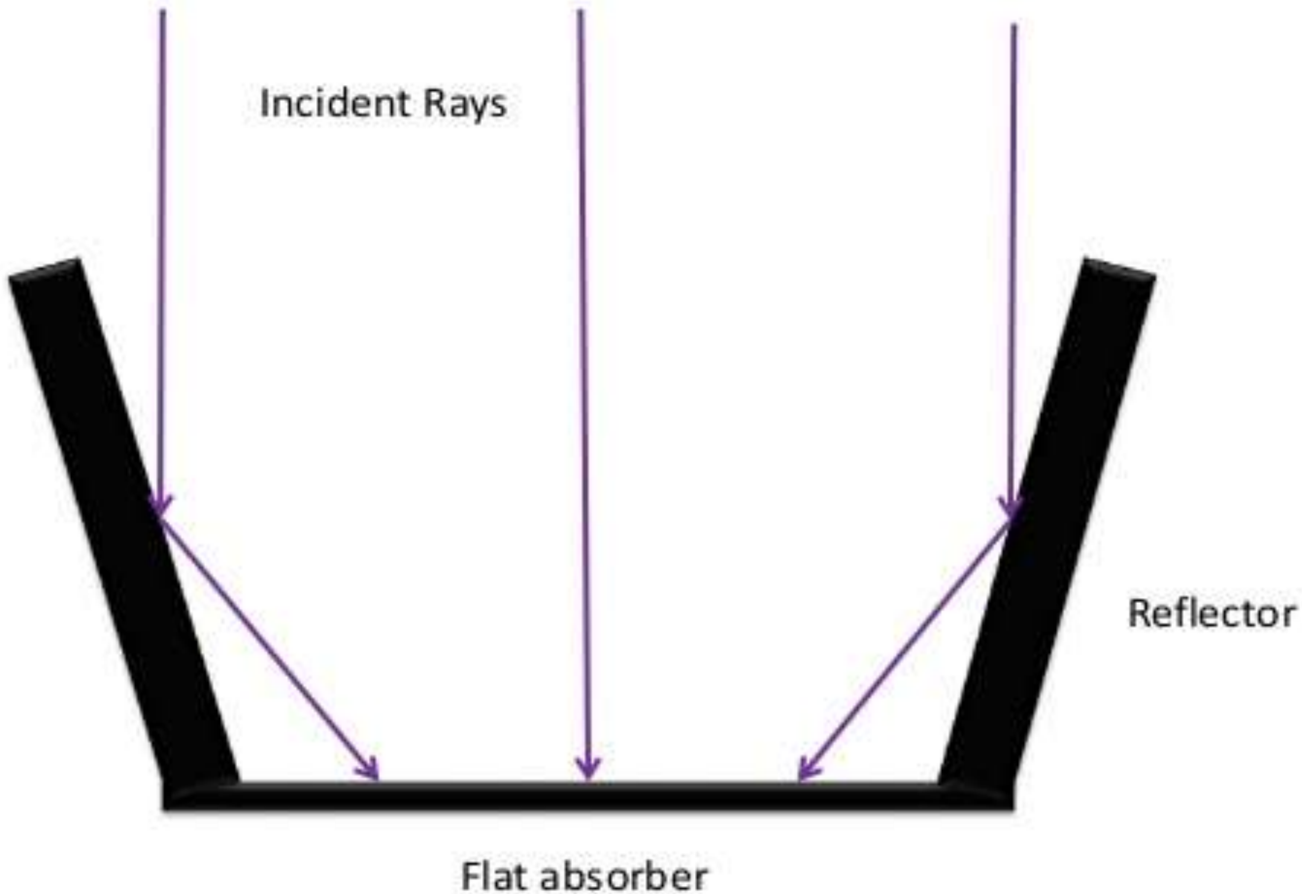


Flat plate collector components





Modified Flat Plate Collector

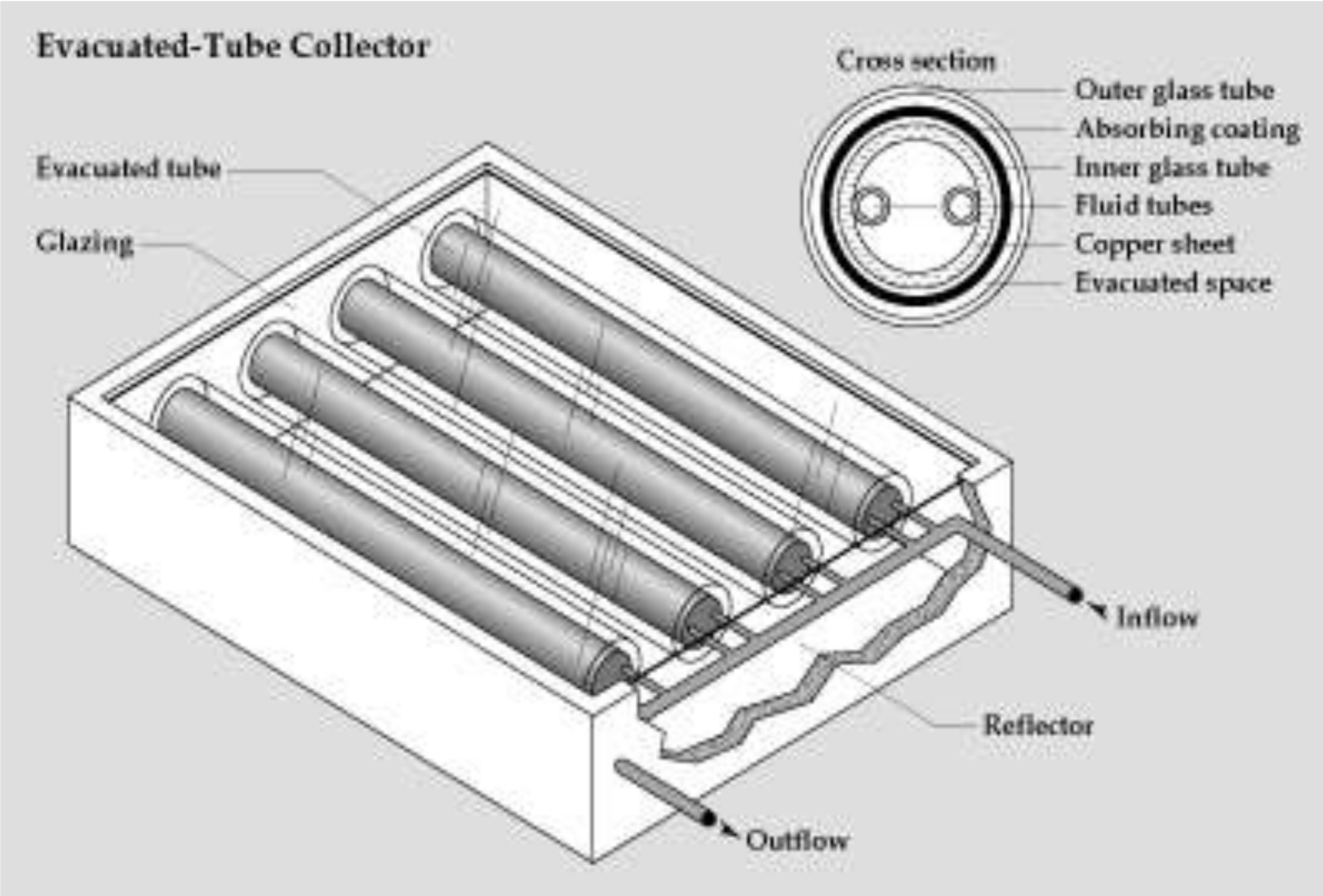


Evacuated tube collector

This type of solar collector uses an array of evacuated glass tubes to heat water for use. These tubes utilize a vacuum, or evacuated space, to capture the suns energy while preventing the loss of heat to the surroundings.

Each tube contains an inner metal tube which acts as the absorber plate and thermally attached to a heat pipe which carry the heat collected from the Sun to the water. This heat pipe is essentially a pipe where the fluid contents are under a very particular pressure. At this pressure, the "hot" end of the pipe has boiling liquid in it while the "cold" end has condensing vapour. This allows for thermal energy to move more efficiently from one end of the pipe to the other.

Water temperature up to 100 ^{0}C can be achieved.


Evacuated-Tube Collector
Cross section
Outer glass tube
Absorbing coating
Inner glass tube
Fluid tubes
Copper sheet
Evacuated space
Evacuated tube
Glazing
Inflow
Reflector
Outflow

. Evacuated Tube Collectors (ETC)

Efficiency is higher at low incidence angle as compared to flat plate Collector.

Concentrating type collectors

Concentrating type collectors uses mirror or lenses to focus the collected solar energy on smaller areas to obtain higher working temperatures.

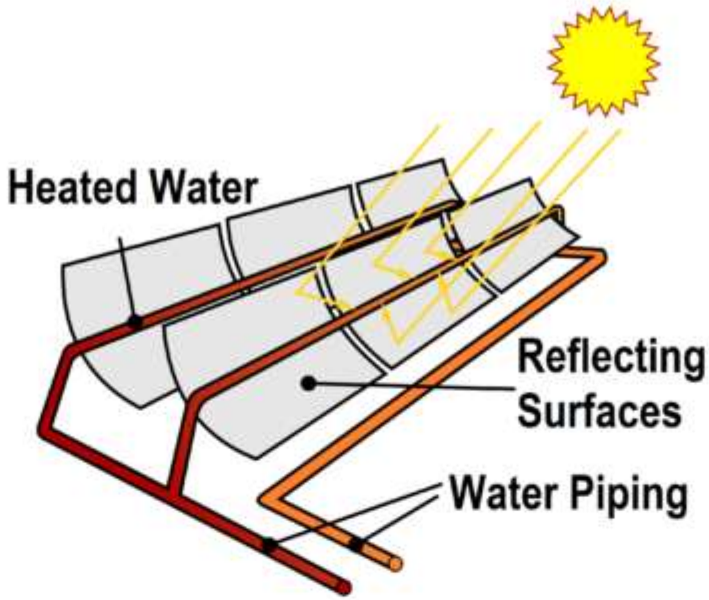
- Converging solar radiation from large area to small area
- Beam radiation utilized
- Optical methods(reflection,refraction)
- Solar tracking required
- Diffused radiation cannot be concentrated
- High temp attained.
- Flexible construction

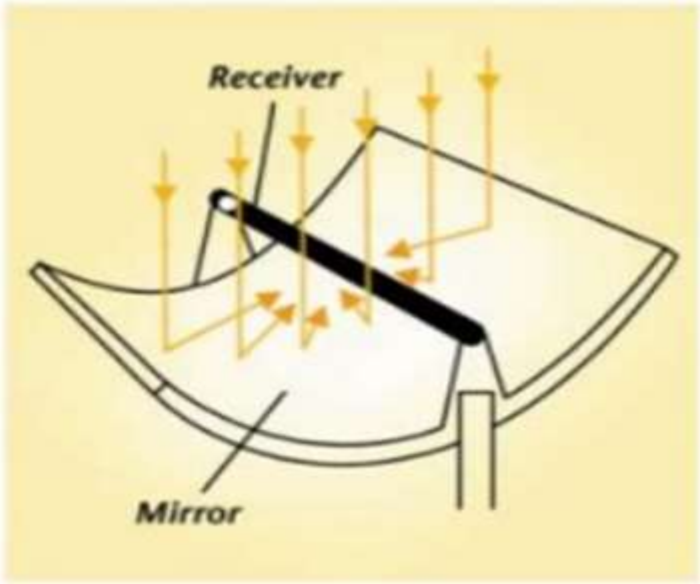
Line focusing collector

These collectors, sometimes known as parabolic troughs, use highly reflective materials to collect and concentrate the heat energy from solar radiation. These collectors are composed of parabolic shaped reflective sections connected into a long trough. A pipe that carries water is placed in the center of this trough so that sunlight falling on the reflective material is focused onto the pipe, heating the contents.

These are very high powered collectors and are thus generally used to generate steam for Solar thermal power plants and are not used in residential applications. These troughs can be extremely effective in generating heat from the Sun, particularly those that can pivot, tracking the Sun in the sky to ensure maximum sunlight collection.

Line focusing collector





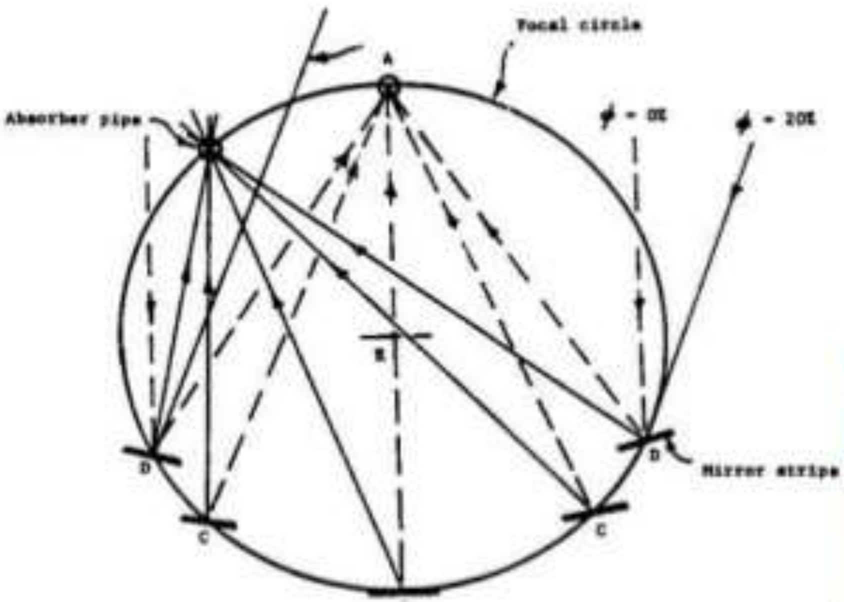
Linear Fresnel Lens Collector

Point focusing collector

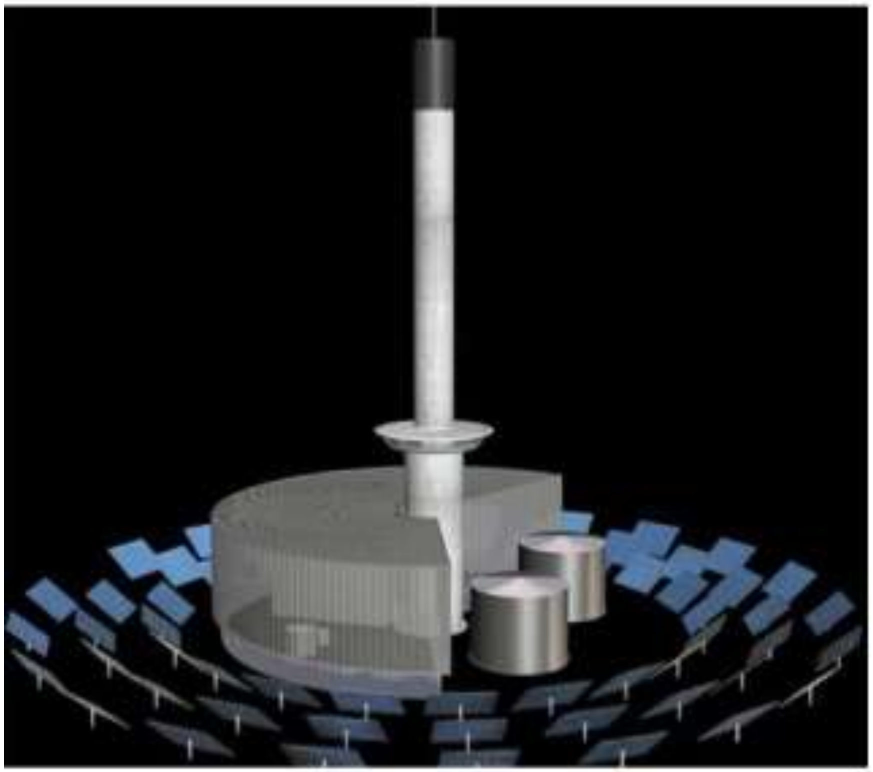
- These collectors are large parabolic dishes composed of some reflective material that focus the Sun's energy onto a single point. Although very effective at collecting sunlight, they must actively track the Sun. These dishes can work alone or be combined into an array to gather even more energy from the Sun.
- Point focus collectors can also be utilized to concentrate solar energy for use with Concentrated photovoltaics. In this case, instead of producing heat, the Sun's energy is converted directly into electricity with high efficiency photovoltaic cells designed specifically to harness concentrated solar energy.

Parabolic Dish Collector

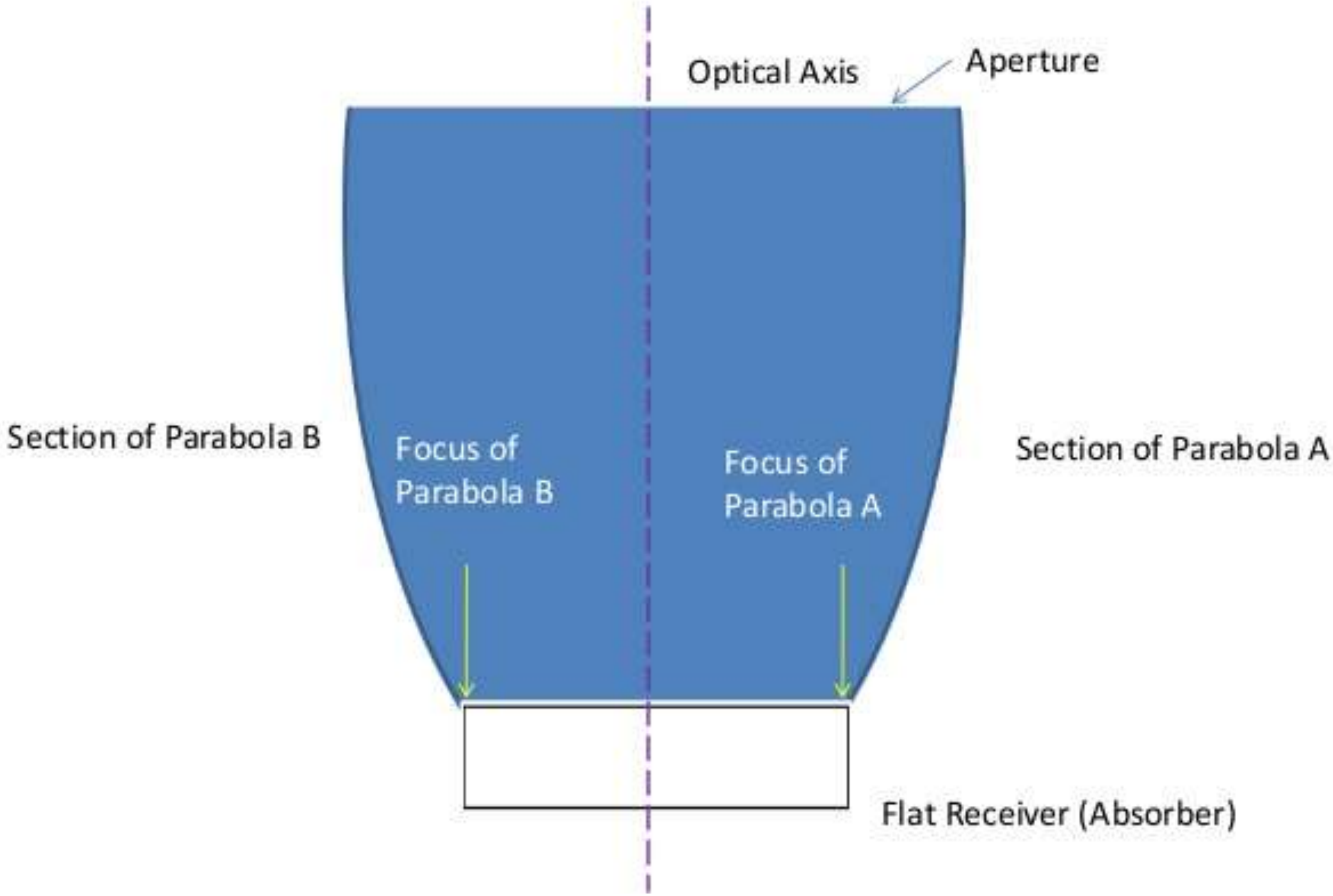
Fixed Mirror Solar Concentrator



Central Tower Receiver



Compound Parabolic Concentrator



Performance Indices

- Collector efficiency: Ratio of the energy actually absorbed and transferred to the heat-transport fluid by the collector (useful energy) to the energy incident on the collector.
- Concentration ratio: ratio of the area of aperture of the system to the area of the receiver. Aperture of the system is the projected area of the collector facing the beam.
- Temperature range: range of temperature to which the heat-transport fluid is heated up by the collector.

Applications of solar collectors

Solar Water Heater

Swimming pool 23 -28˚C
Domestic hot water 45-60 ˚C
Space heating 30-90 ˚C

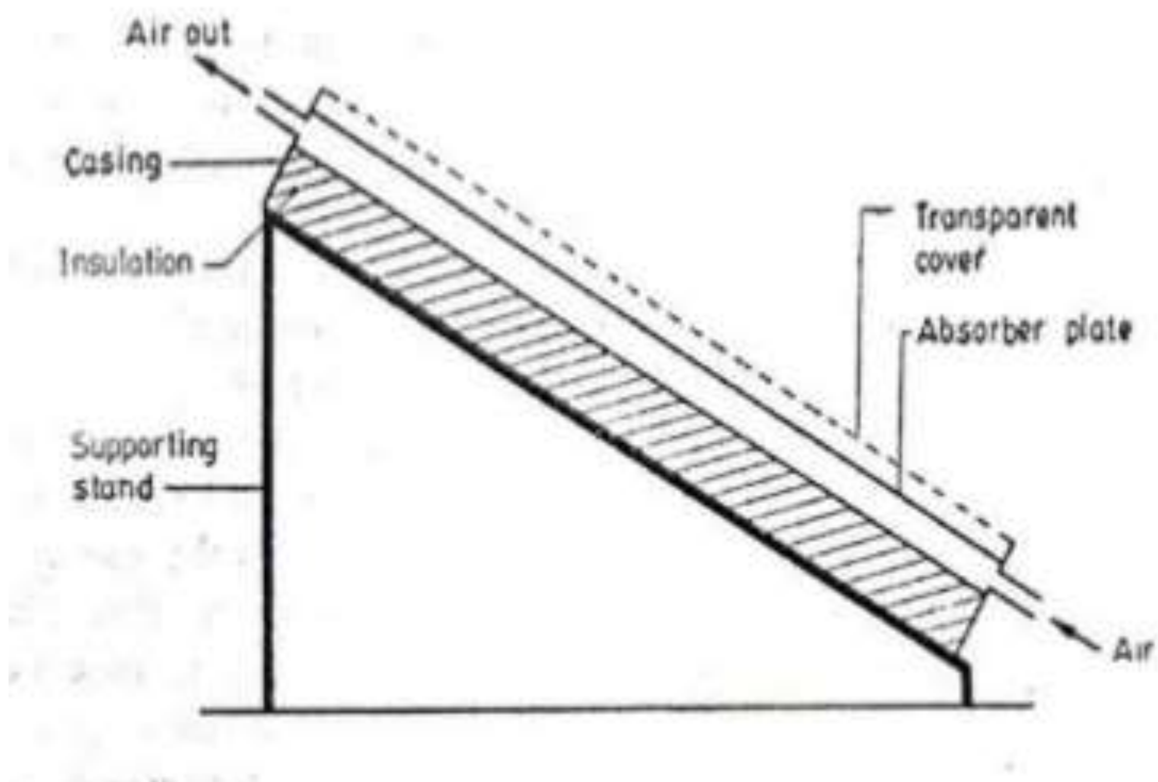
Solar Air Heater

- The heat absorbed by the absorber plate is transmitted to the air drawn into the collector.

- If the size of collector is large, a blower is used to draw air into the collector and transmit the hot air to dryer.

Application of Solar Air Heater

- Heating building
- Drying agricultural produce
- Heating green house



Passive Method Of Space Heating

- Space heating gives a fair degree of comfort by adopting passive method.
- A passive method is one in which thermal energy flows through a living space by natural means without the help of a mechanical device like a pump or blower.

Active Method Of Space Heating

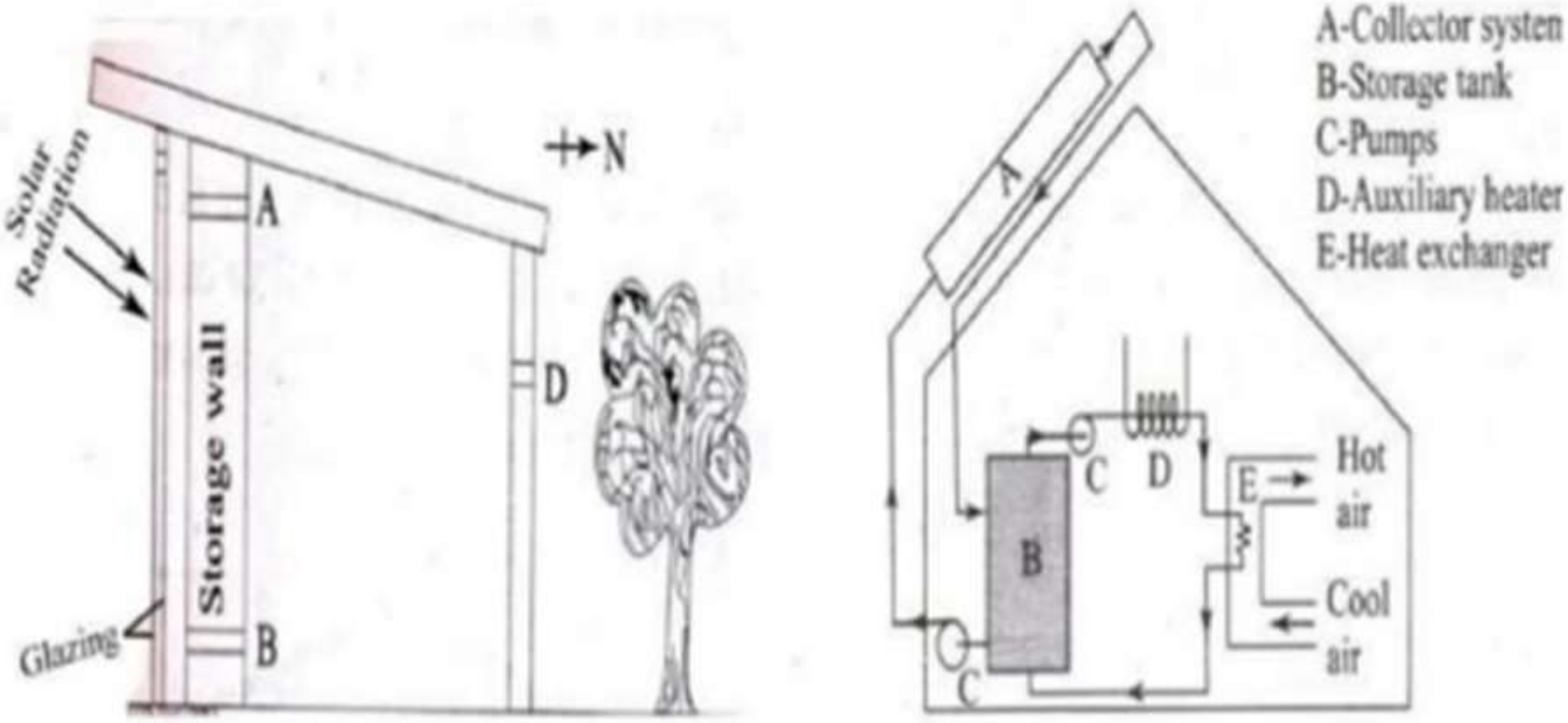
- Space heating system mainly consists of an array of collectors arranged on the roof of a building, insulated storage tank, auxiliary heater, pump/blower and heat exchanger.
- Liquid/air gets heated up in the flat plate collectors.
- The hot fluid passes to storage tank.
- The fluid from storage tank is transmitted by pump/blower to heat exchanger.

- The heat exchanger blows out hot air and heats up the surrounding living space in the building.

- Again the cool air/water passes to the storage tank, which is supplied to flat plate collectors for heating.

- In the absence of solar energy, an auxiliary heater is used for space heating.

Passive and active space heating system



Focusing type collectors for space heating

Lect.-8
Solar Thermal applications in different gadgets.

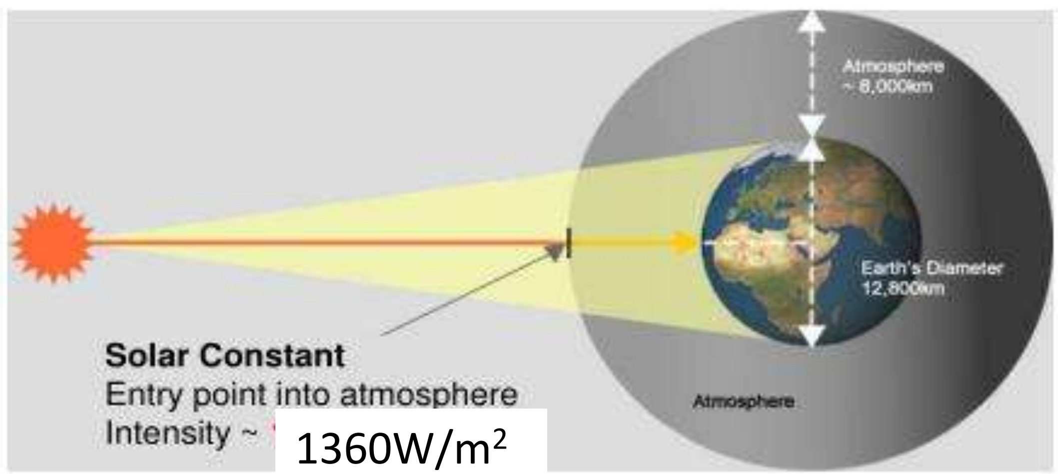
Solar thermal energy is a technology for harnessing solar energy for heat or generating electricity. For the purpose solar thermal collectors are used. These collectors may be classified as Low, medium or High-temperature collectors. Low temperature collectors are flat-plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat-plates but are used for heating water or air for residential and commercial use. High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production.

Physics of Solar Thermal

- The solar constant – $S=1360W/m^2$.
- Portion of light that appears to come straight from the sun – **direct radiation.**
- On a clear day, this can approach a power density of 1 kilowatt per square meter **($1\ kWm^{-2}$).**
- Practical peak power densities are around 900 – 1000 watts per square meter.

Solar Constant

- Amount of incoming solar radiation per unit area incident on a plane perpendicular to the rays.
- At a distance of one 1AU from the sun (roughly the mean distance from the Sun to the Earth).
- Includes a range of wavelength (not just the visible light).



Solar Collectors

Lesson -8

/energyinformative.org/wp-content/uploads/2012/04/solar-thermal-collectors.jp

http://blog.hasslberger.com/img/concentrated-solar-power.jpg

Stationary Collector Types

- 1. Flat plate collectors (FPC);
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Solar energy collectors

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (°C)
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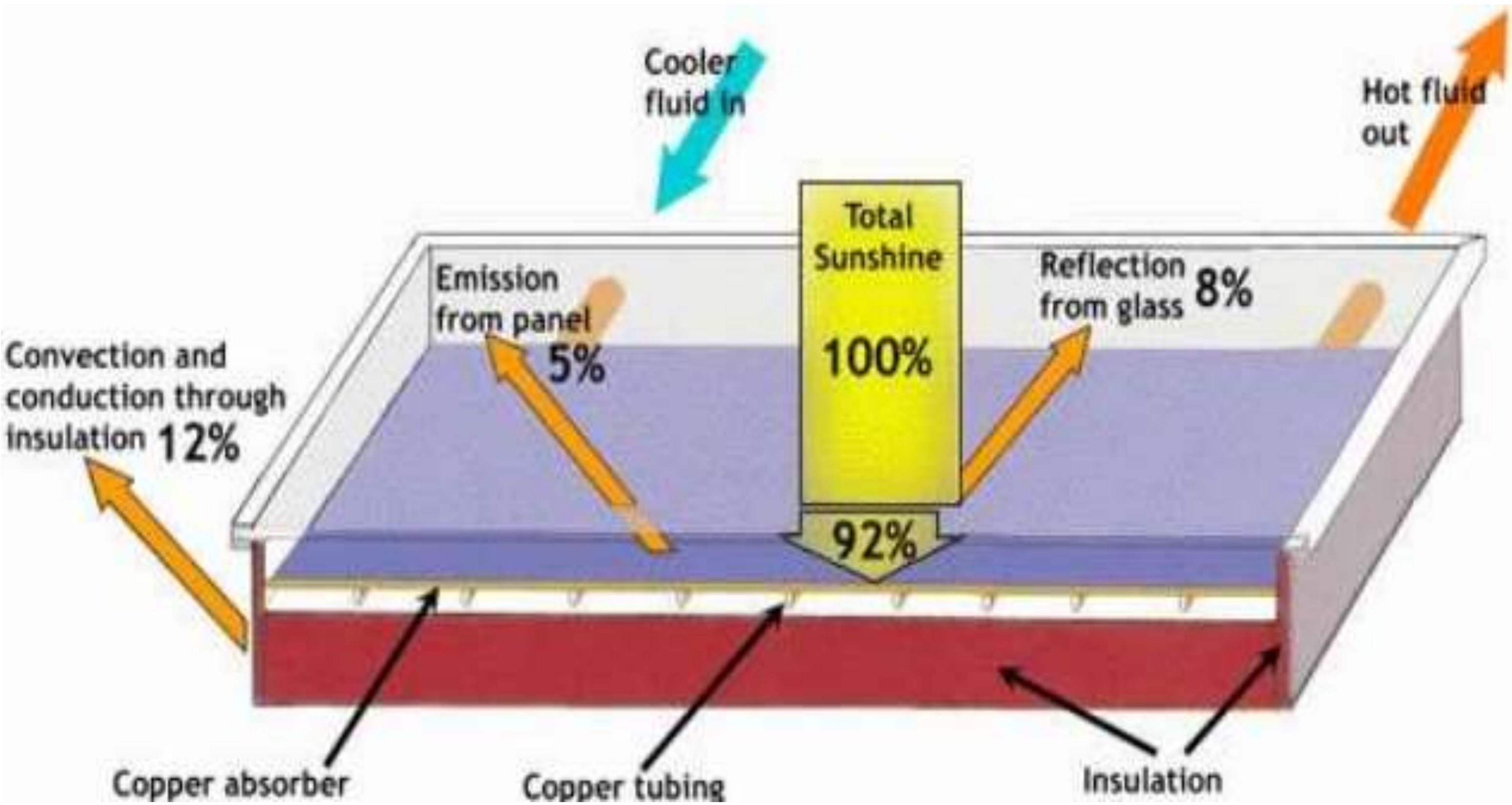
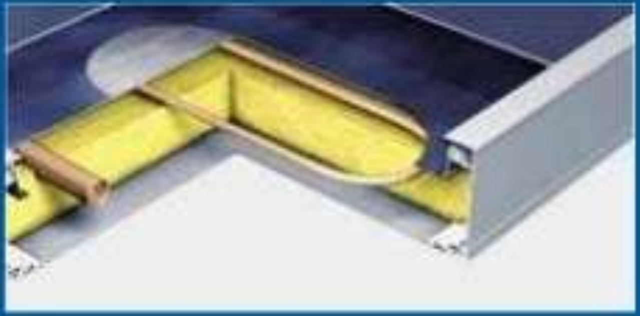
Working of flat plate collector



Opperating temperature

Low temperature applications up to 100˚C.

200˚C can be achieved due to highly selective coatings



. Evacuated Tube Collectors (ETC)

Evacuated Tube Collectors

Evacuated collectors consist of a heat pipe inside a vacuum-sealed tube.

Good performance at high temperatures.

Collectors can operate at higher temperatures than FPC.

Eefficiency is higher at low incidence angles than FPC.

Electricity is generated from solar thermal energy.

Solar thermal power plants use the sun's rays to heat a fluid to high temperatures. The fluid is then circulated through pipes so that it can transfer its heat to water and produce steam.

The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity.

CST and CSP

High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for fulfilling heat requirements up to 300^{o} C / 20 bar pressure in industries, and for electric power production.

Two categories include Concentrated Solar Thermal (CST) for fulfilling heat requirements in industries, and Concentrated Solar Power (CSP) when the heat collected is used for power generation. CST and CSP are not replaceable in terms of application.

Solar Thermal Systems

There are two types of solar thermal systems:

Passive: A passive system requires no equipment, like when heat builds up inside your car when it's left parked in the sun.

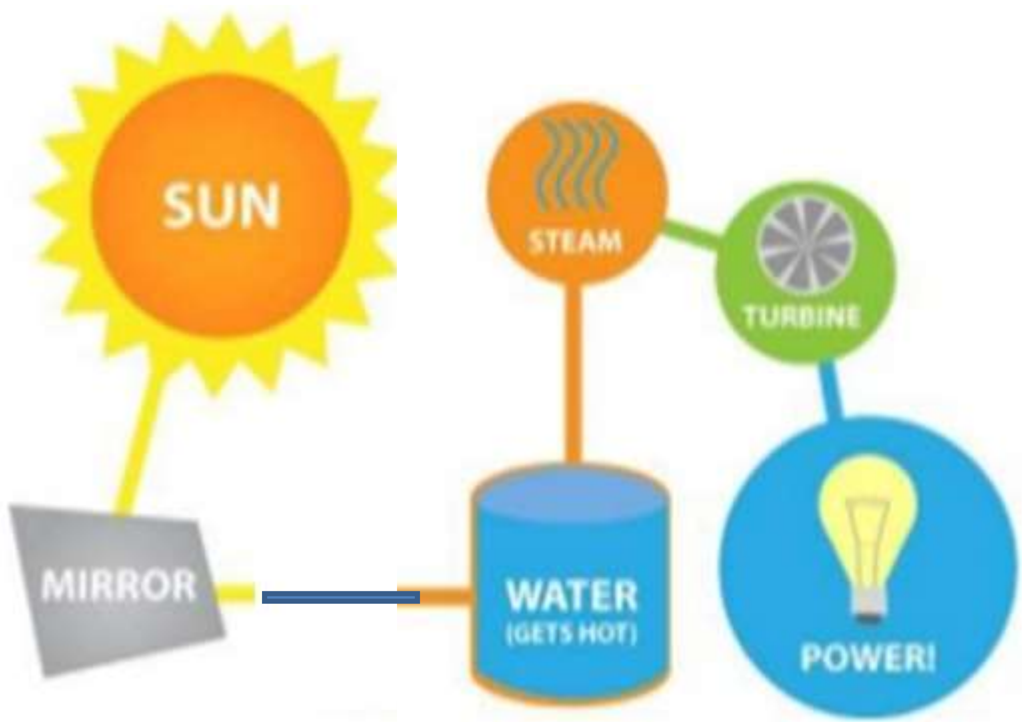
e.g. Thermal chimneys

Active : An active system requires some way to absorb and collect solar radiation and then store it.

e.g. Solar thermal power plants

Basic Working Principle

- Mirrors reflect and concentrate sunlight.
- Receivers collect that solar energy and convert it into heat energy.
- A generator can then be used to produce electricity from this heat energy.

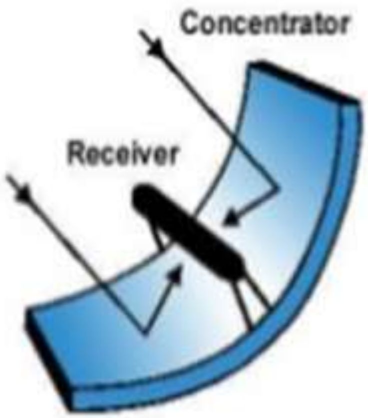


Thermal energy storage (TES)

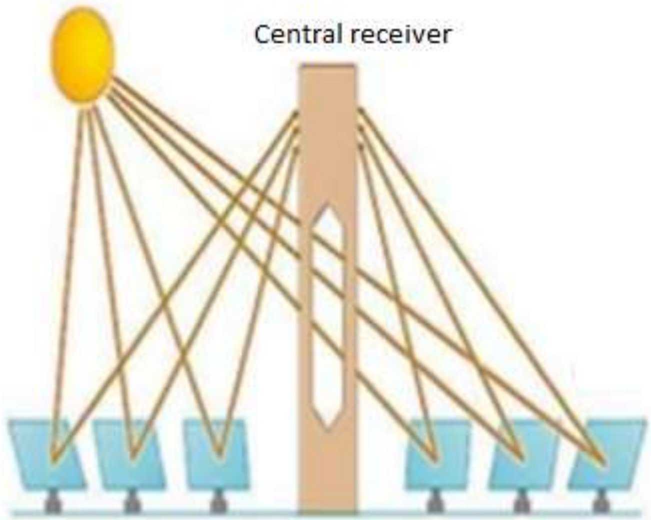
TES are high-pressure liquid storage tanks used along with a solar thermal system to allow plants to bank several hours of potential electricity.

- **Two-tank direct system**: solar thermal energy is stored right in the same heat-transfer fluid that collected it.
- **Two-tank indirect system**: functions basically the same as the direct system except it works with different types of heat-transfer fluids.
- **Single-tank thermocline system**: stores thermal energy as a solid, usually silica sand.

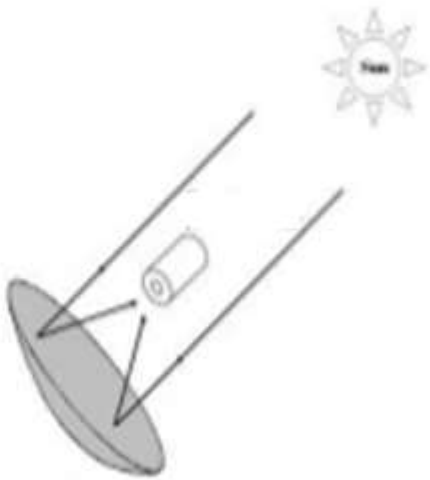
Types of Solar Thermal Power Plants



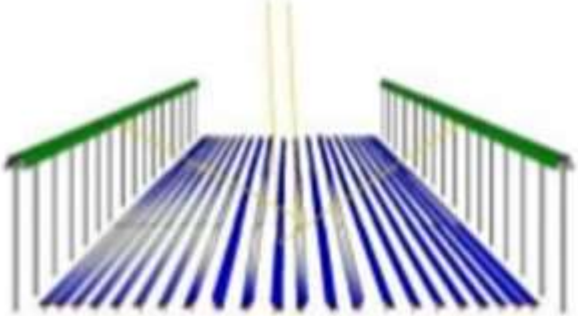
Parabolic trough system



Solar power tower systems



Solar dish/engine system

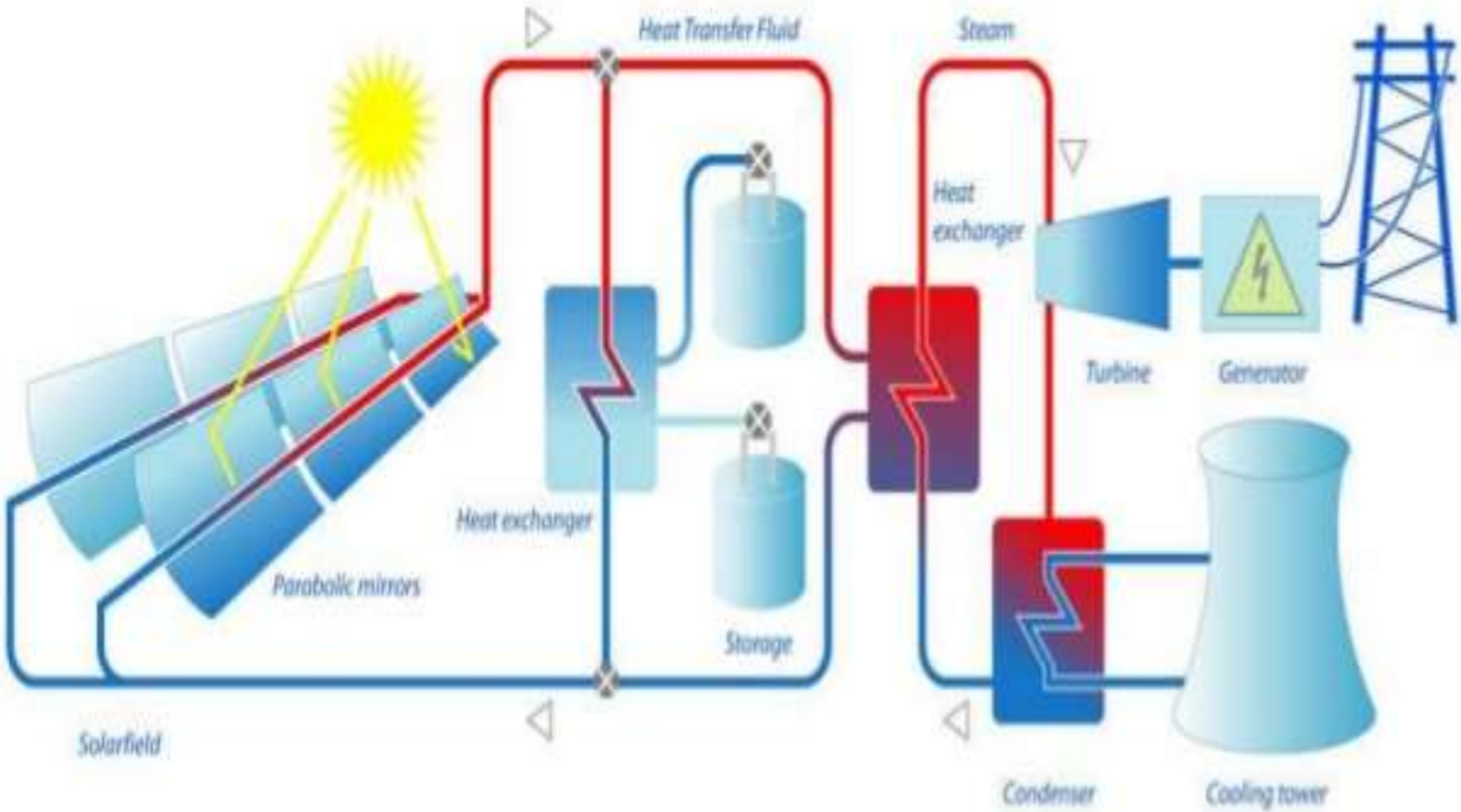


Compact linear Fresnel reflector

Parabolic Trough System

Parabolic trough System

- A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line.
- The receiver is a tube positioned directly above the middle of the parabolic mirror and filled with a working fluid.
- The reflector follows the sun during the daylight hours by tracking along a single axis.
- A working fluid (e.g. molten salt) is heated to 150–350 °C (423–623 K (302–662 °F)) as it flows through the receiver and is then used as a heat source for a power generation system.



Heat Transfer Fluid
Steam
Heat exchanger
Turbine
Generator
Heat exchanger
Parabolic mirrors
Storage
Solarfield
Condenser
Cooling tower

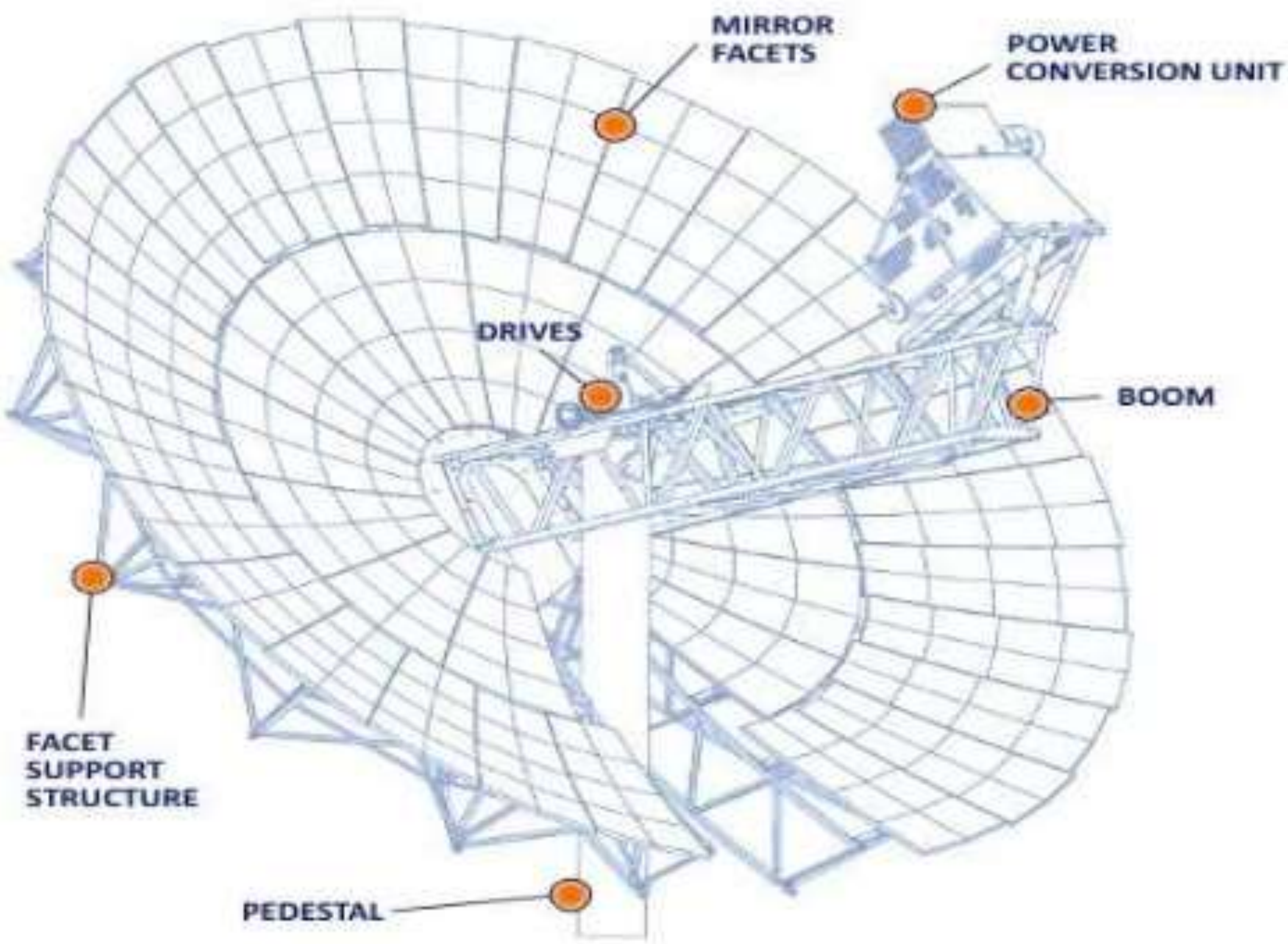
Solar Power Tower System

Solar power tower systems

- Power towers (also known as 'central tower' power plants or 'heliostat' power plants).
- These designs capture and focus the sun's thermal energy with thousands of tracking mirrors (called heliostats) in roughly a two square mile field.
- A tower resides in the center of the heliostat field. The heliostats focus concentrated sunlight on a receiver which sits on top of the tower.
- Within the receiver the concentrated sunlight heats molten salt to over 1,000 °F (538 °C).
- The heated molten salt then flows into a thermal storage tank where it is stored, maintaining 98% thermal efficiency, and eventually pumped to a steam generator.
- The steam drives a standard turbine to generate electricity.

Solar Dish/Engine System

Solar Dish/Engine System



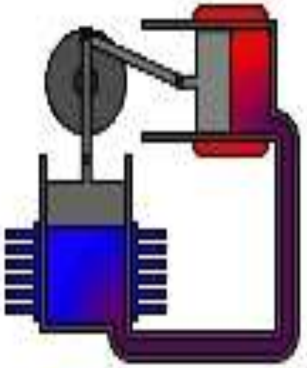
Solar dish/engine system

The system consists of a stand-alone parabolic reflector that concentrates light onto a receiver positioned at the reflector's focal point.

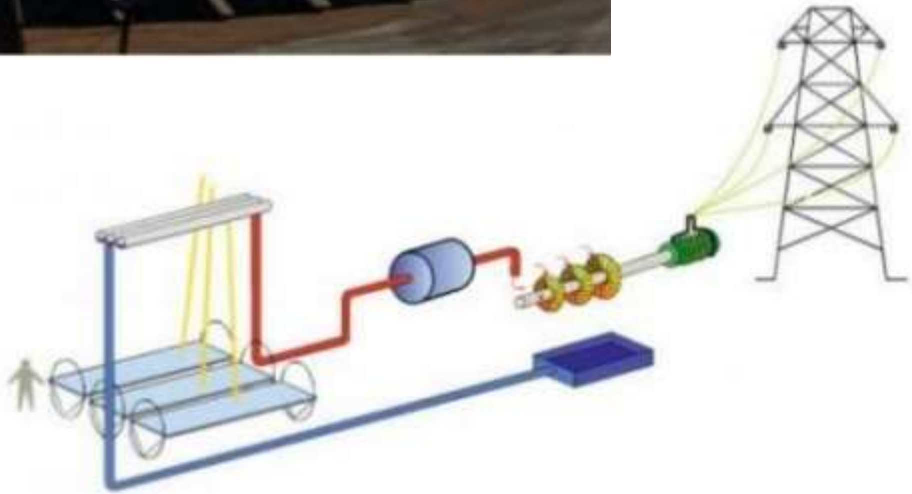
The working fluid in the receiver is heated to 250–700 °C (523–973 K (482–1,292 °F)) and then used by a Stirling engine to generate power.

Parabolic-dish systems have the highest efficiency of all solar technologies provide solar-to-electric efficiency between 31–32%.

Stirling Engine →



Compact Linear Fresnel Reflector



Compact linear Fresnel reflector

- Linear Fresnel reflectors use long, thin segments of mirrors to focus sunlight onto a fixed absorber located at a common focal point of the reflectors.
- These mirrors are capable of concentrating the sun's energy to approximately 30 times its normal intensity.
- This concentrated energy is transferred through the absorber into some thermal fluid.
- The fluid then goes through a heat exchanger to power a steam generator.

Major Challenges

- The major challenge are the Installation Cost and energy storage.
- The costs are still far higher than fossil fuel plants based on units of energy produced.
- The hot water storage products are often stretched to their limits.
- Alternatives could be phase change materials (PCMs) or thermo-chemical materials (TCMs).
- In addition to sensible heat, the technologies of latent heat and thermo-chemical energy storage are on their way to becoming very promising solutions for the future of solar heating and cooling.

Cooking


Box type solar cooker

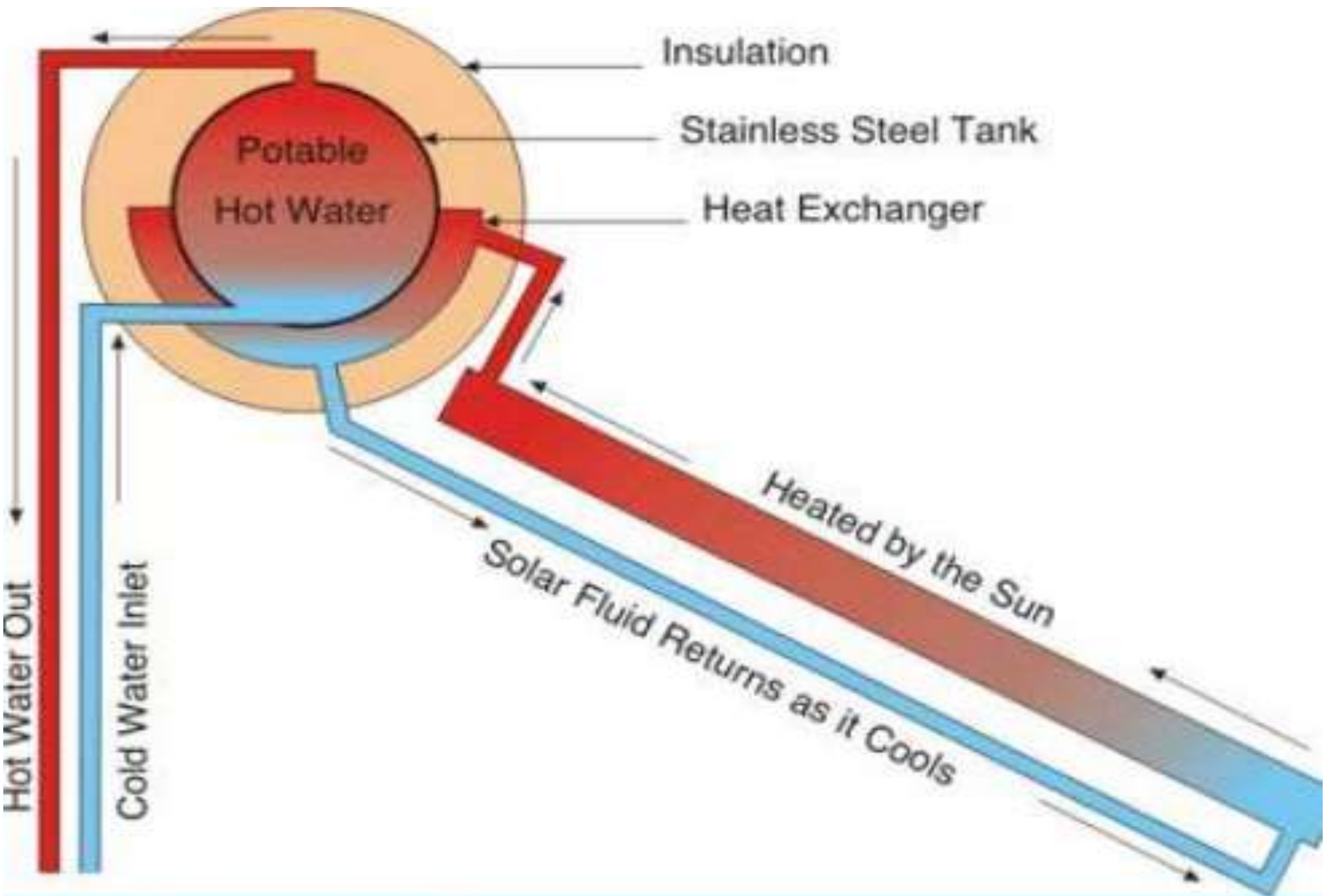

Panel type solar cooker


Parabolic type solar cooker


Solar oven

Water heating

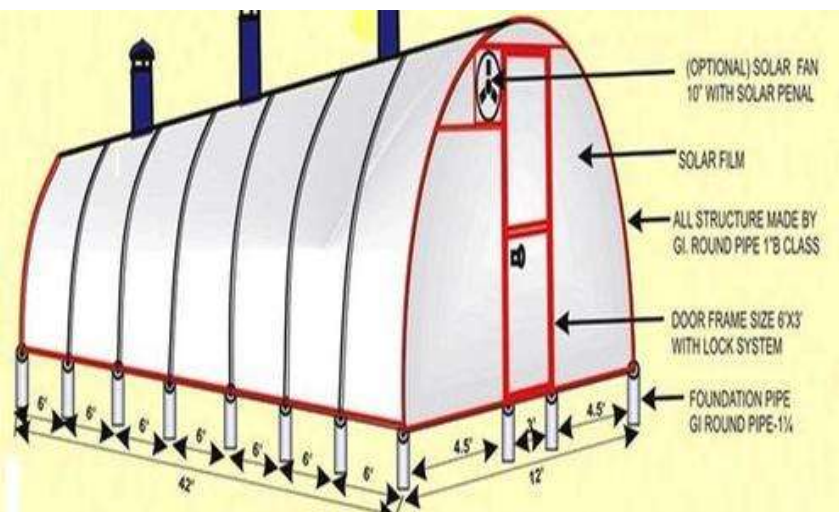
Thermosyphon Systems



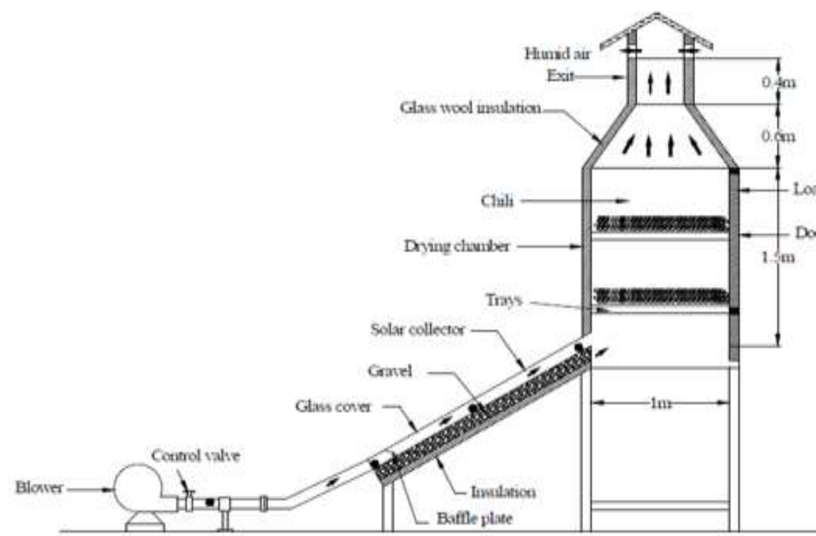
Drying

Direct heating

In direct heating

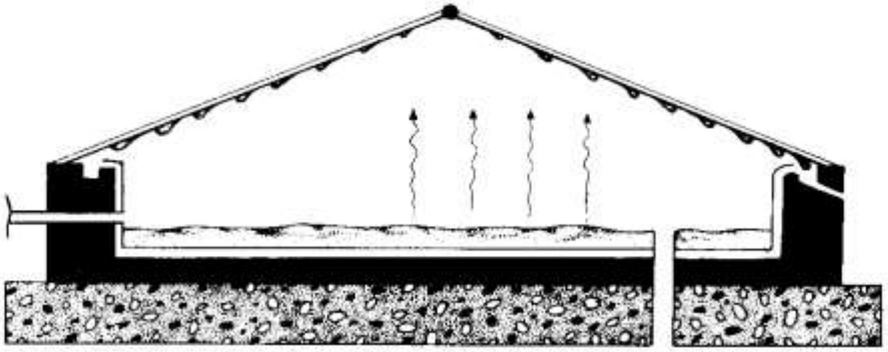


Solar tunnel dryer



Forced convection solar dryer

Solar Distillation Plants



solar still

Solar energy heats up the water in the still. The water then evaporates and condenses on the bottom of the covering glass.

Solar stills can be used to make drinking water in areas where clean water is not common. Solar distillation is necessary in these situations to provide people with purified water.

Soil Solarization

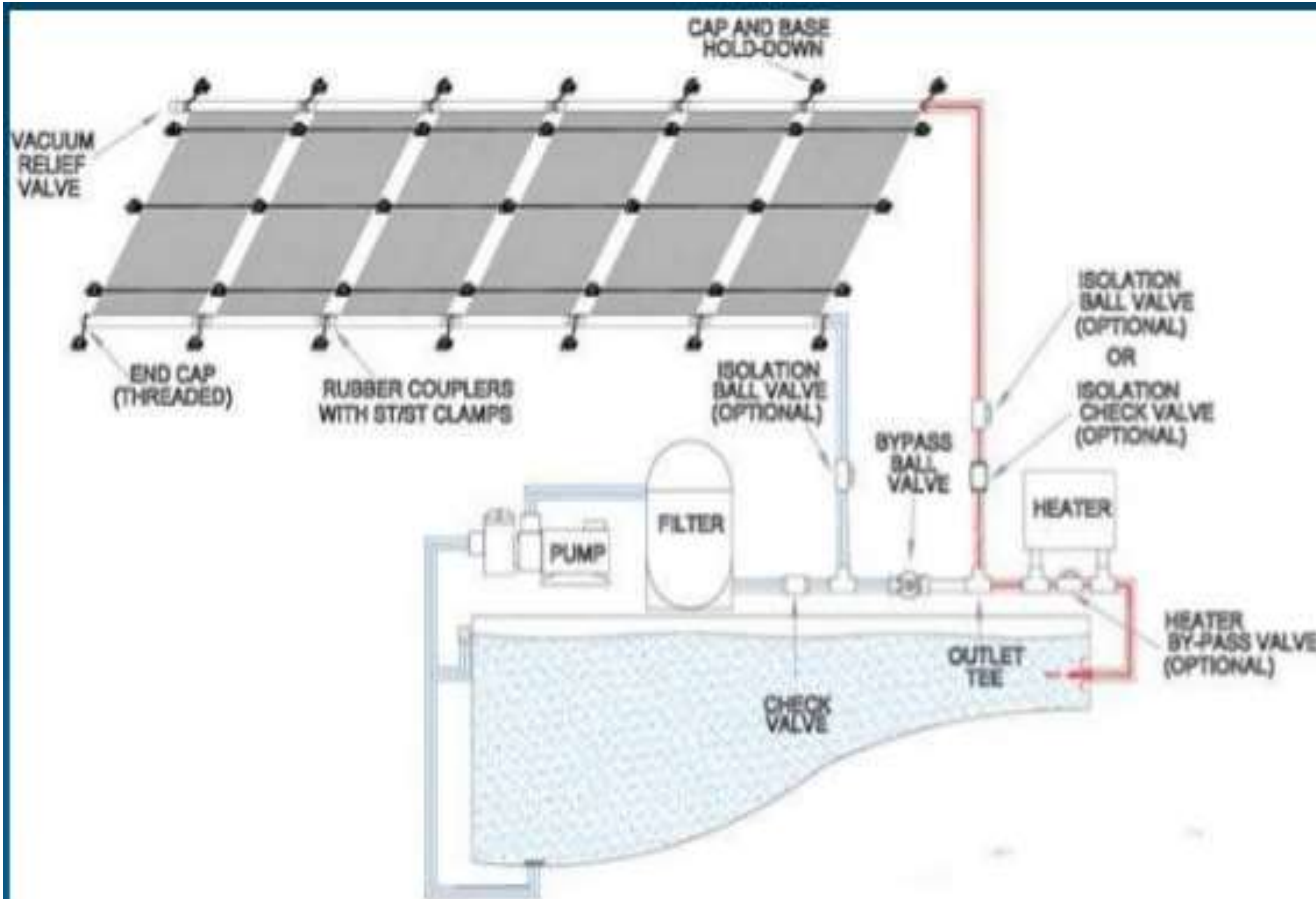
Soil solarization

- Soil solarization is a nonchemical method for controlling soil borne pests using high temperatures produced by capturing radiant energy from the sun.
- The method involves heating the soil by covering it with clear plastic for four to six weeks during a hot period of the year and when the soil will receive the most direct sunlight. Plastic covers allow the sun's radiant energy to be trapped in soil, heating the top 12 to 18 inches to temperatures lethal to a wide range of soil borne pests; including weeds, plant pathogens, nematodes, and insects. When properly done, the top layers of soil will heat up to high temperature depending on the geographic location. Soil moisture is important in this process, as wet soil conducts heat better than dry soil. Moisture also makes soil pests, weakened by the heat, more vulnerable to attack by beneficial soil microorganisms during and after treatment. So the soil below the cover is kept at field capacity.

Solar Animal Feed Cooker

Solar Steam Generator for Steam Engine

Solar Pool Heating System


CAP AND BASE
HOLD-DOWN
VACUUM
RELIEF
VALVE
END CAP
(THREADED)
RUBBER COUPLERS
WITH ST/ST CLAMPS
ISOLATION
BALL VALVE
(OPTIONAL)
ISOLATION
BALL VALVE
(OPTIONAL)
OR
ISOLATION
CHECK VALVE
(OPTIONAL)
BYPASS
BALL
VALVE
HEATER
FILTER
PUMP
HEATER
BY-PASS VALVE
(OPTIONAL)
OUTLET
TEE
CHECK
VALVE

Plant photosynthesis (micro climate control)

Poly house

Glass house

Poly tunnel

Low tunnels

Lect.- 9

Solar photovoltaic techniques and applications

By - Er. J. K. Gaur
S.K.R.A.U., Bikaner

Photovoltaic

- Photovoltaics (PV) comprise the technology to convert sunlight directly into electricity. The term "photo" means light and "voltaic," electricity.
- A photovoltaic (PV) cell, also known as "solar cell," is a semiconductor device that generates electricity when light falls on it.
- When sunlight strikes a PV cell, the photons of the absorbed sunlight dislodge the electrons from the atoms of the cell. The free electrons then move through the cell, creating and filling in holes in the cell. It is this movement of electrons and holes that generates electricity.
- This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally.
- The solar photovoltaic system comprises of three main sub-systems, viz., solar panel, control unit and battery.

Photovoltaic effect

- The physical process in which a PV cell converts sunlight into electricity is known as the photovoltaic effect.
- One single PV cell produces up to 2 watts of power, too small even for powering pocket calculators or wristwatches.
- To increase power output, many PV cells are connected together to form modules, which are further assembled into larger units called arrays.
- Photovoltaic (PV) cells are made of special materials called semiconductors such as silicon.
- The conversion efficiency for single-silicon commercial modules ranges between 15-20%.

- A complete PV system consists not only of PV modules, but also the “balance of system” (BOS) - the support structures, wiring, storage, conversion devices, etc.

  Two major types of PV systems are available:

  (i) Flat plate and (ii) concentrators.

- Flat plate systems build the PV modules on a rigid and flat surface to capture sunlight.
- Concentrator systems use lenses to concentrate sunlight on the PV cells and increase the cell power output.
- Comparing the two systems, flat plate systems are typically less complicated but employ a larger number of cells while the concentrator systems use smaller areas of cells but require more sophisticated and expensive tracking systems.

Gallium Arsenide (GaAs)

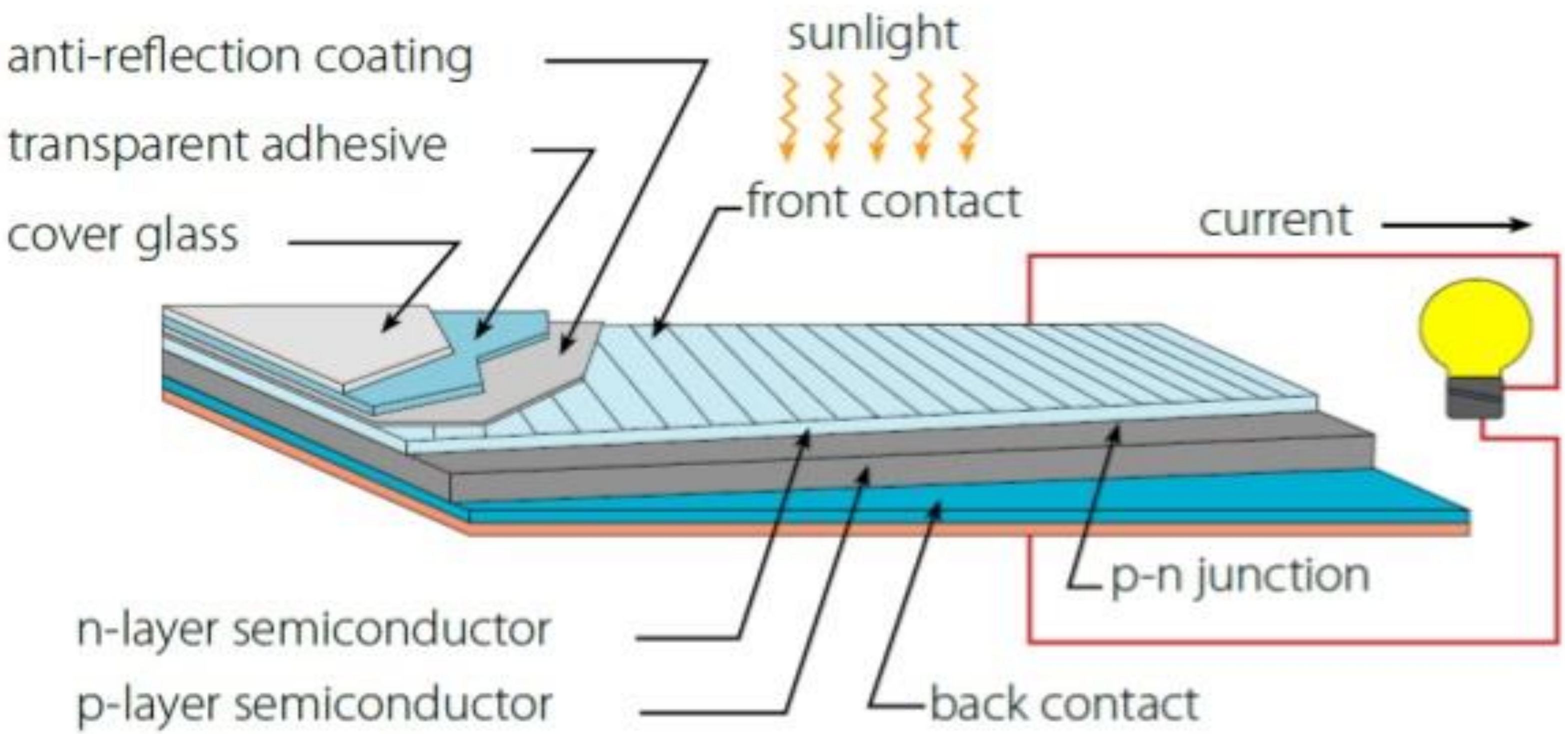
- It is a compound semiconductor made of two elements: gallium (Ga) and arsenic (As),
- GaAs has a crystal structure similar to that of silicon. An advantage of GaAs is that it has high level of light absorptivity.
- To absorb the same amount of sunlight, GaAs requires only a layer of few micrometers thick while crystalline silicon requires a wafer of about 200-300 micrometers thick.
- , GaAs has a much higher energy conversion efficiency than crystal silicon, reaching about 25 to 30%.
- Its high resistance to heat makes it an ideal choice for concentrator systems in which cell temperatures are high.
- GaAs is also popular in space applications where strong resistance radiation damage and high cell efficiency are required.

Amorphous Silicon (a-Si)

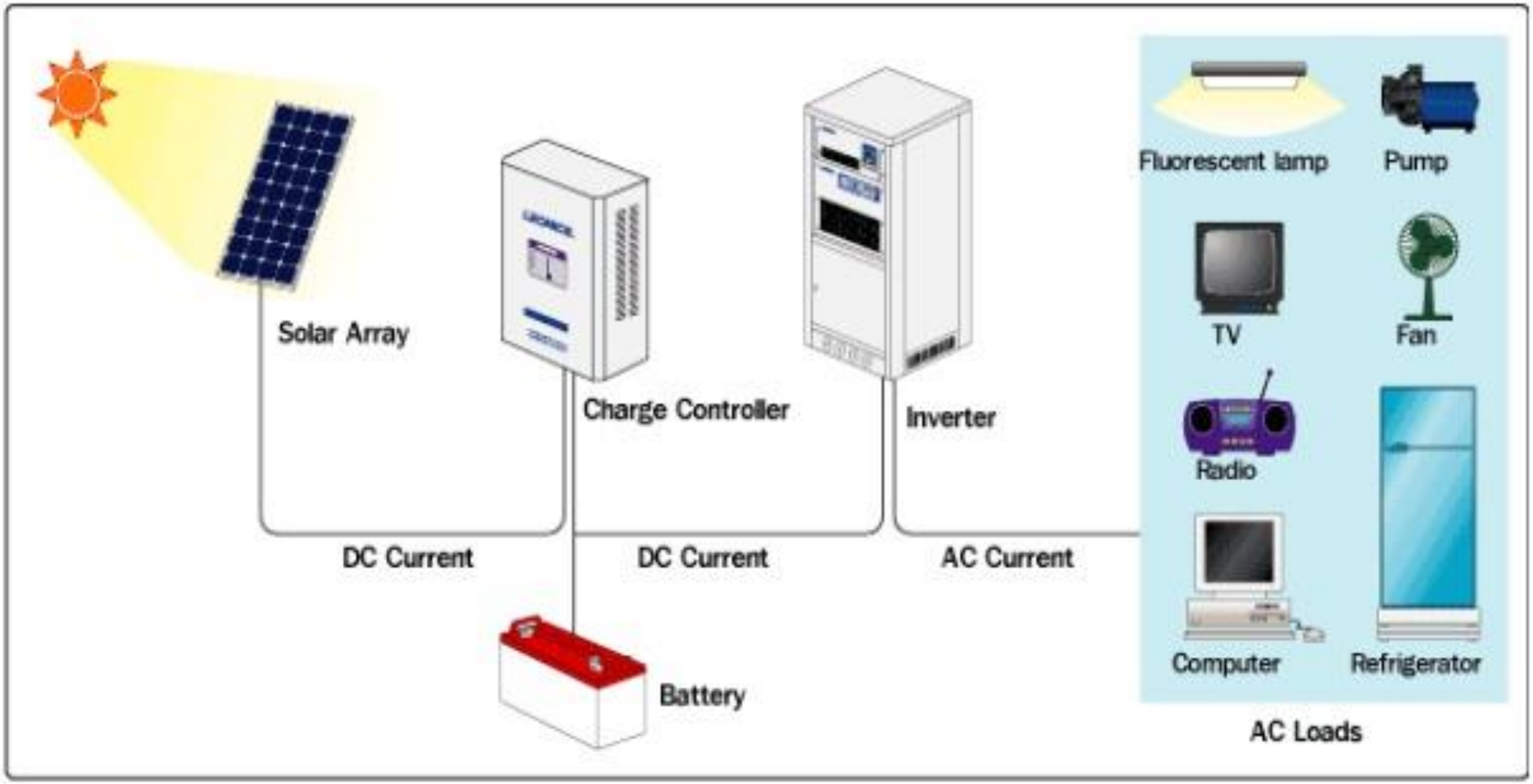
- Amorphous silicon is a non-crystalline form of silicon.
- It is used mostly in consumer electronic products which require lower power output and cost of production.
- Amorphous silicon has been the dominant thin-film PV material.
- A significant advantage of a-Si is its high light absorptivity, about 40 times higher than that of single-crystal silicon. Therefore only a thin layer of a-Si is sufficient for making PV cells (about 1 micrometer thick).

Cadmium Telluride (a polycrystalline semiconductor compound made of cadmium and tellurium**) and Copper Indium Diselenide (**A polycrystalline semiconductor compound of copper, indium and selnium) **are other options for solar cell.**

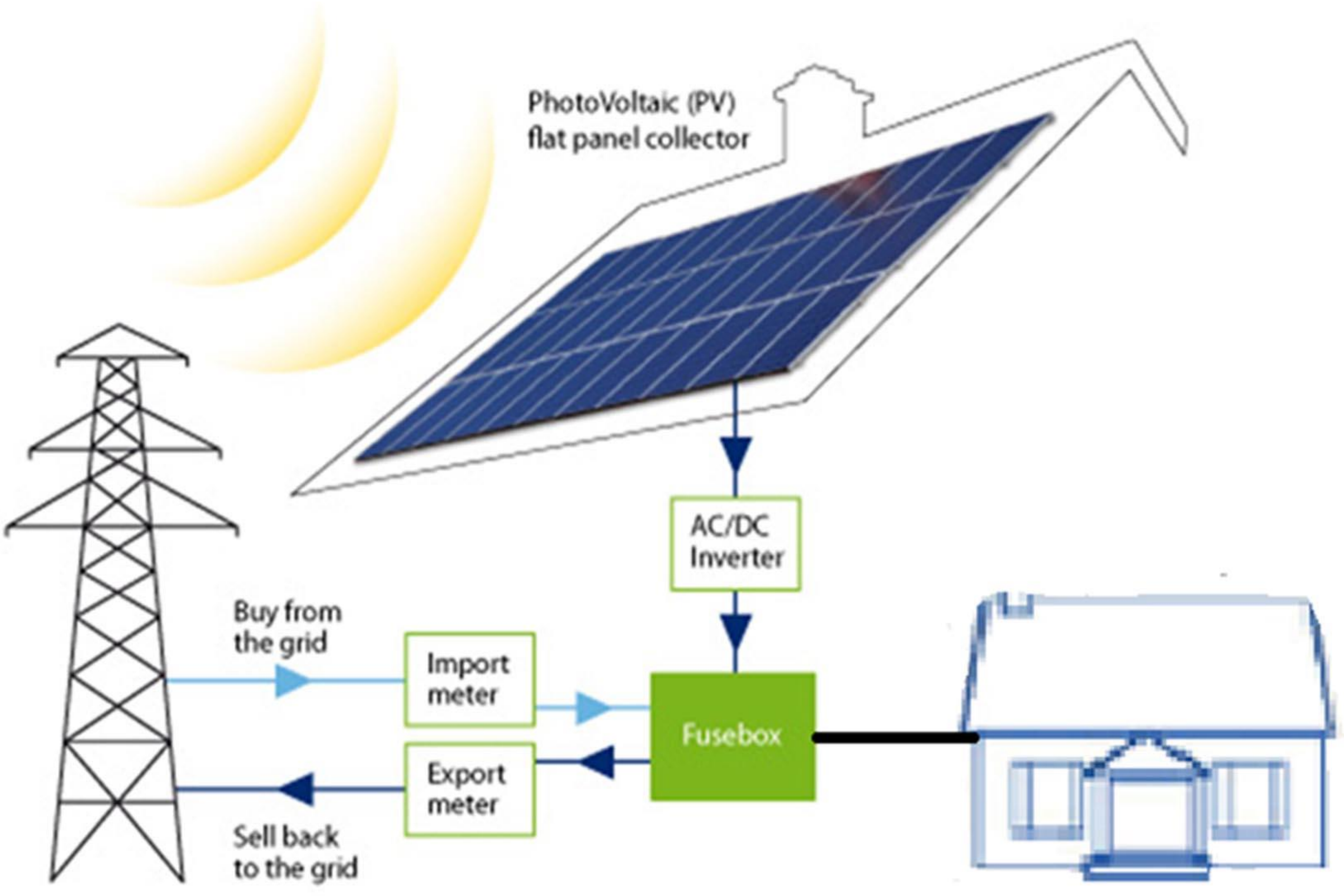
Structure of a Solar Cell



Stand Alone-off grid



Solar Photovoltaic on Grid System



Solar lantern

The solar lantern is a portable solar photovoltaic lighting system which provides about 2-3 hours of light per night based on the days charge.

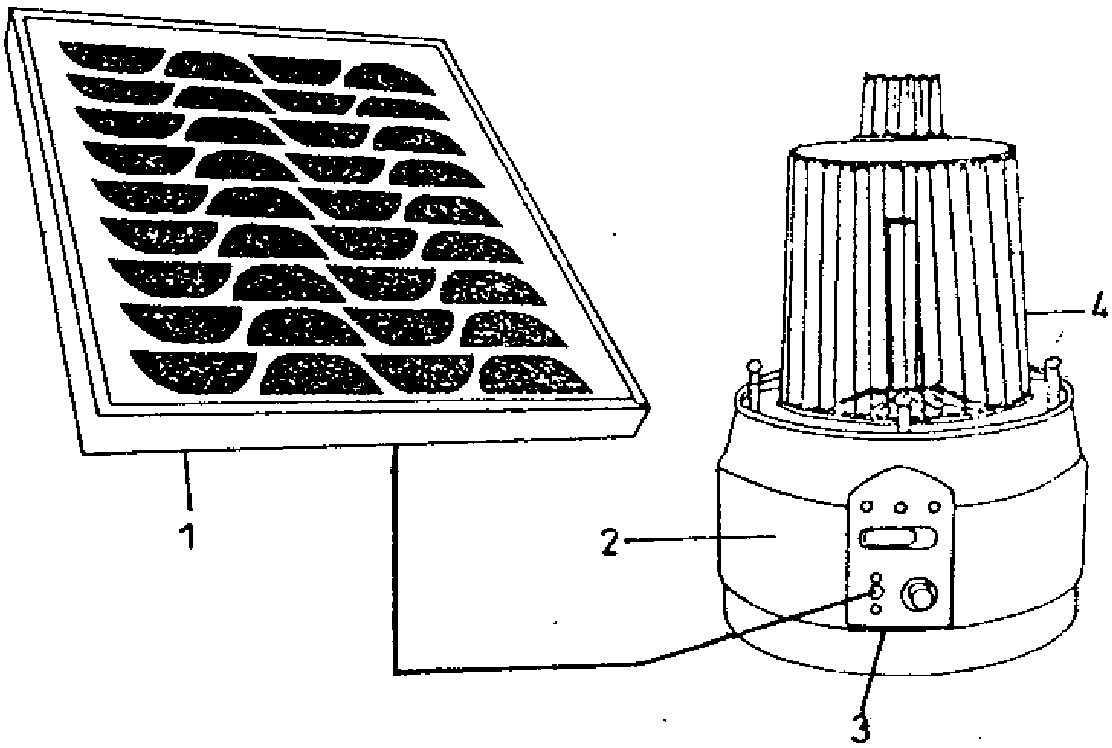
The lantern is designed to be similar to a hurricane lantern in its shape and about a hundred times brighter.

The system consists of 5 watt tube which is driven at a specially designed frequency choke / inverter operating at a frequency above 30 Khz.

As these lanterns are portable, a person as per his requirements and convenience can carry it.

The battery is a sealed maintenance free type.

Solar lantern



1.Solar module 2. Battery
3. Control circuits 4. Lamp

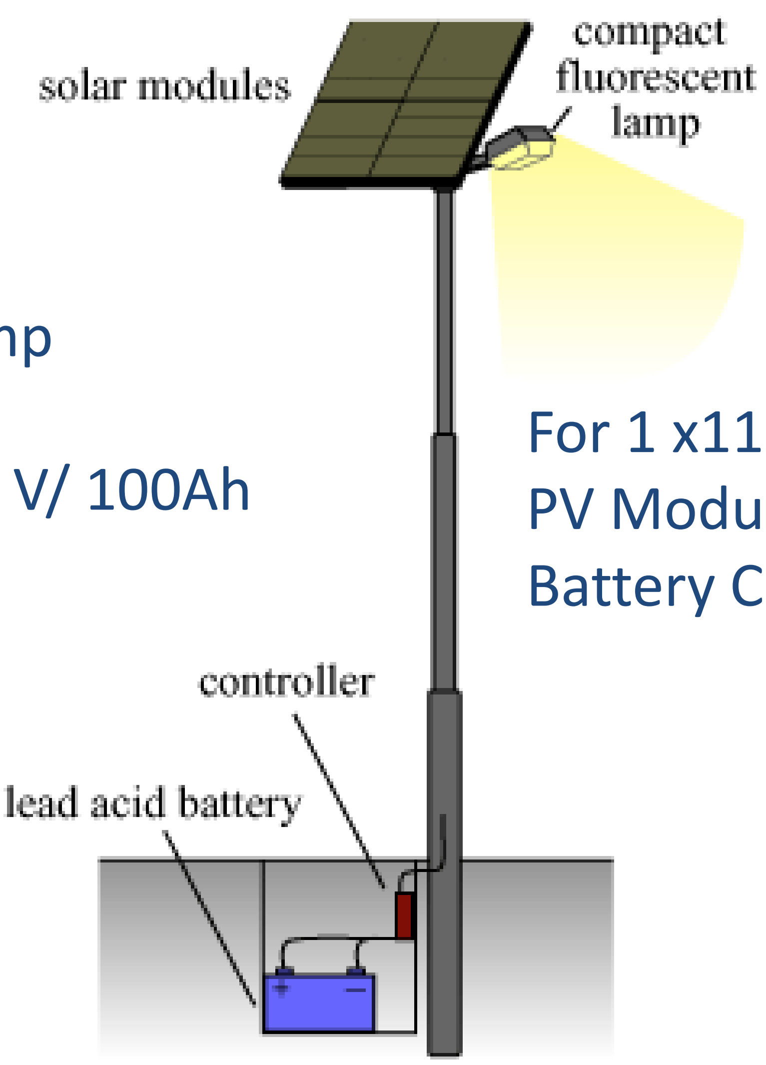
Solar water floating light

Solar wall mounted light

Solar lantern Cost

Solar lawn light

Solar Street Light



For 2 X 11 W CFL Lamp
PV Module : 120 Wp
Battery Capacity : 12 V/ 100Ah

For 1 x11 W CFL Lamp
PV Module : 74 Wp
Battery Capacity : 12 V/ 75Ah

Solar Green Houses based on photovoltaic Technology

Solar PV water pump

- Solar photovoltaic system operates on the basis of the photovoltaic effect on a silicon junction diode designed to facilitate the collection of usable magnitudes of electricity. Usually of the order of 1.5A at 0.5V.
- Such a junction diode is called a solar cell. Number of cells are string up in series to generate power at usable voltages.
- The system has to be optimized according to the load profile and the geographic location in which it is used.

Components of Solar PV pump

- A solar photovoltaic water pumping system, essentially consists of a SPV panel / array directly powering a water pump.
- The water pumped during the day can be stored in storage tanks for use during night.
- The generated electricity from the panel is fed to the pump through a switch and a 3 phase inverter, in case of AC submersible pumpset.
- Normally, no storage batteries are provided as the water can be stored in storage tanks, if required.

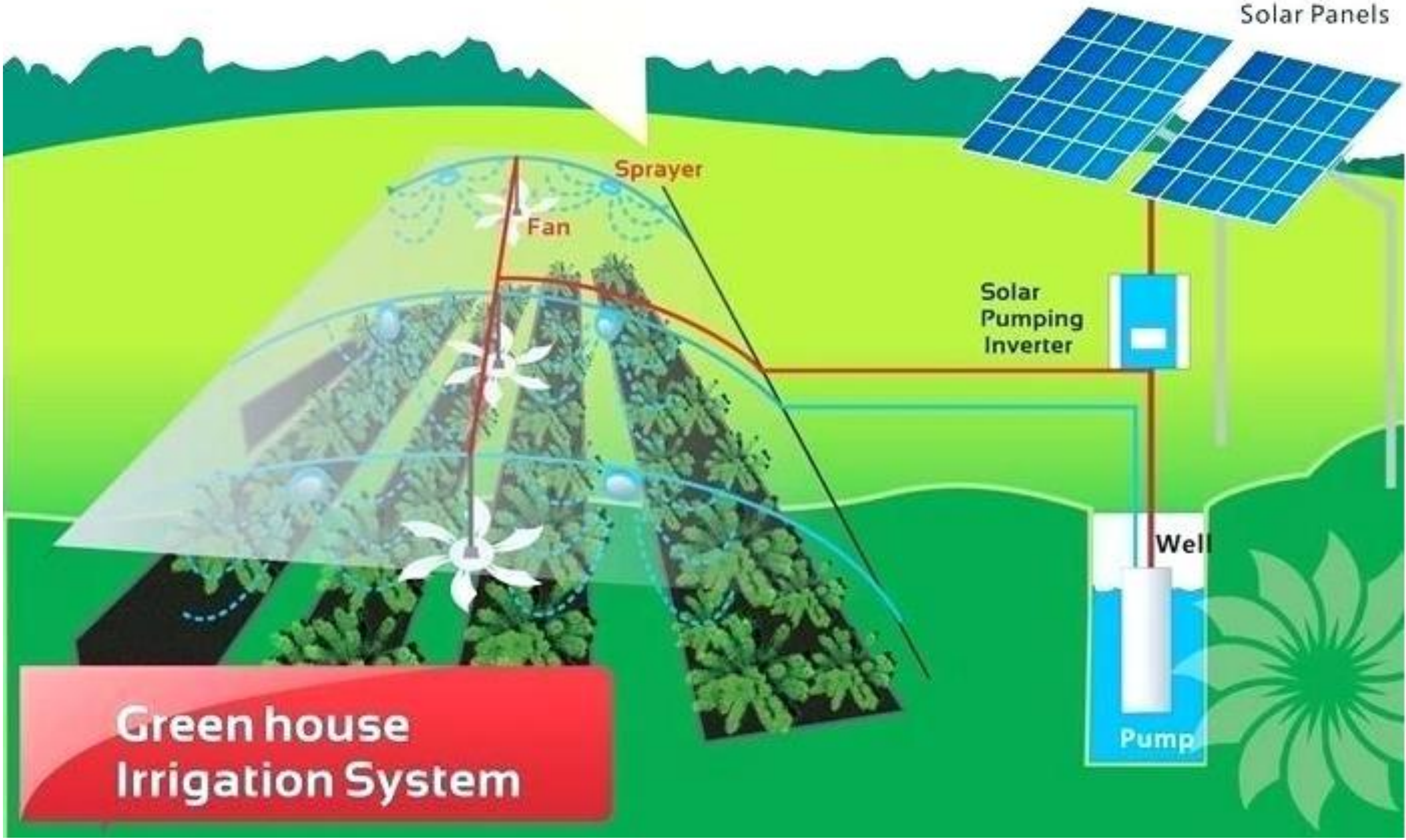
Solar water pumping system

Features :

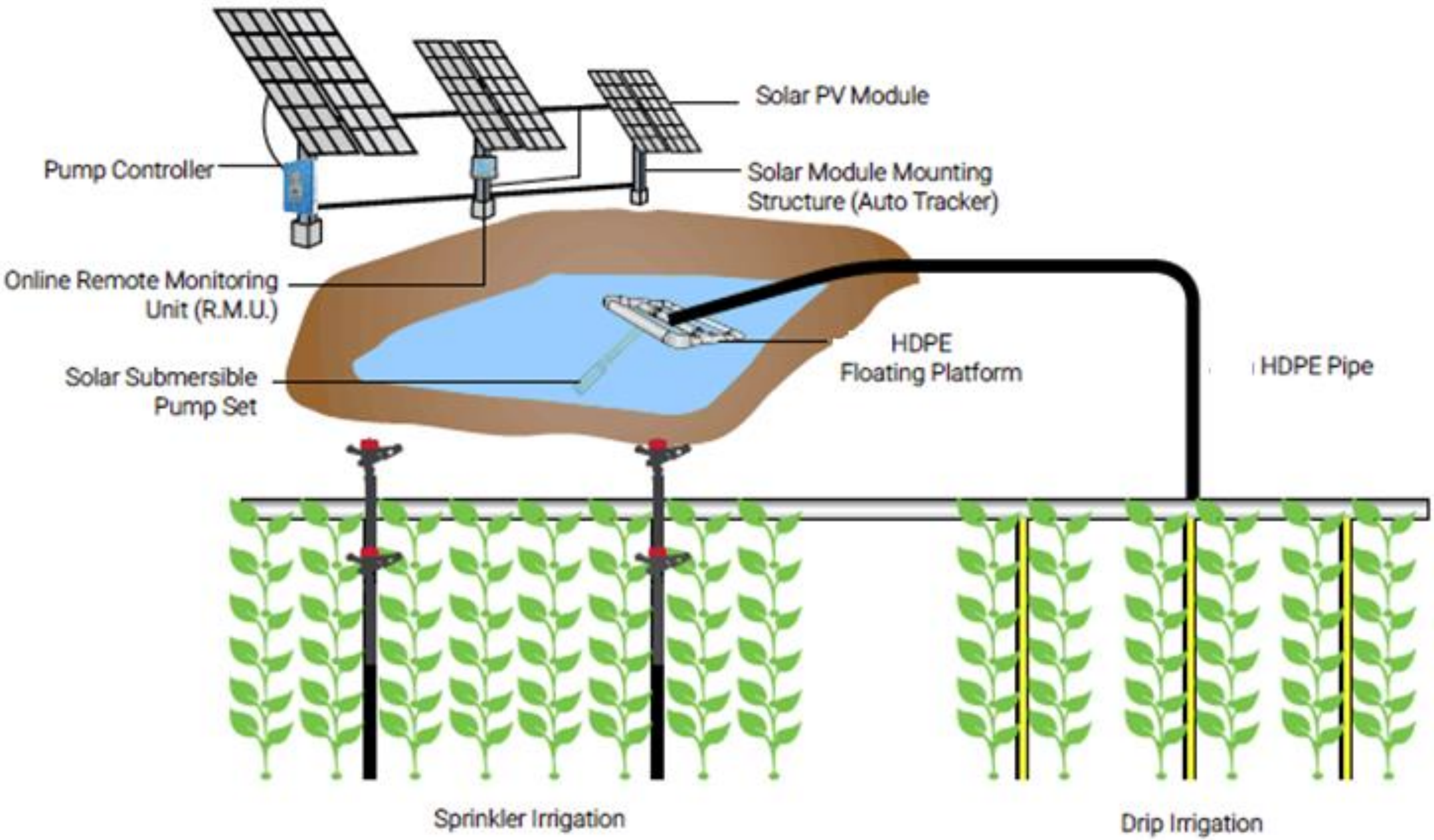
1. Noise and pollution free operation.
2. Does not require any fuel
3. Simple to install, operate and maintain.
4. Designed to give optimum output even during low sunshine period.

Photovoltaic pumping system specifications (Examples)

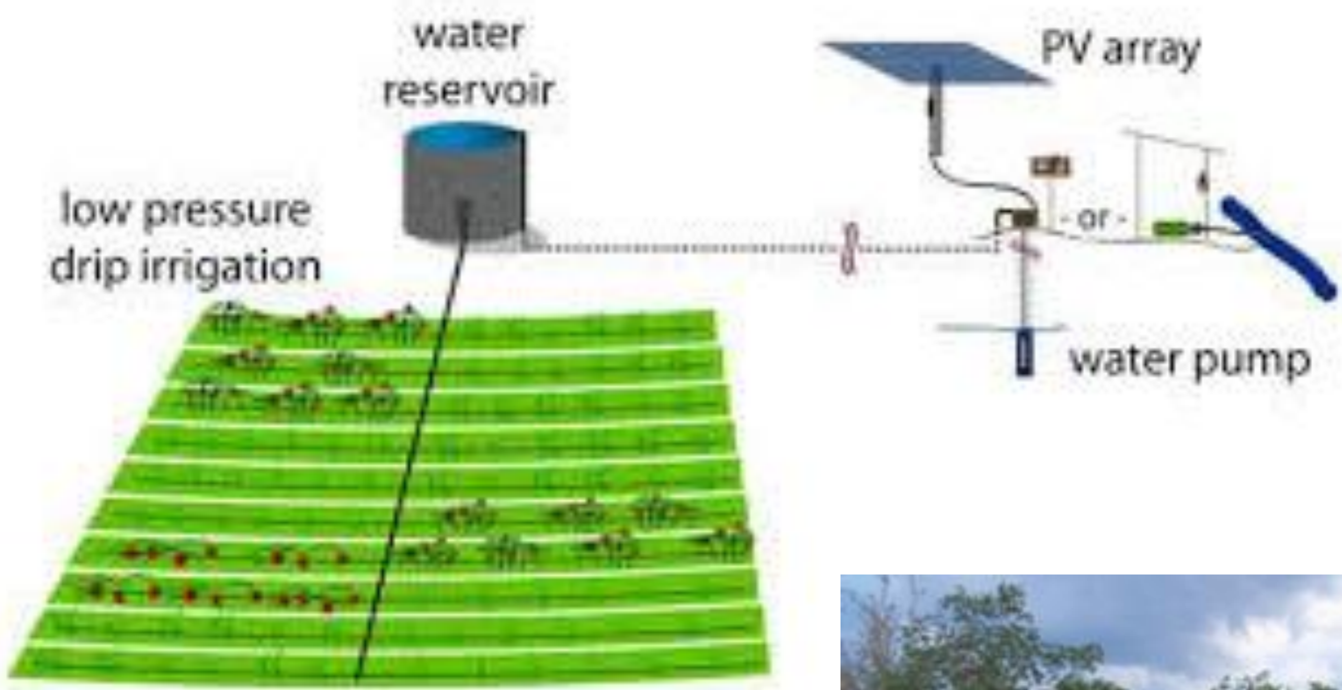
Motor pump/ Configuration	**Output (m^3.day)**	**Head (m)**	**Solar Array (Wp)**
Submerged borehole motor pump	40 25	20 20	1200 800
Surface motor/ submerged pump	60	7	840
Reciprocating positive displacement pump	6	100	1200
Floating motor/pumpset	100 10	3 3	530 85
Surface suction pump	40	4	350


Solar Panels
Sprayer
Fan
Solar
Pumping
Inverter
Well
Pump
Green house
Irrigation System

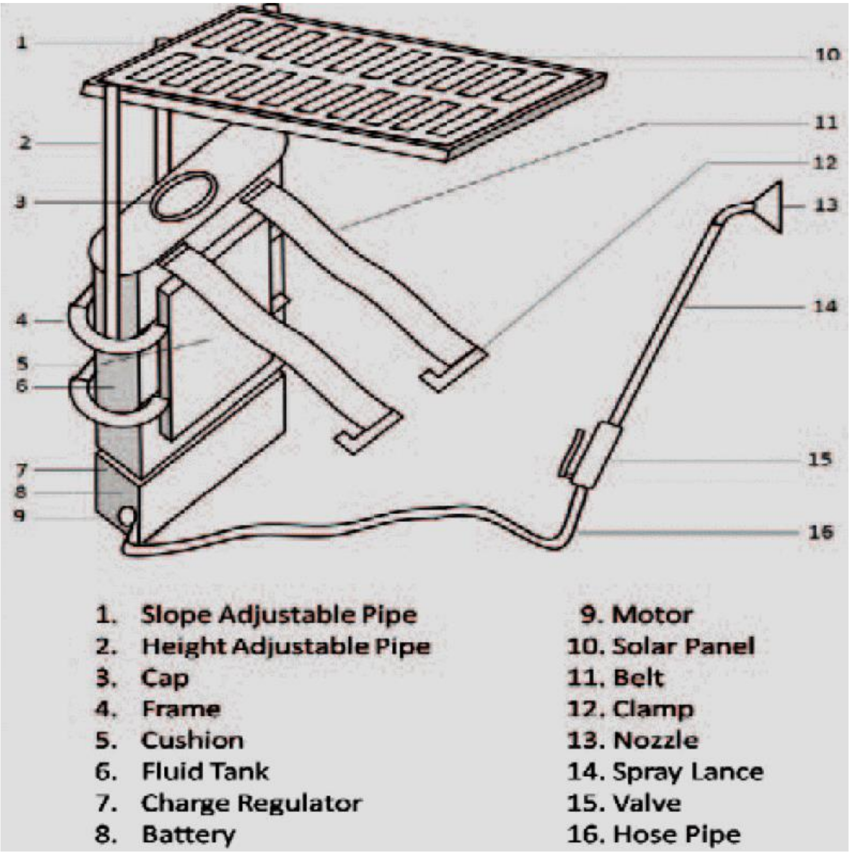
Solar PV pump for irrigation



Low Pressure Drip Irrigation



Solar Photovoltaic Sprayer



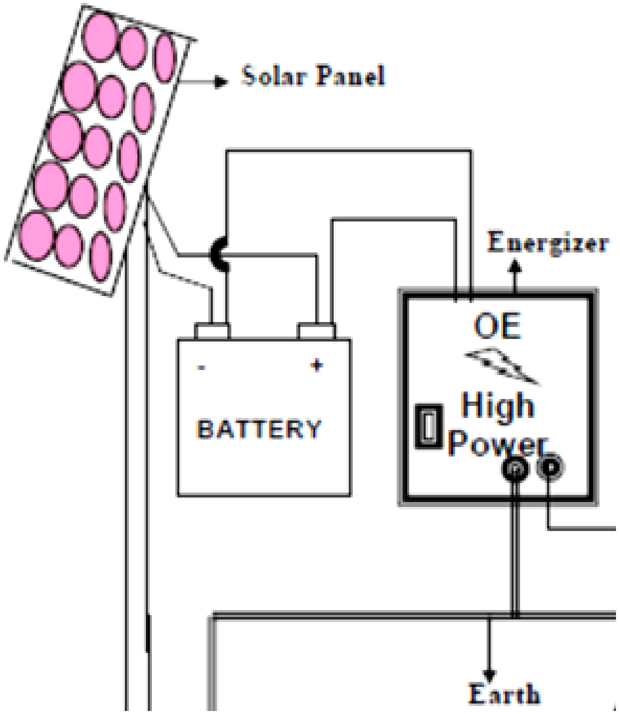
Solar panel of 20 W capacity, a 12V DC battery, a DC motor, a pump, to spray the pesticide and a tank to hold the pesticide.

Solar Photovoltaic Duster

Solar PV duster is a novel device suitable for aerial application of pesticides and insecticides in the powder form.

Duster is an impeller type centrifugal blower, gear reduction mechanism, dispensers with D.C motor.

Solar powered electric fence



Solar Power Electric Fence

- One of the risks in Indian farming is damage to crops by stray/ wild animals and also theft of the produce especially in orchards.
- Proper fencing is one of the solutions to overcome such type of risks.
- The fencing of barbed wire with multiple strands of plain wires or woven wire and metal/cement/ wooden posts is common. A channel linked fencing costs about Rs 950 per running meter for a height of 1.5 m using angle posts of 50 x50 x 6 mm at 3 m spacing and plain wire channel of 75 x 75 x3.15 mm.

Solar powered electric fence

- It gives a sharp shock to create psychological fear, against any tampering. Electricity is generated by 75 watts solar panel which charges a 12 volt, 40 AH battery and ensures that the battery remains charged at all times.

Various Components of Solar Power Fencing

Solar Panel and control Unit

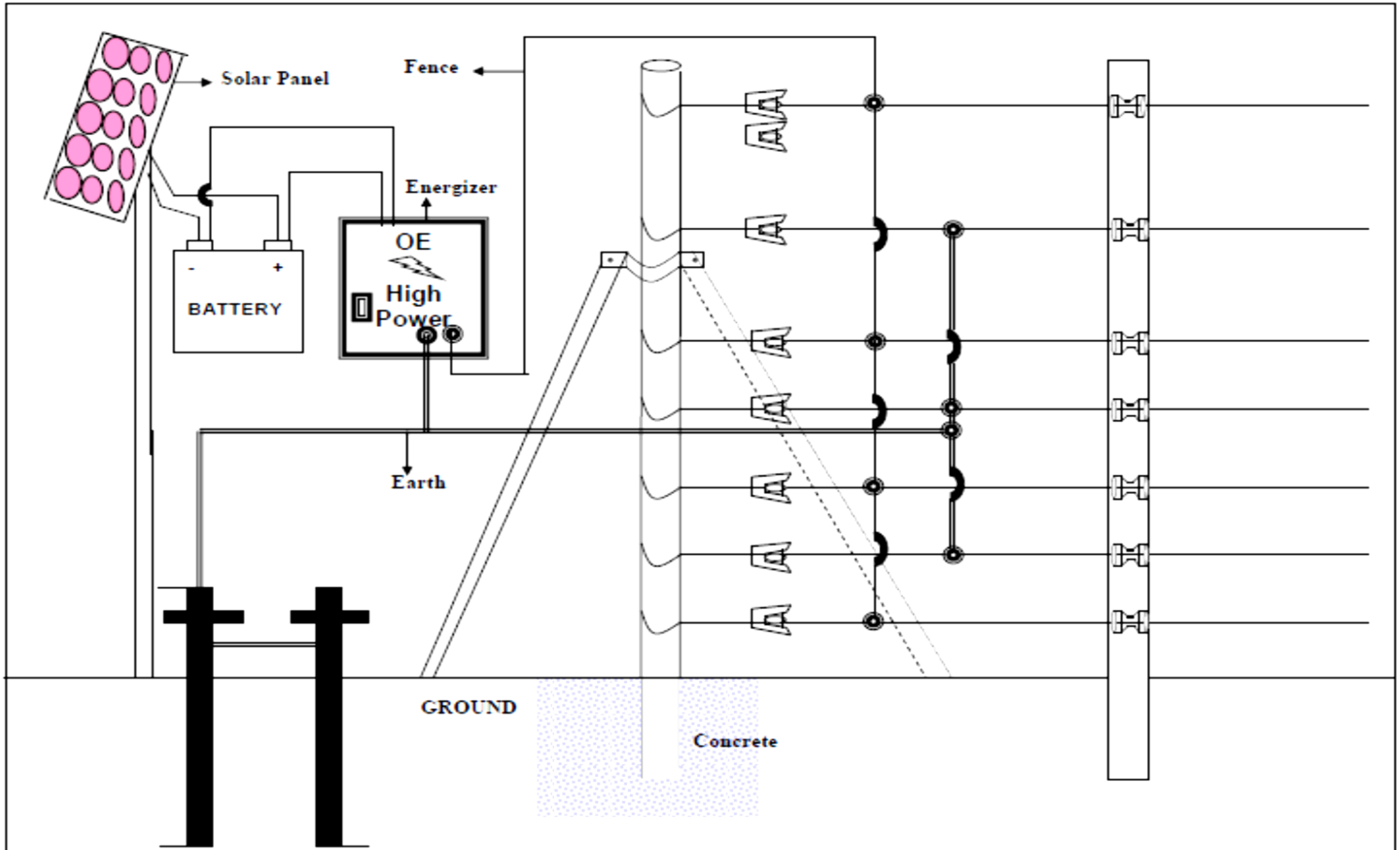
Digital Volt Meter


Solar Fence

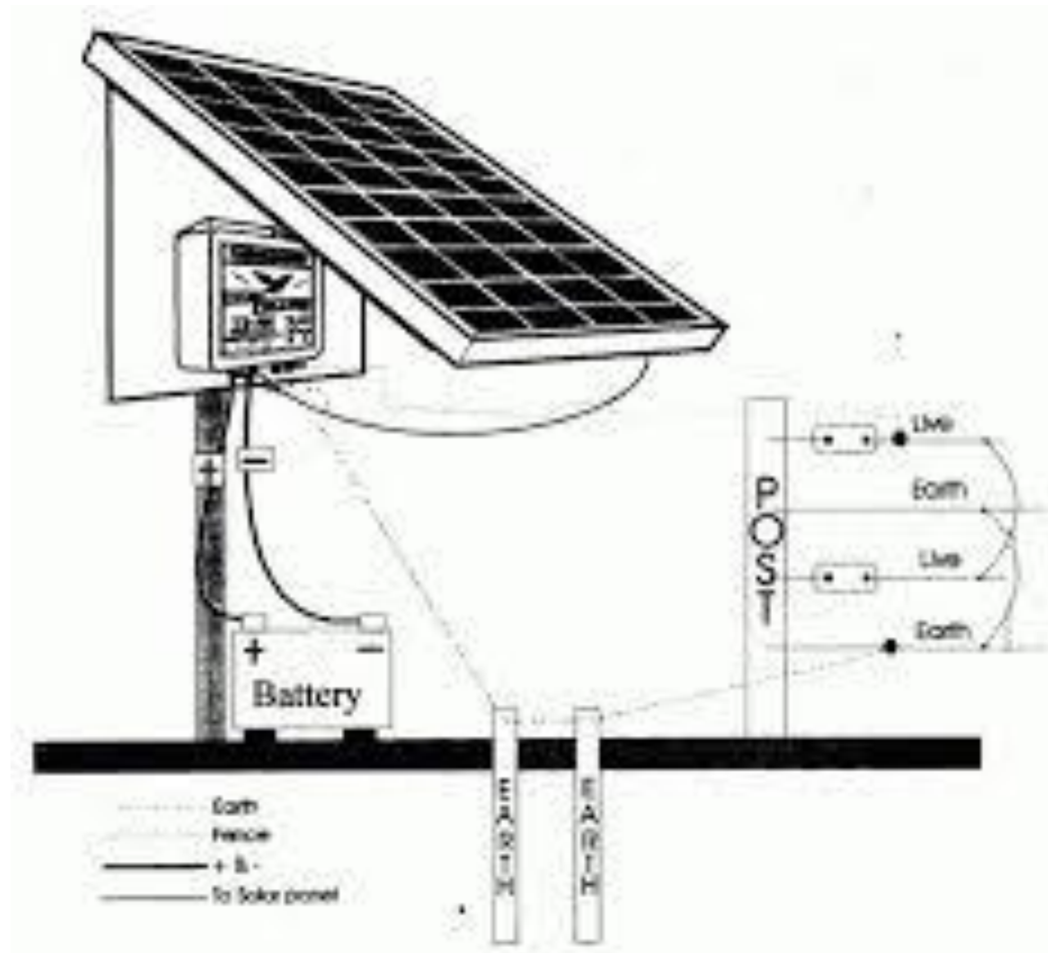

TENSION SPRING
WIRE TIGHTENER
CORNER
IRON REEL INSULATOR

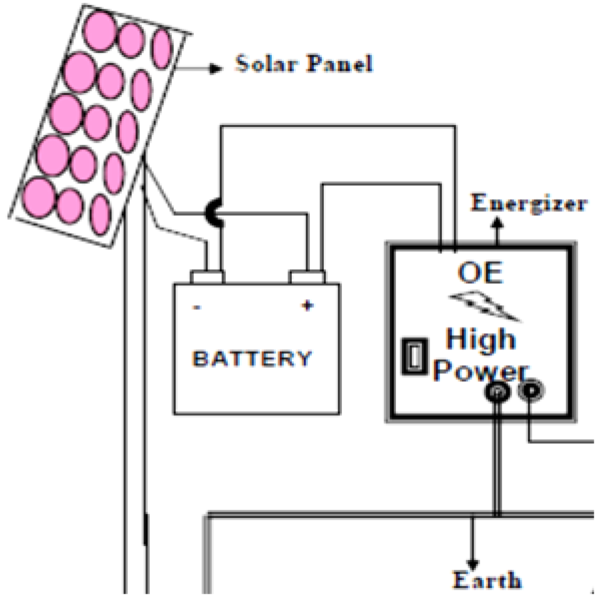
The alarm incorporated in the system gets activated and alert the inmates of the protected area.

Solar fencing system



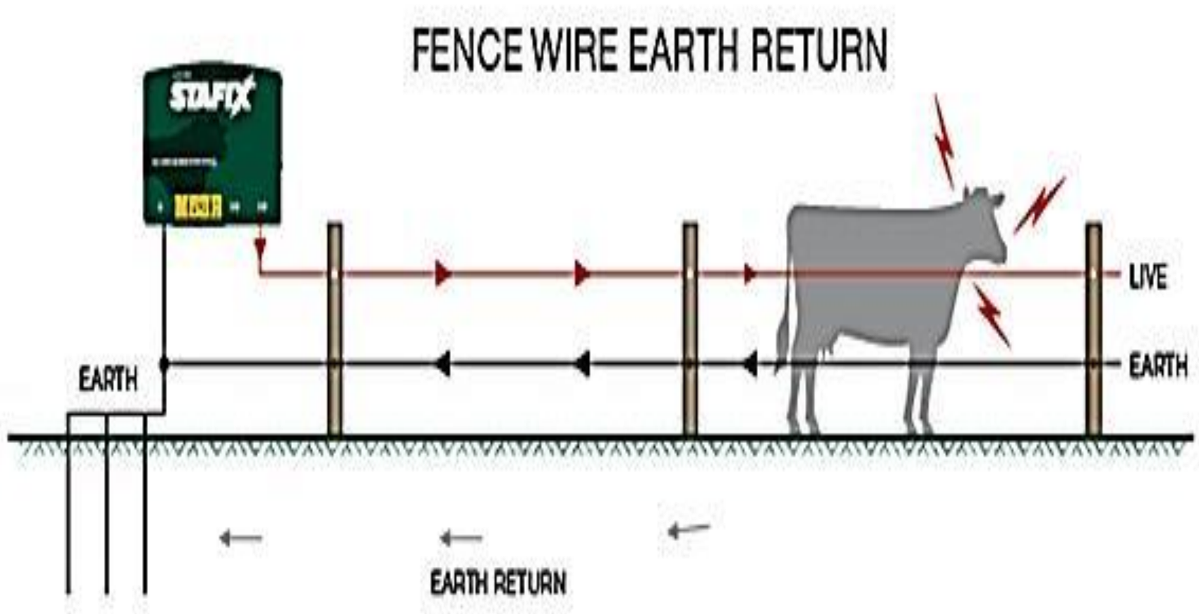
Solar fence system





An energizer is used which transforms the low voltage current from battery to high voltage (up to 10,000 volts) current and sends it to the electric fence. This way the fence is electrified and animals touching the fence receive the high voltage shock and run away from the fence. The electric shock is completely safe and non-lethal for human and animals.

- As current is pulsating (not live) and passing at every 1 to 1.2 second and only for a milli-second of time, the animal gets enough time to get away from the fence. The pulsating current does not grab the animal which generally happens in continuous current which causes contraction of muscles/cramps.



In solar fencing, even if an animal is trapped in the fence, after 10 consecutive shocks the system will trip and hooter will sound so that farmer can intervene and no death causes.

Cost and Maintenance

- The average cost per running meter of 7 rows fence comes to Rs.396/Meter .
- Solar panel need to be cleaned regularly.
- Check electrolyte level in battery periodically.
- Check all exposed terminals and wires for evidence of corrosion from environmental conditions such as salt or chemicals.
- **Electric Fence Energizers should be as per**

  IS 302- 1 (1979) for safety.

Thank You

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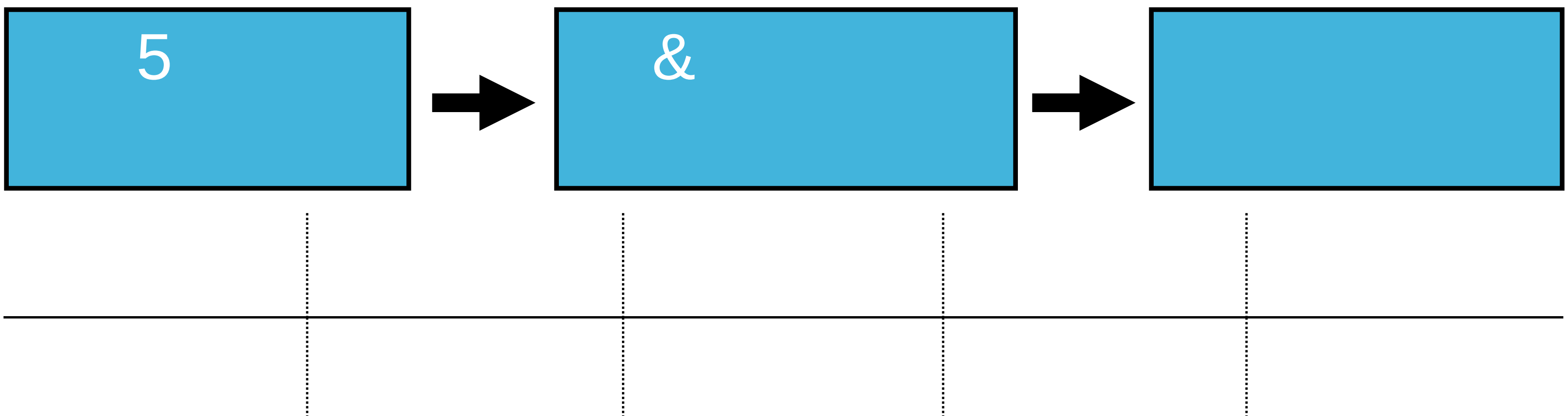
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