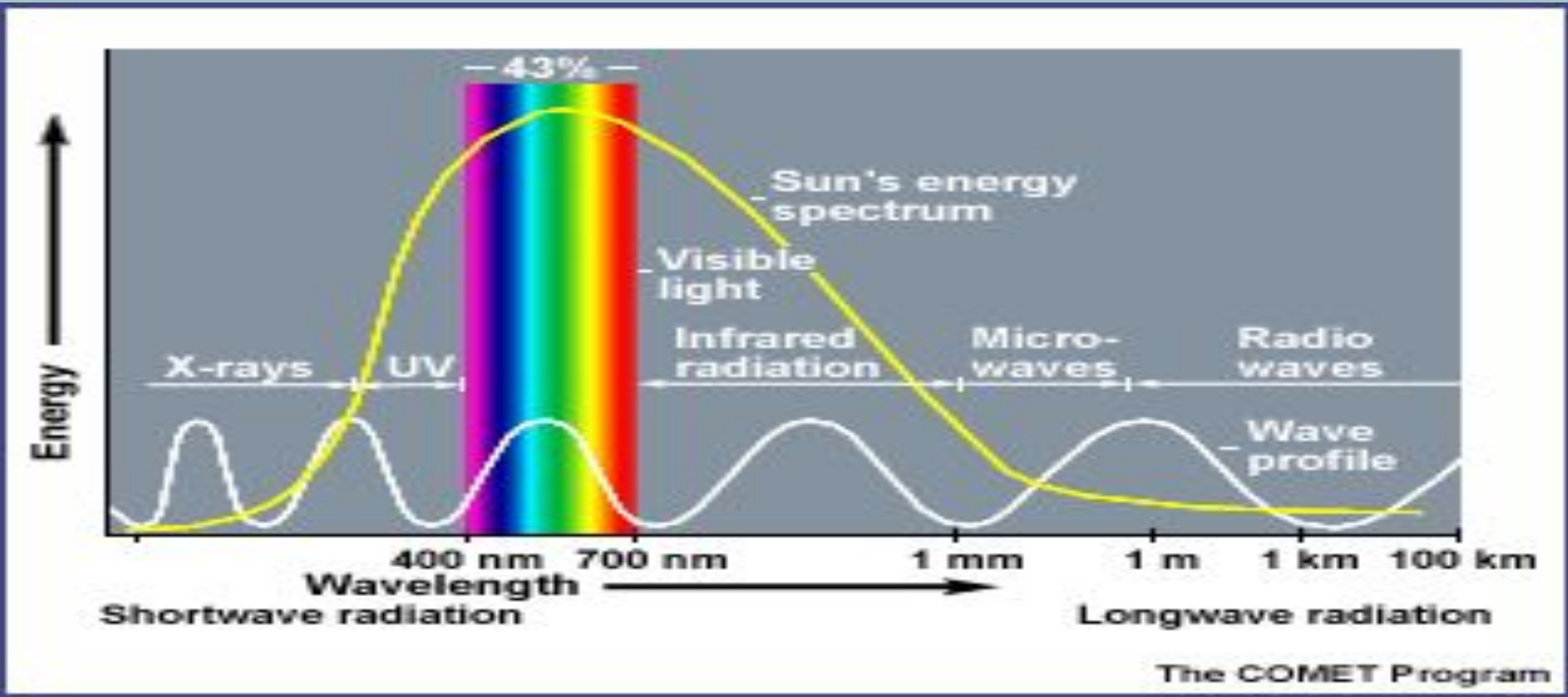
RENEWABLE ENERGY SOURCES

What is Solar Energy?

- Originates with the thermonuclear fusion reactions occurring in the sun.
- Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).



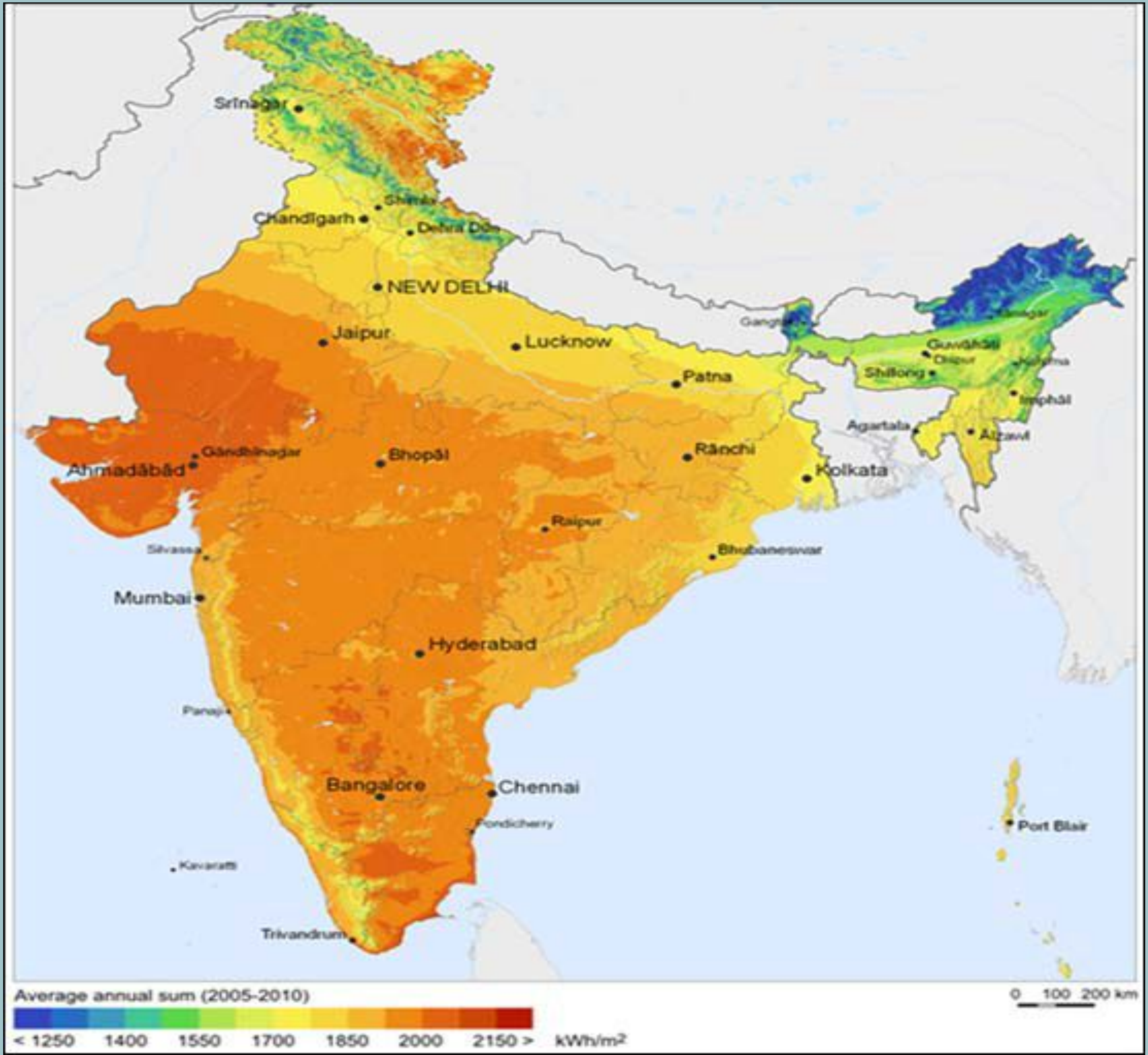
SOLAR ENERGY SCENERIO

- With its abundance of sunlight, India has tremendous potential to emerge as one of the leaders in solar power generation. According to the Government of India's policy for the solar sector – Jawaharlal Nehru National Solar Mission (JNNSM) – **a target of 20 GW of solar installations by 2022 has been set.**
- **Solar Energy demand globally has been growing at about 30% per annum over the past 15 years.**

Why In India

- India is in the sunny regions of the world with most parts of the country receiving 4-7 kWh of solar radiation per square meter per day, 250-300 sunny days in a year.
- Even though Solar energy constitutes a miniscule part in India’s installed power generation capacity (with grid connected solar PV generation at a mere 6 MW as of March 2010), in the medium and long run, it is expected that solar energy, especially solar PV will form a vital component of the country's energy mix.

SOLAR RESOURCSE MAP OF INDIA



INSOLATION

- Insolation is the amount of solar radiation reaching the earth.
- Maximum value is 1000 kW/m2
- Components of solar radiation
  - Direct radiation
  - Diffuse radiation
  - Reflect radiation

HOW SOLAR ENERGY IS USED

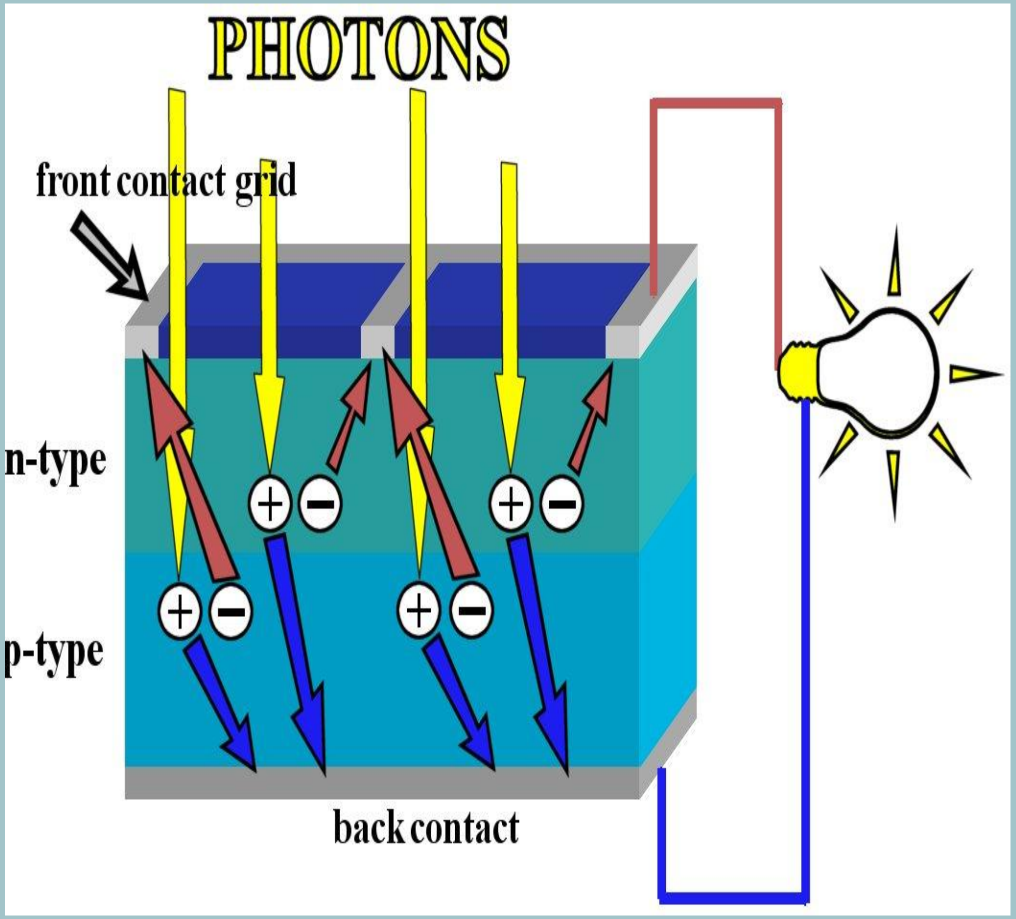
- Solar thermal energy
- Solar heating
- Electricity generation using solar concentrators
- Photovoltaic cells

SOLAR PHOTOVOLTAIC CELL

- Solar power is the conversion of sunlight into electricity either directly by using photovoltaic or concentrated solar power
- A solar cell, or photovoltaic cell is a device that converts light into electric current using the photoelectric effect.

PHOTOELECTRIC EFFECT

- Basic process by which a photovoltaic cell converts absorbed sunlight into electricity
- “Photons” knock electrons free from the silicon structure, freeing them to enter electric current and power a “load” (like a light bulb)



Grid-Connected PV

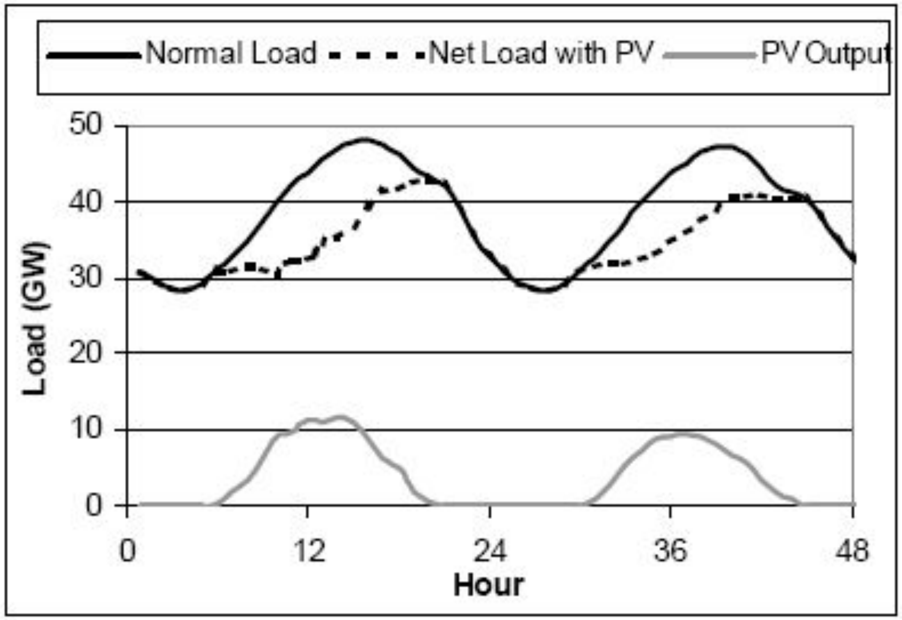


Fig. 1: System Load With and Without a Large (16 GW) PV System on Two Summer Days

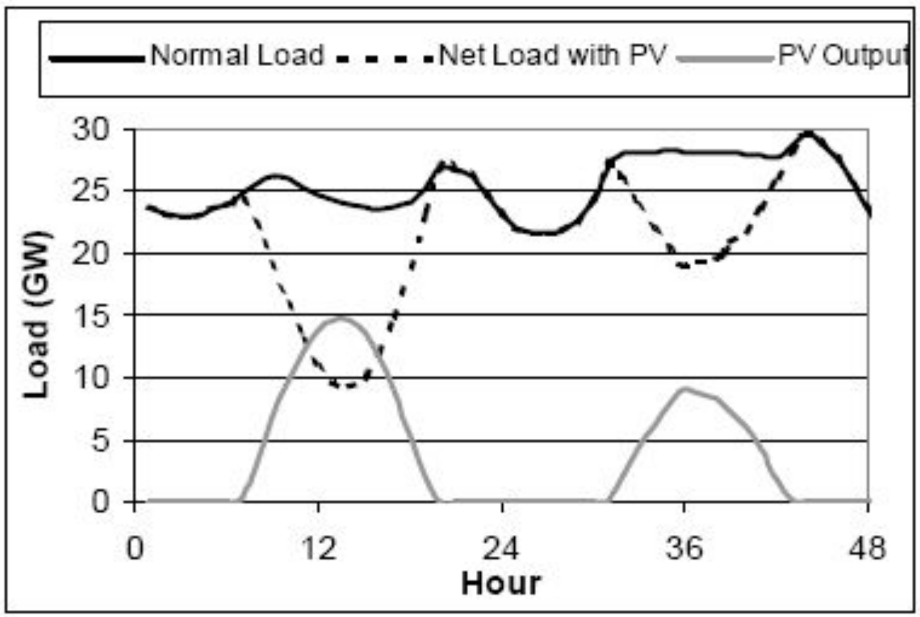


Fig. 2: System Load With and Without a Large (16 GW) PV System on Two Spring Days

Advantages

- All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun, while only pure radiant energy reaches the Earth.

- Energy reaching the earth is incredible. By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused.

DISADVANTAGES

- Still not “price-competitive” with traditional sources of electricity
- ✔ If we don't include the environmental costs of coal-fired electricity when comparing them with solar, it becomes very difficult.

- Poor conversion efficiency
- Location
- Reliability
- Addressed by approaching the problem through:

  1) collection, 2) conversion, 3) storage.

WIND ENERGY

- Wind results from air in motion due to pressure gradient that is caused by the solar energy irradiating the earth.

- **WIND POWER**
  - Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air can extract part of the energy and convert into useful work.

Following factors control the output of wind energy converter : -

- The wind speed
- Cross-section of the wind swept by rotor
- Conversion efficiently of rotor
- Generator
- Transmission system

PRINCIPLE OF ENERGY CONVERSION

- **Wind mills or turbines works on the principle of converting kinetic energy of the wind in to mechanical energy.**

  Power available from wind mill= $\frac{1}{2} \rho A V^3$

Where, ρ– air density = 1.225 Kg. / m^3 at sea level

A – area swept by windmill rotor = πD^2 sq-m. (D – diameter)

V – wind speed m/sec.

- This equation tells us that maximum power available depends on rotor diameter.

SITE SELECTION

Following factors are to be considered for selection of good site for wind power generation: -

- High annual wind speed.
- No tall obstructions for a radius of 3 Km.
- Open plain or open shore
- Top of a smooth, well rounded hill with gentle slop

GENERATING SYSTEM

Wind - electric conversion system consists of the following components :-

1) Wind Turbine- Converts wind energy into rotational(mechanical) energy
2) Gear system and coupling - It steps up the speed and transmits it to the generator rotor
3) Generator- Converts rotational energy into electrical energy.
4) Controller-Senses wind direction, wind speed generator output and temperature and initiates appropriate control signals to take control action.

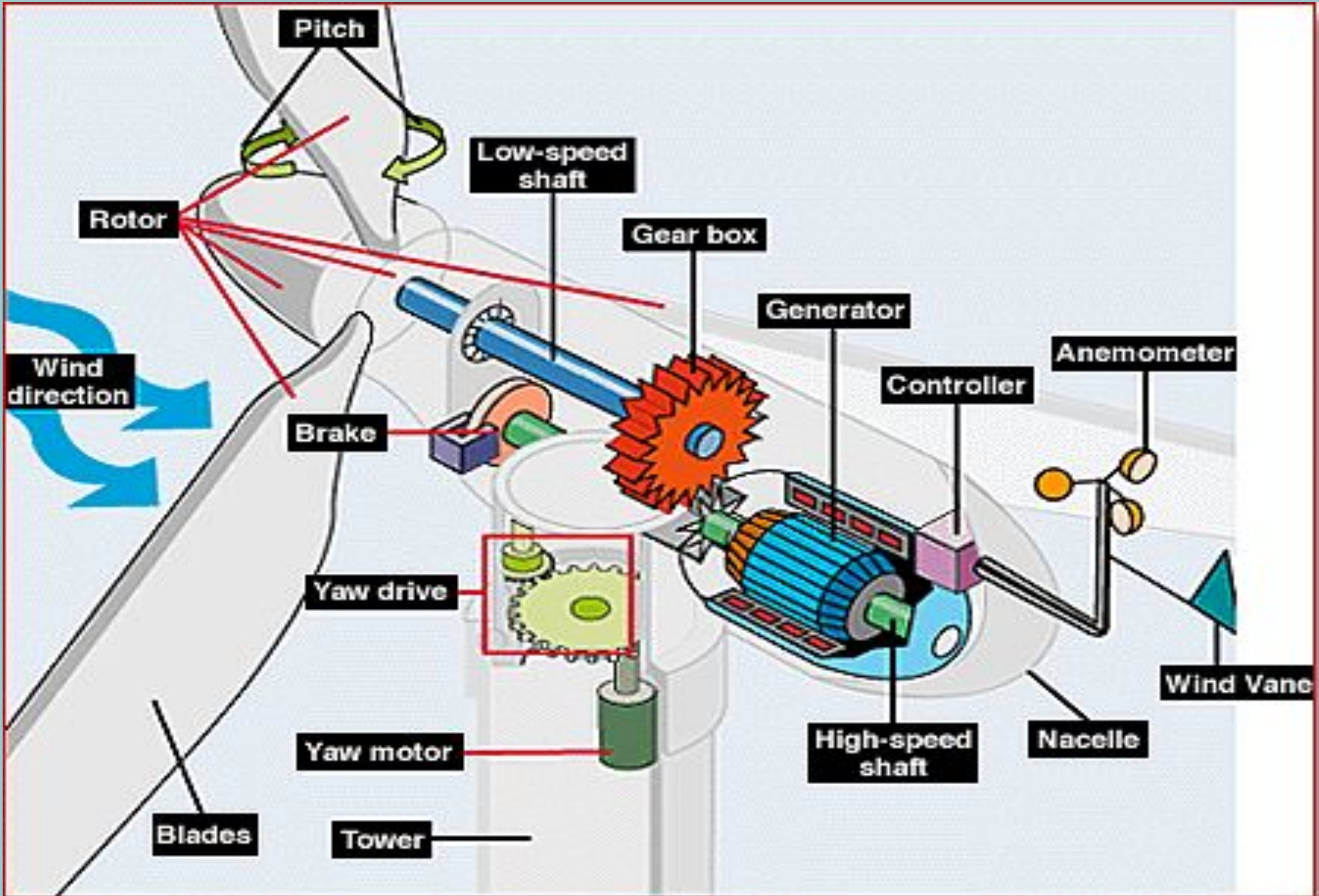
Wind Turbines

- Rotary engine in which the kinetic energy of a moving fluid is converted into mechanical energy by causing a bladed rotor to rotate.
- opposite of a fan
  - turbine blades spin from the wind and make energy, instead of using energy to make wind
  - Wind rotates the turbine blades
    - spins a shaft connected to a generator
    - The spinning of the shaft in the generator makes electricity

CONTRUCTION OF WIND TURBINE

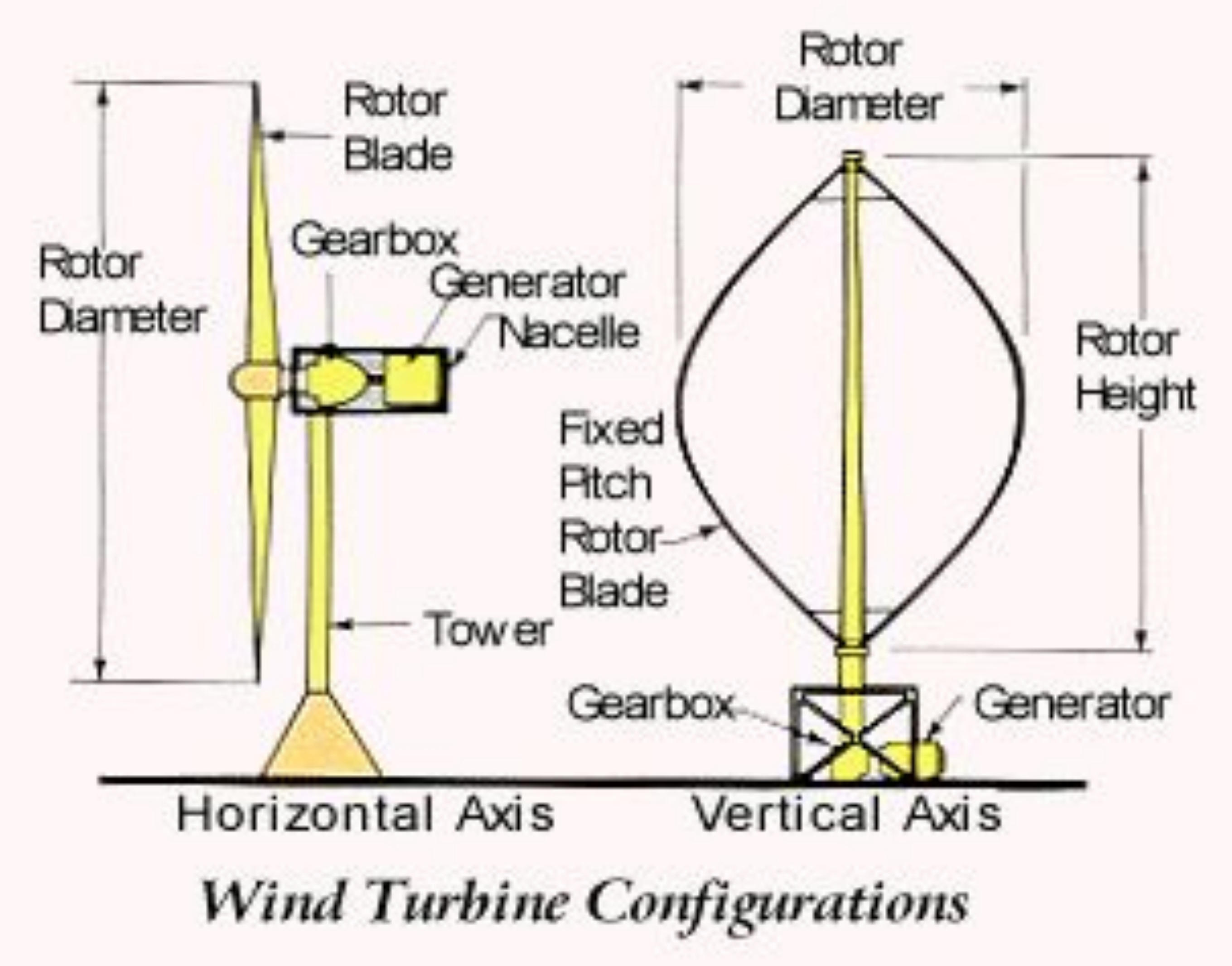
- Wind turbines, like windmills, are mounted on a tower to capture the most wind energy
- wind speed varies by height
- wind current 100m above the ground dropped in speed by 10% when its height declined to 50m
- property is known as wind sheer
  - wind speed increases in speed with height,
  - due to friction at the Earth’s surface
- The Hub heights of modern wind turbines, which produce 600 to 1,500 kW of electricity, are usually 40 to 80 meters above ground

INTERNAL PARTS



TYPES OF TURBINES

- Horizontal Axis Wind Turbines
- Vertical Axis Wind Turbines



DIFFERENCES

- **Vertical Axis Advantages**
  - Can place generator on ground
  - You don’t need a yaw mechanism for wind angle
- **Disadvantages**
  - Lower wind speeds at ground level
  - Less efficiency
  - Requires a “push”
- **Horizontal Advantages**
  - Higher wind speeds
  - Great efficiency
- **Disadvantages**
  - Angle of turbine is relevant
  - Difficult access to generator for repairs

Wind Turbines: Effect of Number of Blades

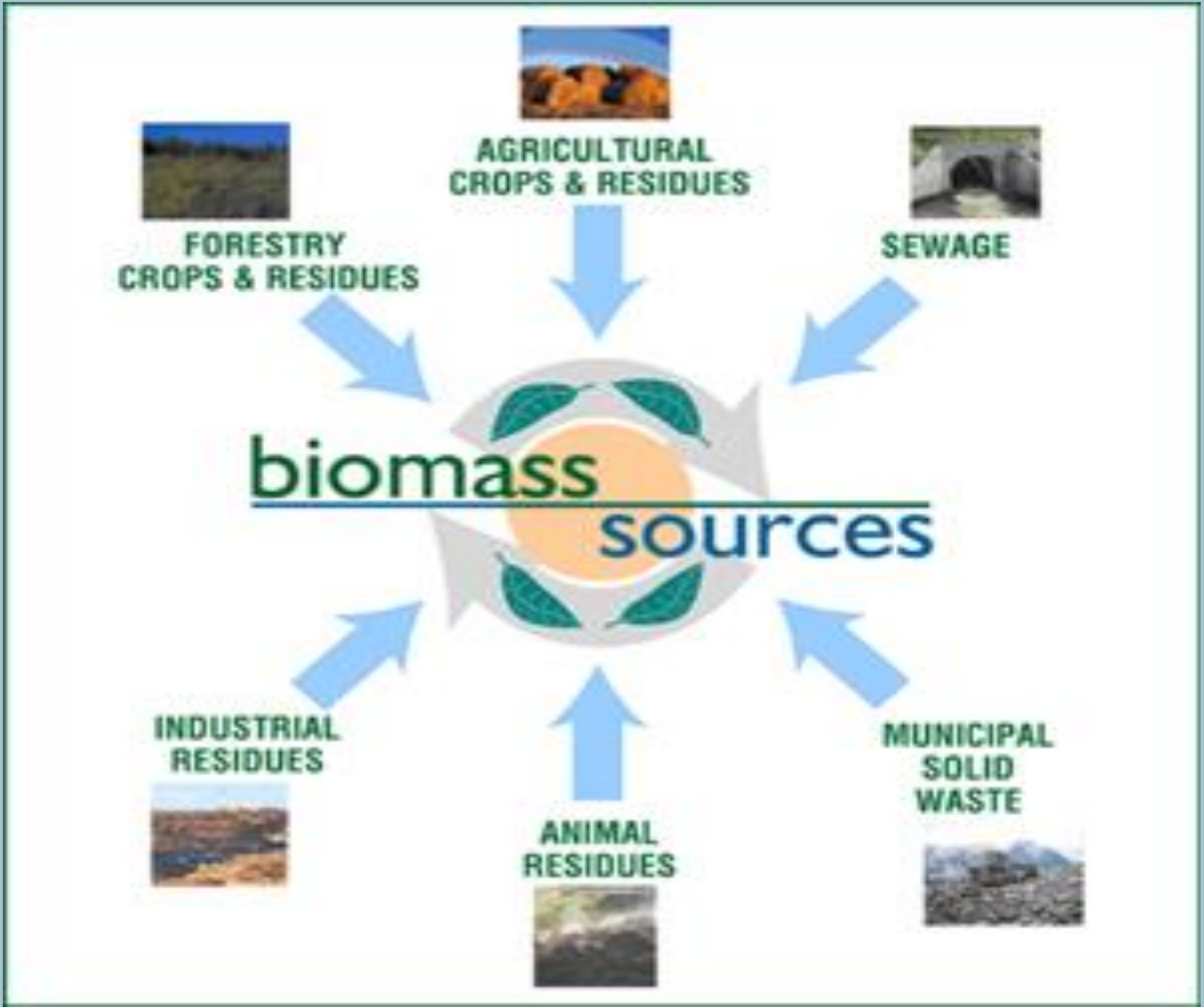
- Most common design is the three-bladed turbine. The most important reason is the stability of the turbine.

- A rotor with an even number of blades will give stability problems for a machine with a stiff structure. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower.

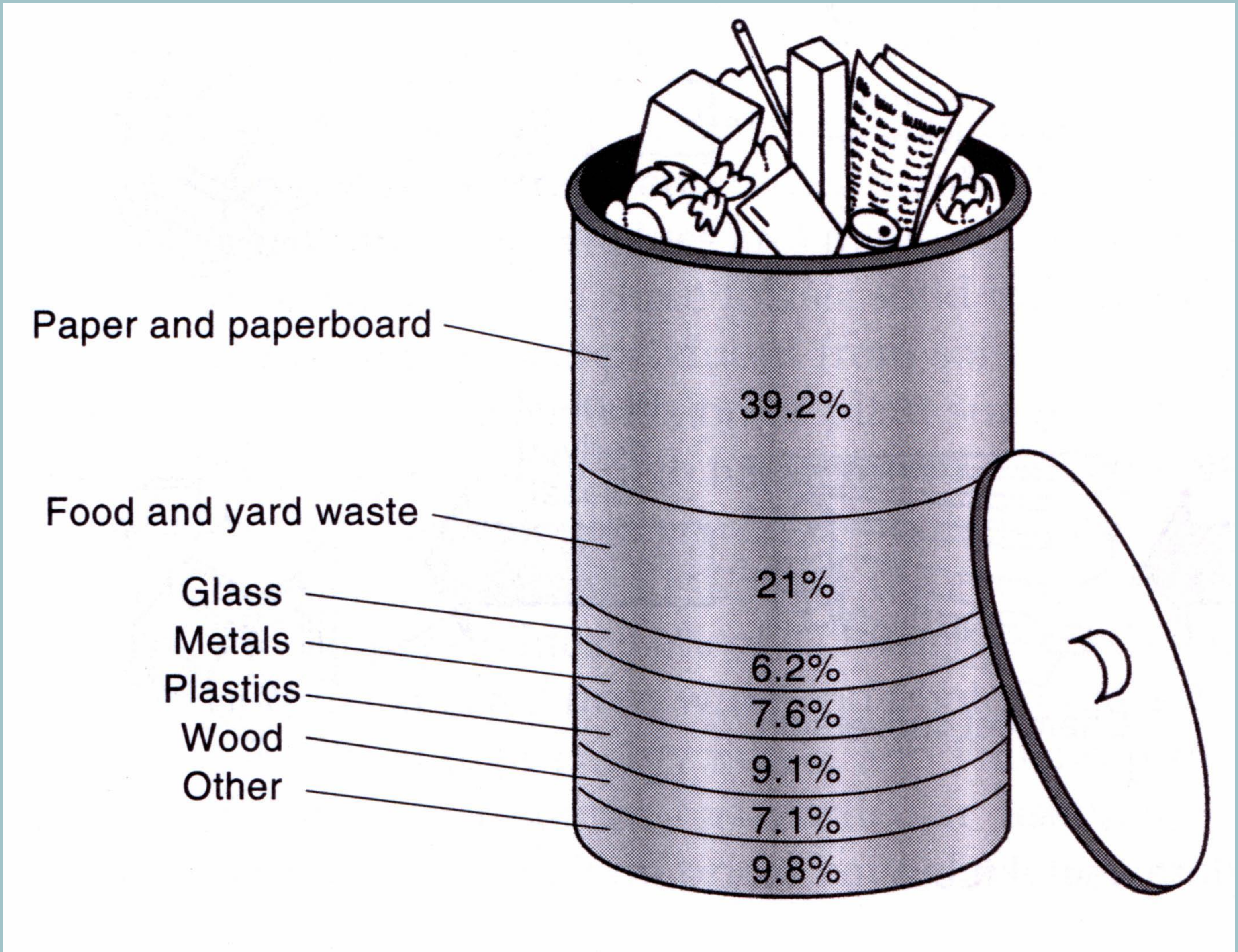
What is Biomass

- Biomass is a renewable energy source that is derived from living or recently living organisms.
- Biomass includes biological material, not organic material like coal.
- Energy derived from biomass is mostly used to generate electricity or to produce heat.
- Thermal energy is extracted by means of combustion, torrefaction, pyrolysis, and gasification.
- Biomass can be chemically and biochemically treated to convert it to a energy-rich fuel.

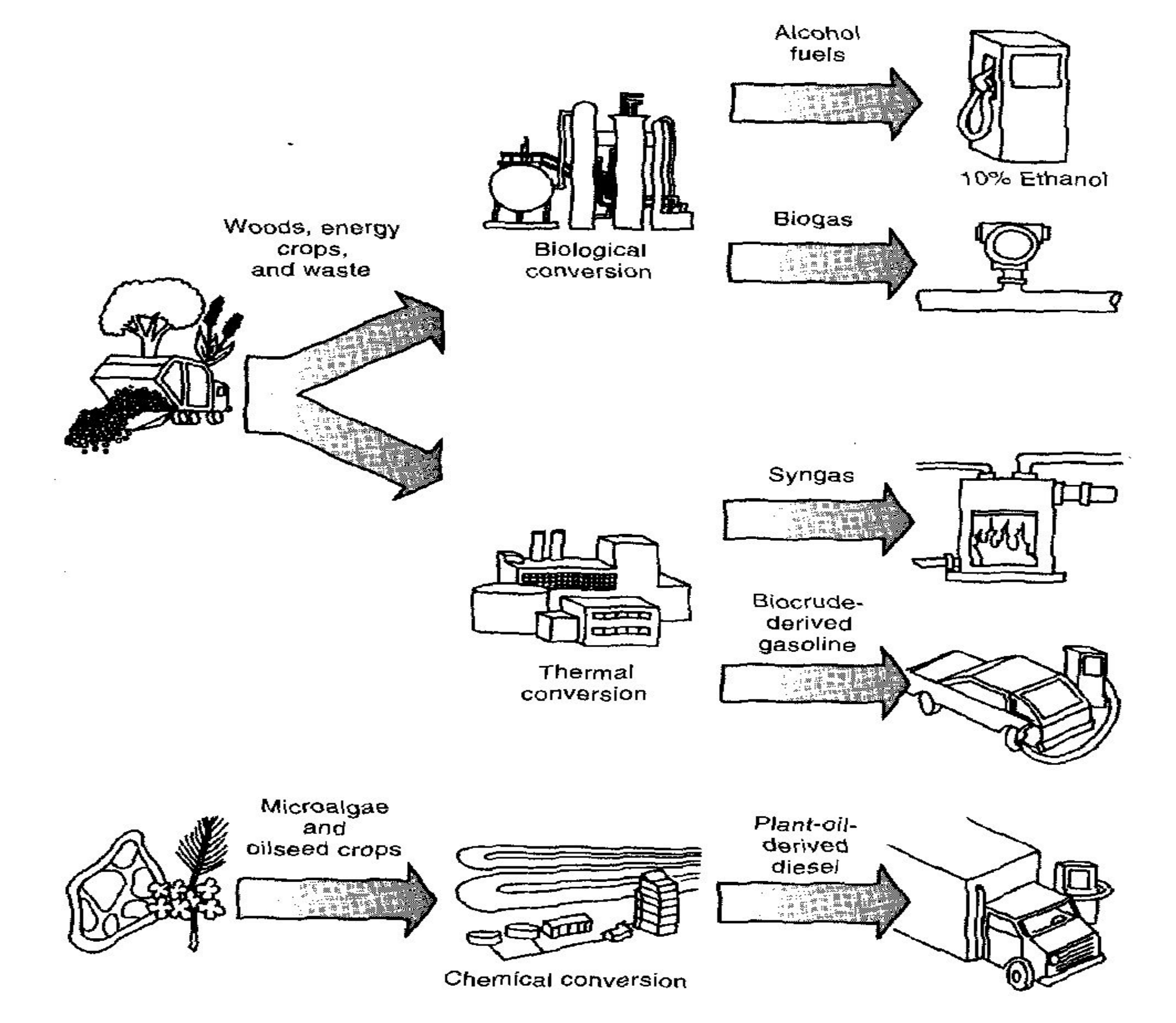
Sources of Biomass

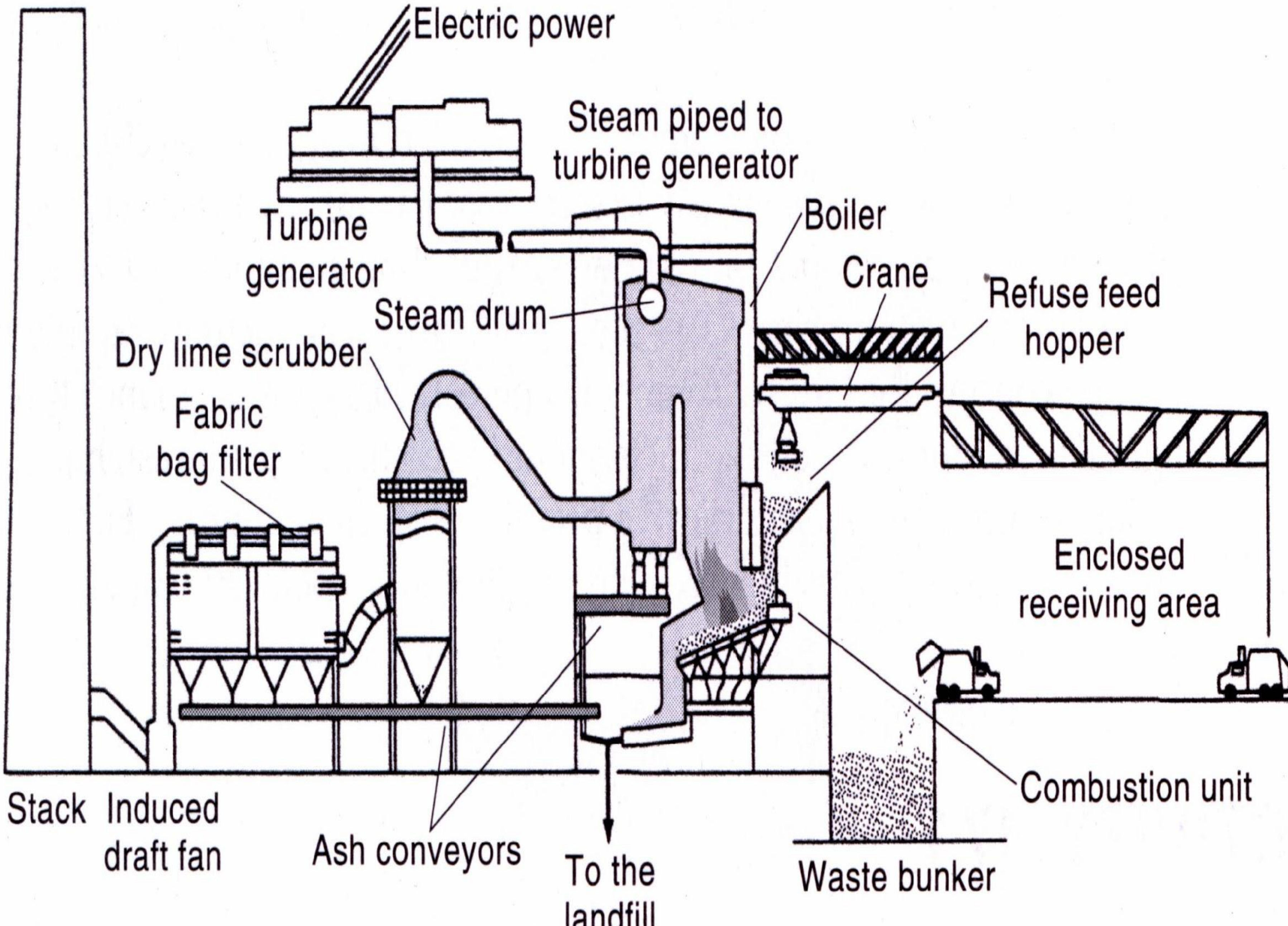


Waste products



Usage


Alcohol fuels
10% Ethanol
Biogas
Woods, energy crops, and waste
Biological conversion
Syngas
Biocrude-derived gasoline
Thermal conversion
Microalgae and oilseed crops
Plant-oil-derived diesel
Chemical conversion


Electric power
Steam piped to turbine generator
Turbine generator
Boiler
Crane
Refuse feed hopper
Steam drum
Dry lime scrubber
Fabric bag filter
Enclosed receiving area
Combustion unit
Stack
Induced draft fan
Ash conveyors
To the landfill
Waste bunker

What is geothermal energy

- **Geothermal energy**- energy that comes from the ground; power extracted from heat stored in the earth
  - *Geo:* earth
  - *Thermal:* heat
- 70% comes from the decay of radioactive nuclei with long half lives that are embedded within the Earth
- Some energy is from residual heat left over from Earths formation.
- The rest of the energy comes from meteorite impacts

Different Geothermal Energy Sources

- **Hot Water Reservoirs**: As the name implies these are reservoirs of hot underground water. There is a large amount of them in the US, but they are more suited for space heating than for electricity production.
- **Natural Stem Reservoirs**: In this case a hole dug into the ground can cause steam to come to the surface. This type of resource is rare in the US.
- **Geopressured Reservoirs**: In this type of reserve, brine completely saturated with natural gas in stored under pressure from the weight of overlying rock. This type of resource can be used for both heat and for natural gas.

Different Geothermal Energy Sources

- **Normal Geothermal Gradient**: At any place on the planet, there is a normal temperature gradient of +30^{0}C per km dug into the earth. Therefore, if one digs 20,000 feet the temperature will be about 190^{0}C above the surface temperature. This difference will be enough to produce electricity. However, no useful and economical technology has been developed to extracted this large source of energy.
- **Hot Dry Rock**: This type of condition exists in 5% of the US. It is similar to Normal Geothermal Gradient, but the gradient is 40^{0}C/km dug underground.
- **Molten Magma**: No technology exists to tap into the heat reserves stored in magma. The best sources for this in the US are in Alaska and Hawaii.

USAGE

Direct

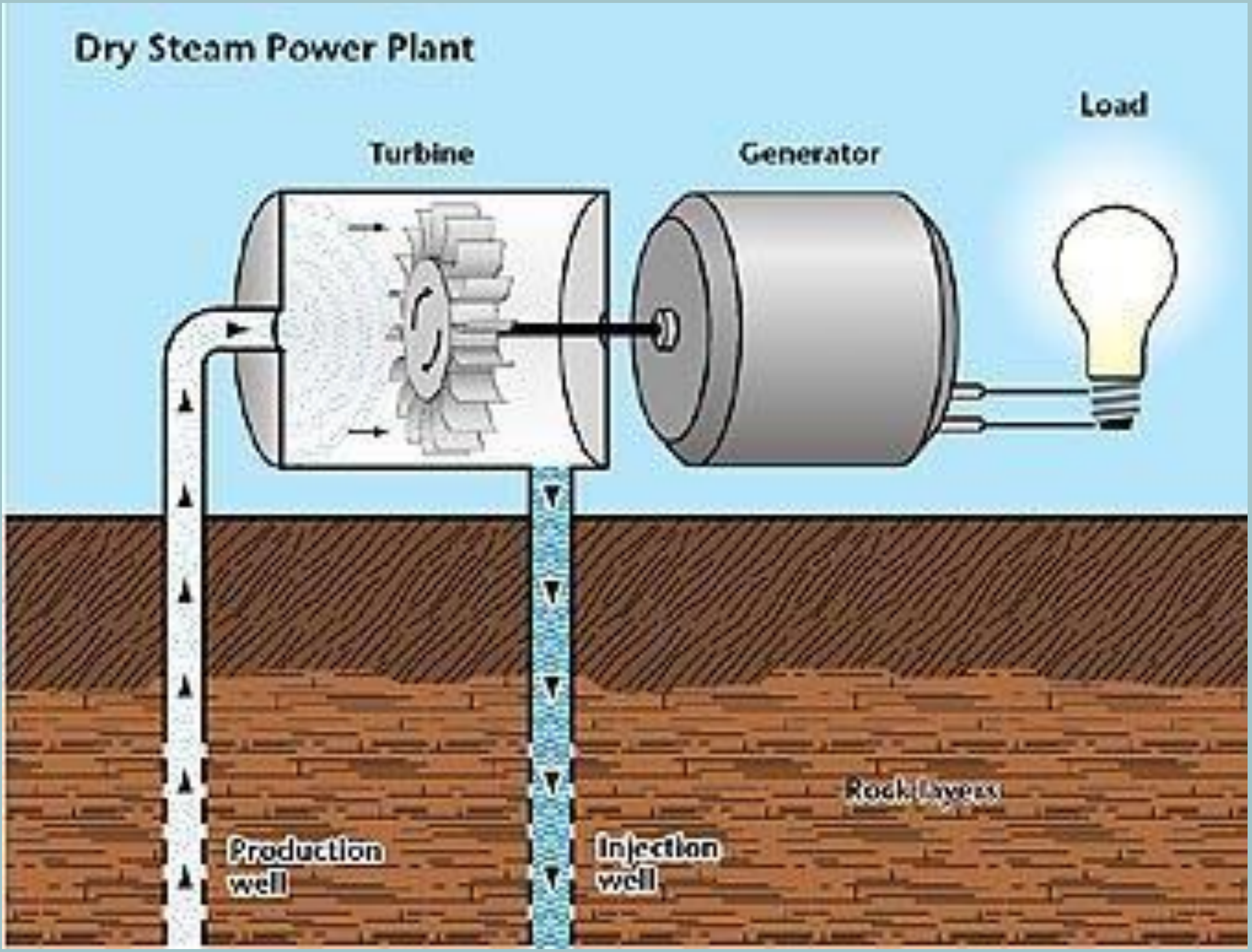
- Heating homes
- Hot springs
- Greenhouse heating
- Food dehydration plants
- Agriculture
  - Crop drying
  - Milk pasteurization

Electrical

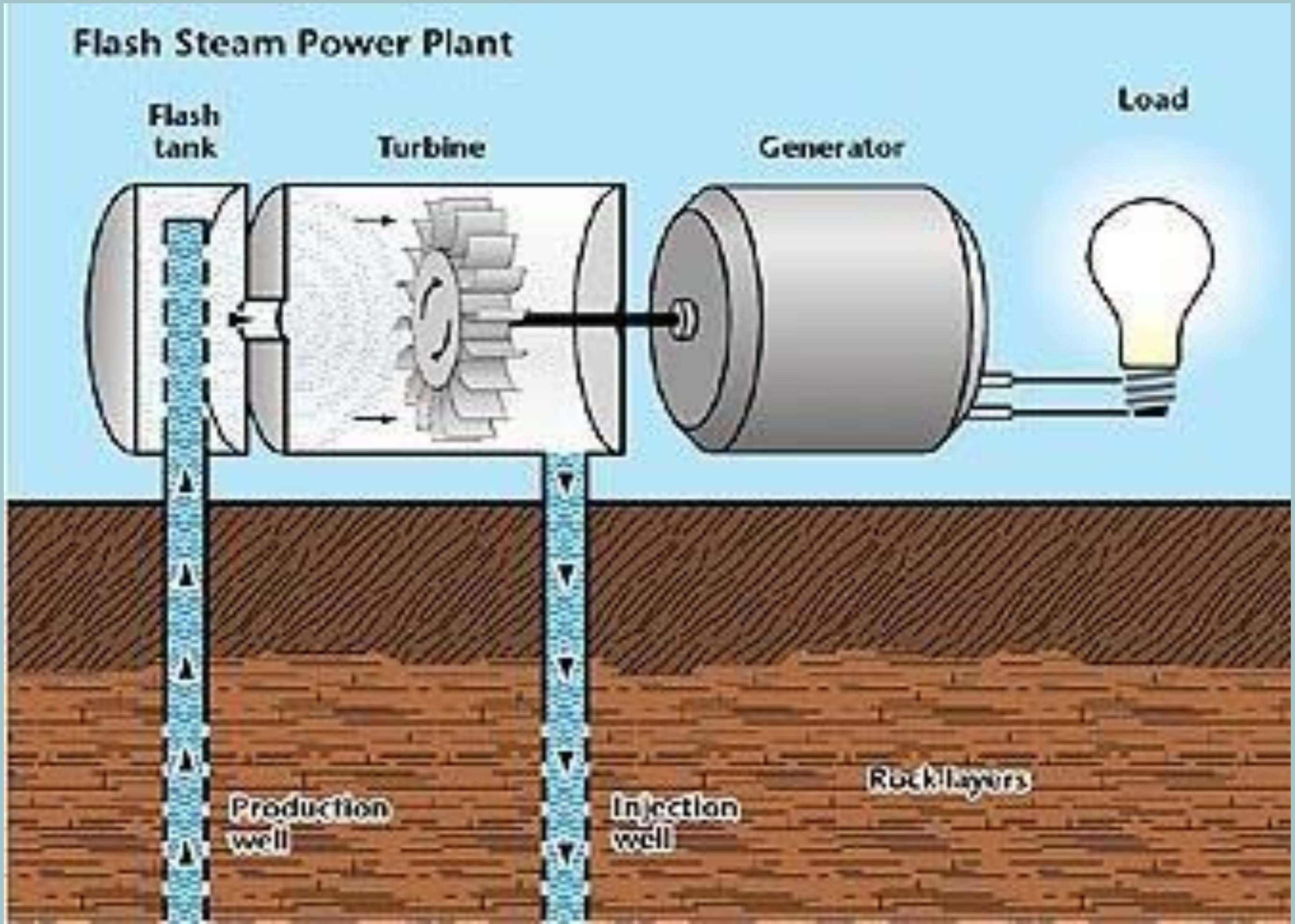
- Dry steam
- Flash steam
- Binary cycle

FOR ELECTRICITY

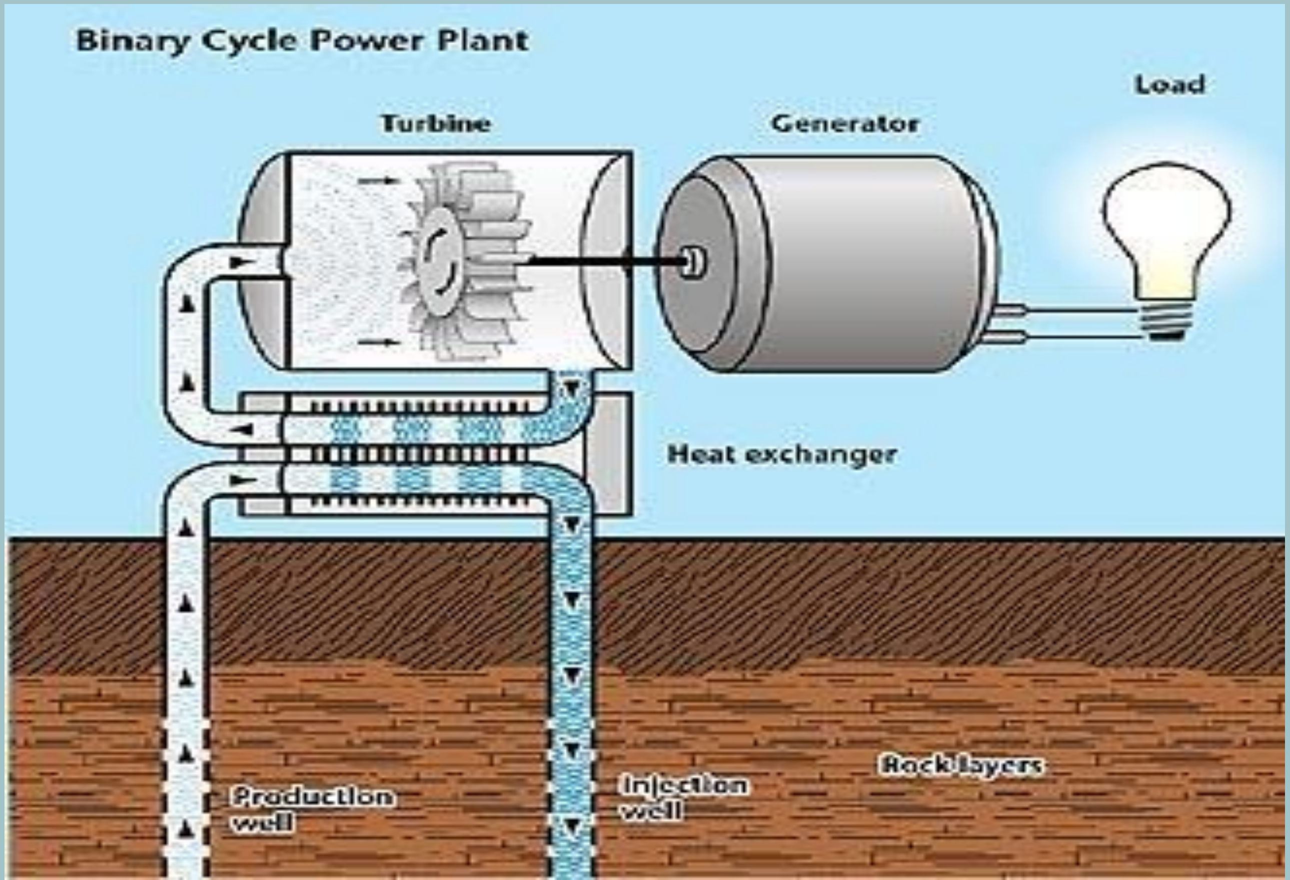
- **Dry Steam Plants**: These were the first type of plants created. They use underground steam to directly turn the turbines.



- **Flash Steam Plants**: These are the most common plants. These systems pull deep, high pressured hot water that reaches temperatures of 360^{0}F or more to the surface. This water is transported to low pressure chambers, and the resulting steam drives the turbines. The remaining water and steam are then injected back into the source from which they were taken.



- **Binary Cycle Plants**: This system passes moderately hot geothermal water past a liquid, usually an organic fluid, that has a lower boiling point. The resulting steam from the organic liquid drives the turbines. This process does not produce any emissions and the water temperature needed for the water is lower than that needed in the Flash Steam Plants (250^0F – 360^0F).



Environmental Effects/ Disadvantages

- Fluids drawn from the deep earth carry a mixture of gases
- Pollutants contribute to global warming and acid rain
- Construction of Plants can adversely affect land stability
- Sources may hold trace amounts of toxic chemicals/mineral deposits
- Loud Noises
- Initial start up cost (expensive)
- Extracting large amounts of water can cause land subsidence, and this can lead to an increase in seismic activity. To prevented this the cooled water must be injected back into the reserve in order to keep the water pressure constant underground.
- Power plants that do not inject the cooled water back into the ground can release H_2S, the “rotten eggs” gas. This gas can cause problems if large quantities escape because inhaling too much is fatal.

Geothermal Positive Attributes

- Useful minerals, such as zinc and silica, can be extracted from underground water.
- Geothermal energy is "homegrown." This will create jobs, a better global trading position and less reliance on oil producing countries.
- US geothermal companies have signed $6 billion worth of contracts to build plants in foreign countries in the past couple of years.
- In large plants the cost is 4-8 cents per kilowatt hour. This cost is almost competitive with conventional energy sources.

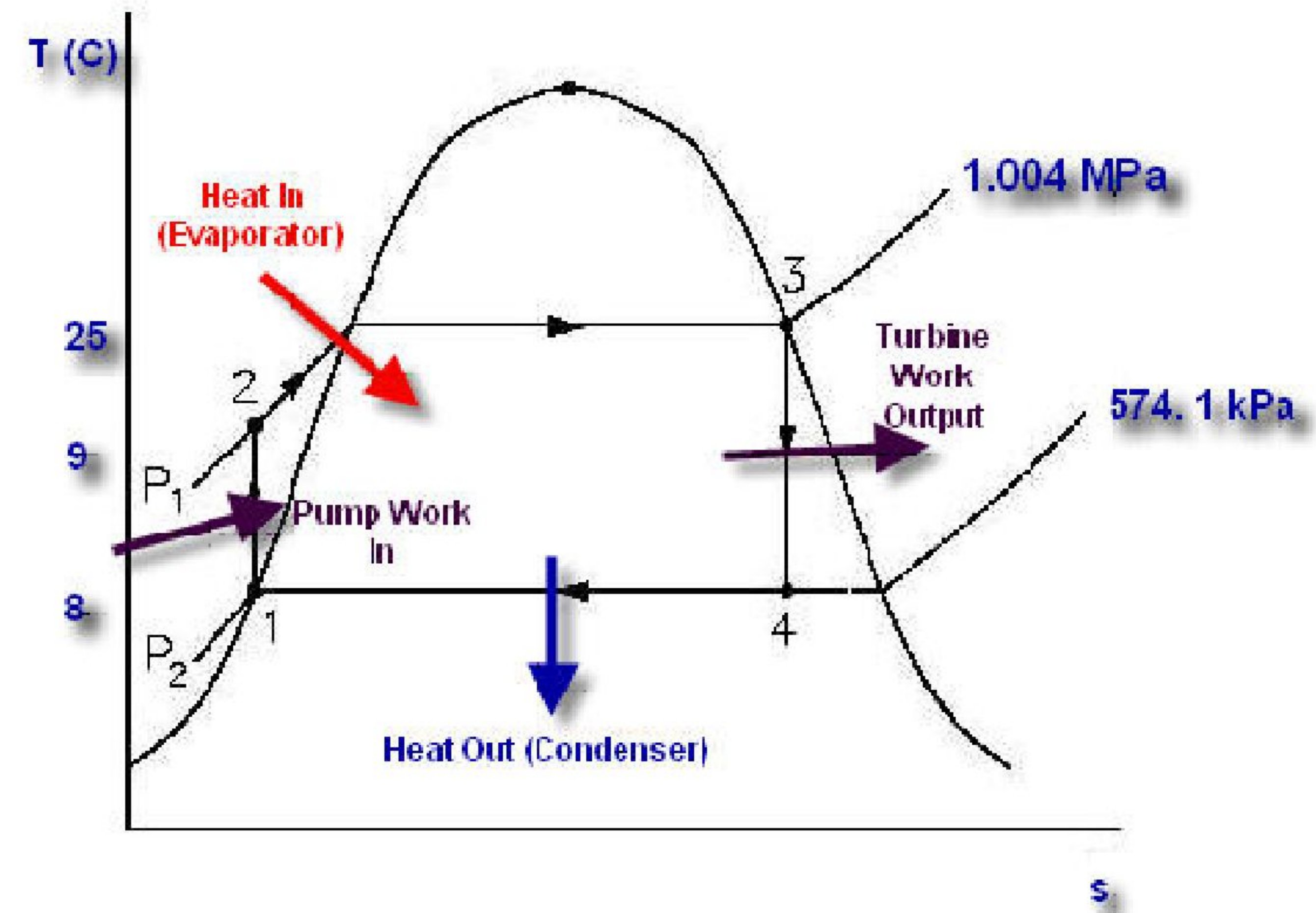
Ocean-thermal energy

- ocean energy is replenished by the sun and through tidal influences of the moon’s and sun’s gravitational forces
- near-surface winds induce wave action and cause wind-blown currents at about 3% of the wind speed
- tides cause strong currents into and out of coastal basins and rivers
- ocean surface heating by some 70% of the incoming sunlight adds to the surface water thermal energy, causing expansion and flow
- wind energy is stronger over the ocean due to less drag, although technically, only sea breezes are from ocean energy

OTEC

- OTEC utilizes the ocean's 20ºC natural thermal gradient between the warm surface water and the cold deep sea water to drive a Rankine Cycle
- OTEC utilizes the world's largest solar radiation collector - the ocean. The ocean contains enough energy power all of the world's electrical needs.

OTEC process



RANKINE CYCLE

ADVANTAGES

- No dependency on oil
- Minimal maintenance costs compared to conventional power production plants

DISADVANTAGES

- Low thermal efficiency due to small temperature gradient between heat sink and source
- OTEC technology is only ideally suitable in equatorial waters
- Only moderate power outputs are available
- Currently this technology is not as monetarily feasible as conventional power production plants
- The manufacturing and installation of the extremely long cold water pipes is extremely time consuming and costly.

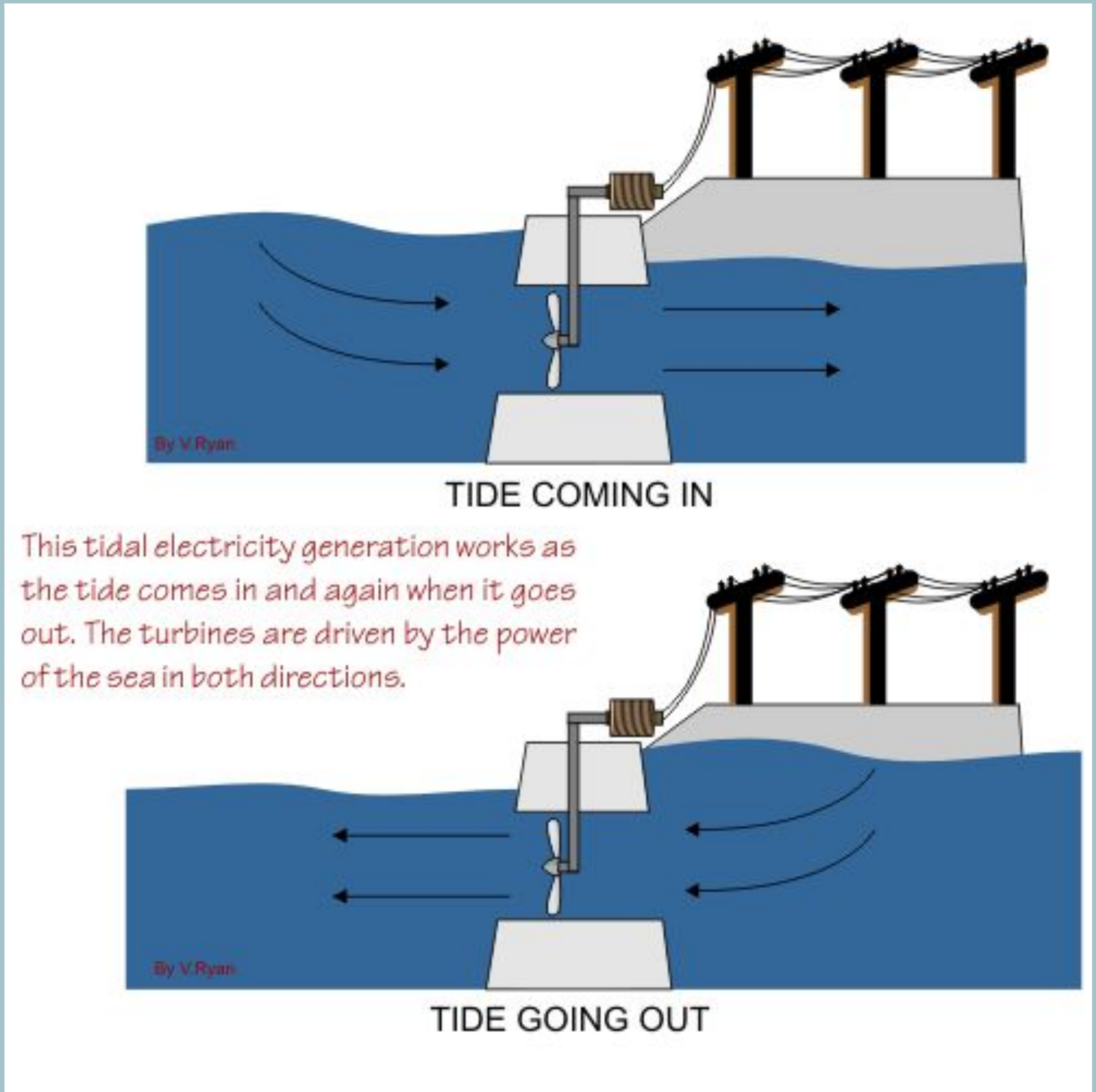
TIDAL ENERGY

- Tides generated by the combination of the moon and sun's gravitational forces
- Greatest affect in spring when moon and sun combine forces
- In order to be practical for energy production, the height difference needs to be at least 5 meters
- Only 40 sites around the world of this magnitude
- Overall potential of 3000 gigawatts from movement of tides

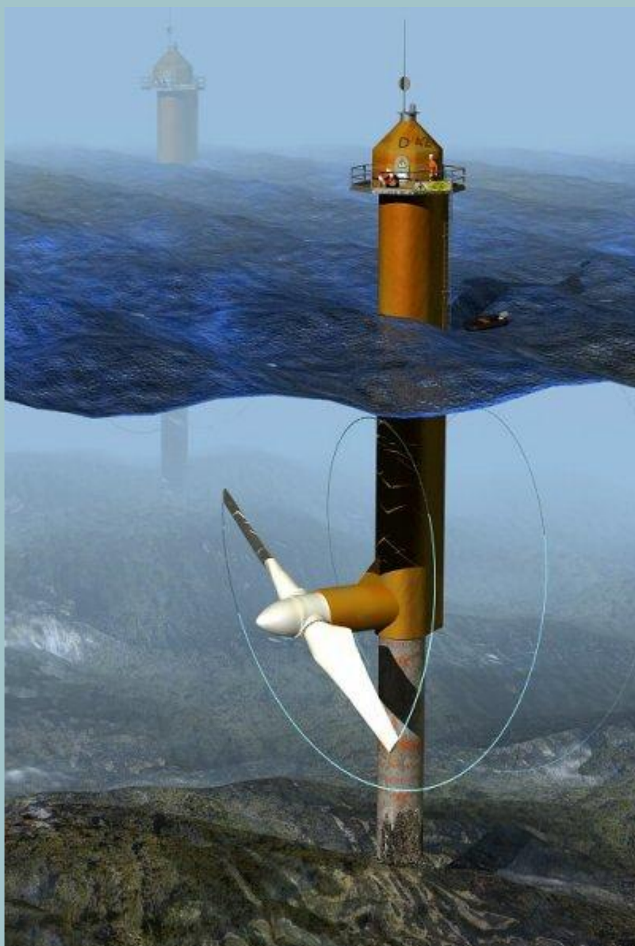
Tidal Power

- Tidal power generators derive their energy from movement of the tides.
- Obviously requires large bodies of water nearby.
- Has potential for generation of very large amounts of electricity, or can be used in smaller scale.
- Tidal power is not a new concept and has been used since at least the 11th Century in Britain and France for the milling of grains.
- There are a number of places around the world that have adopted pilot projects for different types of tidal generators

Barrage Tidal power



Tidal turbines



DISADVANTAGES

- Presently costly
  - Expensive to build and maintain
  - A 1085MW facility could cost as much as 1.2 billion dollars to construct and run
- Connection to the grid
- Technology is not fully developed

Advantages

- The energy is free – no fuel needed, no waste produced
- Not expensive to operate and maintain
- Can produce a great deal of energy

HYDROGEN AS ENERGY

- The first element on the periodic table
- The lightest, most explosive and most abundant element on Earth
- These characteristics make it useful for lifting and as an explosive i.e. the Hydrogen Bomb

HYDROGEN AS ENERGY

- existing freely in nature
- an invisible, extremely flammable gas
- highly reactive and essential in many chemical and biological processes
- not an energy source, but rather an energy carrier from which a secondary form of energy must be created

CHARACTERISTICS

- Hydrogen is the most abundant substance within the universe, making up 3/4 of all matter.
- The sun still being in the early stages of it's life is made up of 75% hydrogen.
- Millions of years ago Hydrogen reacted to produce Helium and all the energy was emitted to space, but a small amount was captured on Earth by plants that had died and have now become the fossil fuels that are now the basis of today's leading world industry.

SOURCES OF HYDROGEN

Sources that Hydrogen can be extracted from:

- Natural Gas, Water, Coal, Gasoline, Methanol, Biomass

- Other sources being researched include the uses of solar energy, photosynthesis, decomposition, and fuel cells themselves can tri-generate electricity, heat, and hydrogen

HYDR0GEN PR0DUCTI0N

- H is difficult and costly to compress, store, and transport.
- It has one of the lowest energy densities of any fuel, 1/3rd of any natural gas.
- Hydrogen has major safety issues; it’s flammable over a wide range of concentrations and is very easily ignited.
- Hydrogen is one of the most leak prone gases, set to a strict set of regulations and standards.

HISTORY

- William Grove first experimented with electrolysis in 1839. This is the process of separating water into it's core elements: hydrogen and oxygen, in an attempt to produce an electrical current.

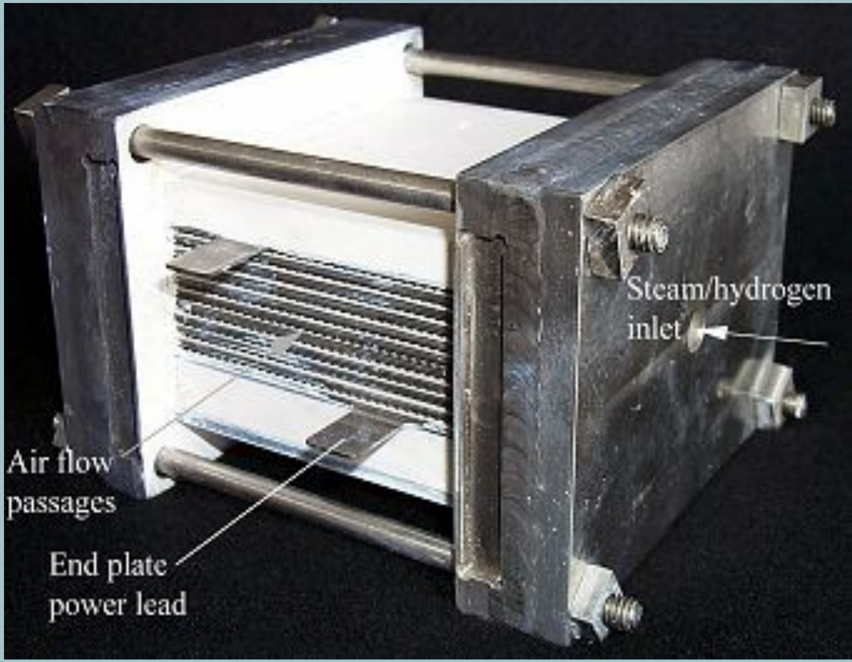
- 50 years later the term "fuel cell" would be coined for a modernized version of this process, and would be the birth of hydrogen power.

FUEL CELL: THE STARTUP

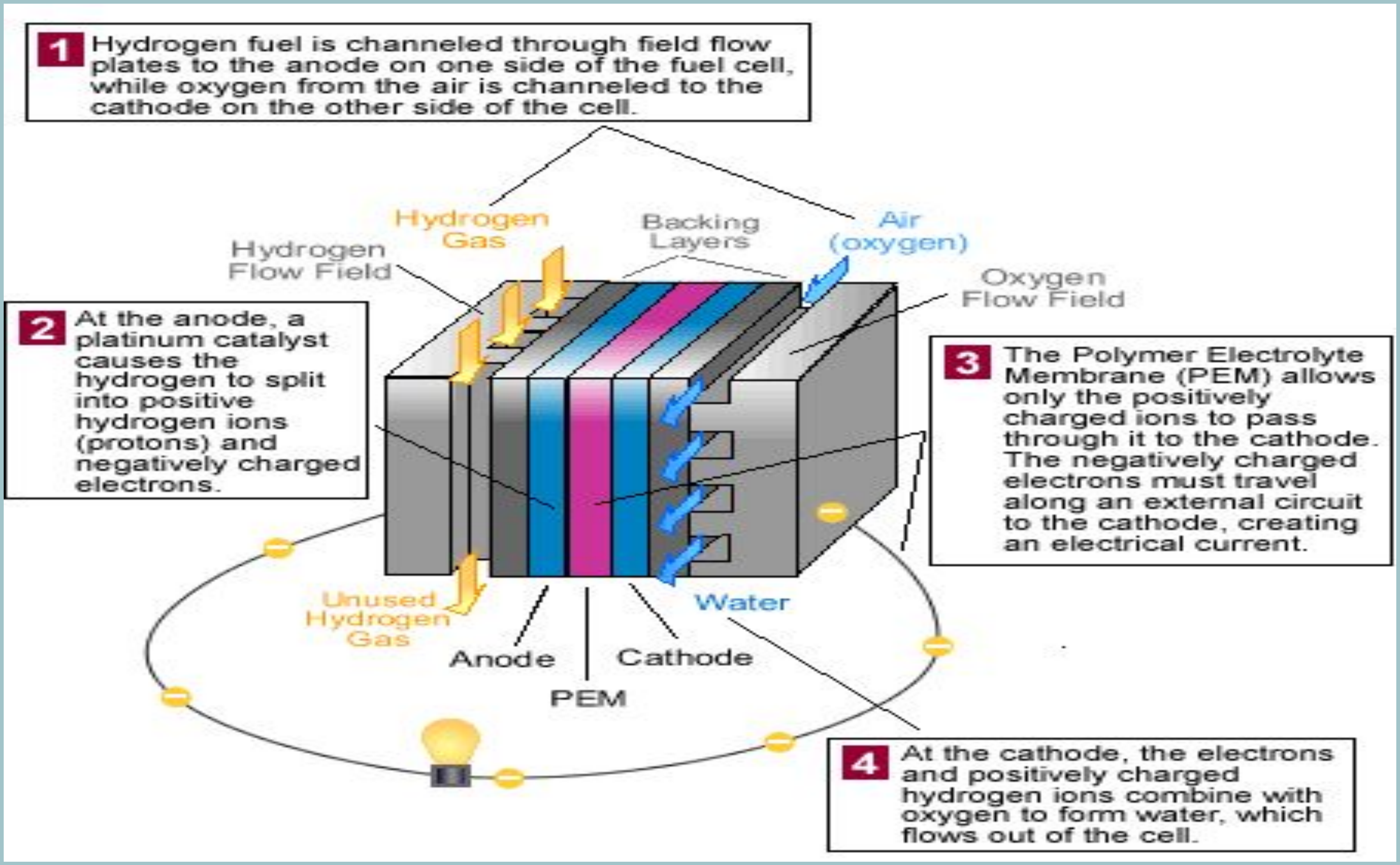
- Invented in 1839 by Sir William Grove
- Generate electrical power quietly and efficiently, without pollution
- Only byproducts are heat and water, unlike fossil fuels
- A fuel cell is an electrochemical conversion device: $H_2 + O_2$ = water and electricity

WHAT IS A HYDROGEN FUEL CELL?

- Hydrogen fuel cells (HFCs) are a type of electrochemical cell.
- HFCs generate electricity by reduction and oxidation reactions within the cell.
- They use three main components, a fuel, an oxidant and an electrolyte.
- HFCs operate like batteries, although they require external fuel.
- HFCs are a thermodynamically open system.
- HFCs use hydrogen as a fuel, oxygen as an oxidant, a proton exchange membrane as an electrolyte, and emit only water as waste.



H0W D0ES IT W0RK?



EFFICIENCY

- The reaction in a single fuel cell produces only 0.7 volts
- To bring the voltage up to a reasonable level, many separate fuel cells must be combined to form a fuel cell stack
- Bipolar plates are used to connect one fuel cell to another

USES OF HYDROGEN FUEL CELLS

- Power sources for vehicles such as cars, trucks, buses and even boats and submarines
- Power sources for spacecraft, remote weather stations and military technology
- Batteries for electronics such as laptops and smart phones
- Sources for uninterruptable power supplies

PROBLEMS REGARDING HYDROGEN FUEL CELLS

- Lack of hydrogen infrastructure
  - Need for refueling stations
  - Lack of consumer distribution system
- Cost of hydrogen fuel cells
  - 2009 Department of Energy estimated $61/Kw
- Problems with HFC cars
  - Short range (~260 miles)
  - Warm up time (~5 minutes)

DURABILITY

- Cell membranes must be durable and function at extreme temperatures
- cars start and stop frequently - important for membranes to remain stable under cycling temperature.
- The membranes used now tend to degrade when fuel cells are turned on and off

THE PROS AND CONS OF HYDROGEN

- Abundant- will never deplete.
- Will be a viable replacement for fossil fuel.
- Used widely in industry with much experience.
- Can be generated by renewable energy.
- It's only emission is pure, drinkable water.

- One gallon of hydrogen produces an equal amount of energy as 1/4 gallon of gasoline.
- Difficult to extract
- Expensive, renewables more so
- Flammable, leak-prone
- Strict standards

HYDRO POWER

1) One of the most widely used renewable source of energy for generating electricity on large scale basis is hydropower

2) The power obtained from river or ocean water is called as hydropower

3) Hydropower is the renewable source of energy since water is available in large quantities from rain, rivers, and oceans and this is will be available for unlimited time to come

HISTORY

- Nearly 2000 years ago the Greeks used water wheels to grind wheat into flour

- In the 1700's, hydropower was broadly used for milling of lumber and grain and for pumping irrigation water

- Appleton, Wisconsin became the first operational hydroelectric generating station in the United States, in 1882, producing 12.5 kilowatts (kW) of power
- The total electrical capacity generated was equivalent to 250 lights

- The largest and last masonry dam built by the U.S. Bureau of Reclamation was the Roosevelt Dam in Arizona between 1905-1911; its power output has increased from 4,500 kW to 36,000 kW

- Still in use today, Niagra Falls was the first hydropower site developed for a vast quantity of electricity

Based on Quantity of Water Available

1) Run-off river hydro plants with pond

2) Run-off river hydro plants with pond

3) Reservoir hydroelectric power plants

Based on the Head of Water Available

1) Low head hydroelectric power plants

2)Medium head hydroelectric power plants

3) High head hydroelectric power plants

Based on the Nature of Load

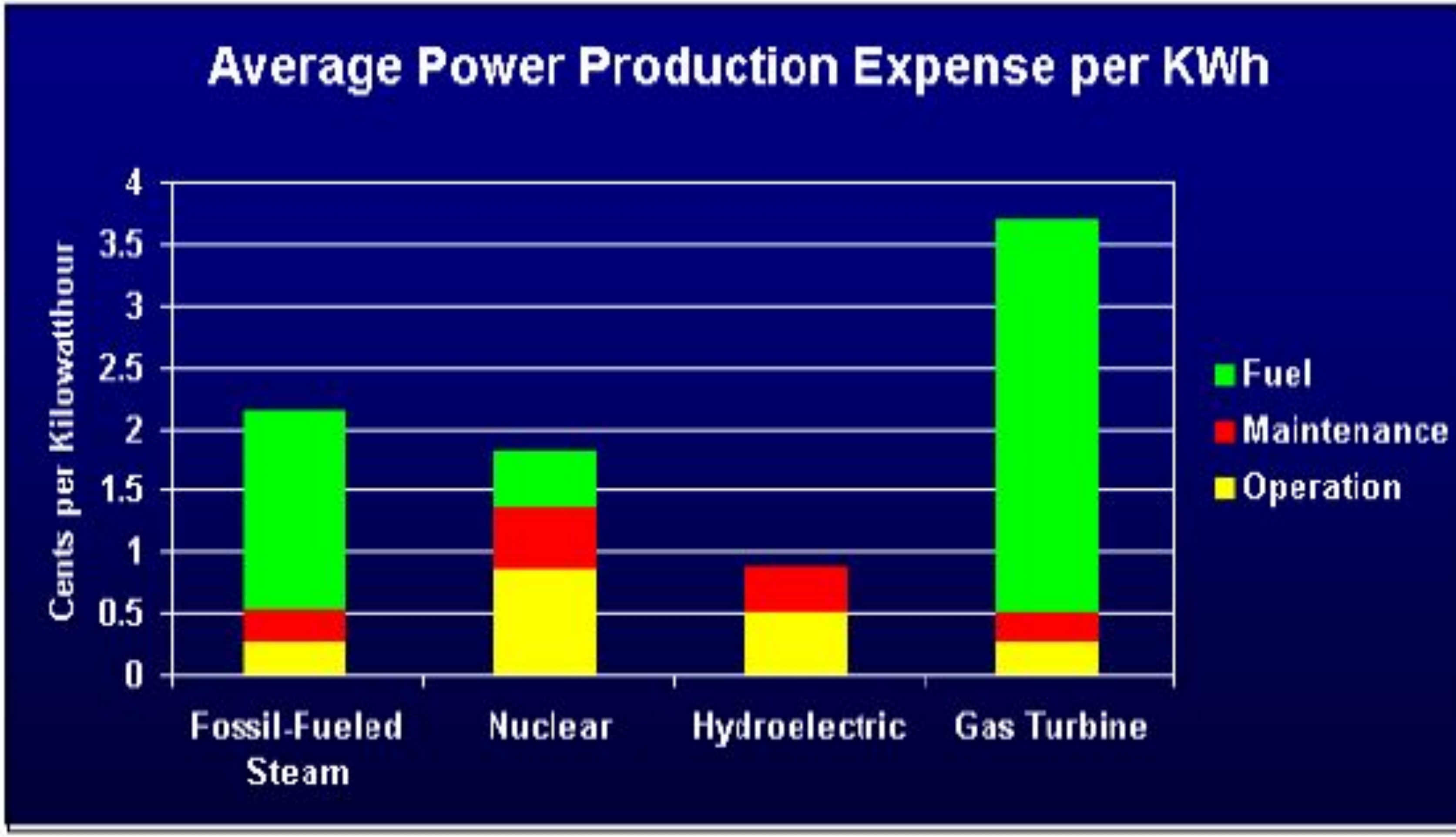
1) Base load hydroelectric power plants

2) Peak load hydroelectric power plants

List Of Hydro Electric Power Stations In The Country With Station Capacity Above 25 MW as On 30 June 2013

REGION/	NO.OF STATIONS	NO.OF UNITS	CAPACITY (MW)
Northern	61	206	15523.25
Western	28	101	7392.00
Southern	67	240	11387.45
Eastern	18	65	4078.70
North Eastern	10	29	1242.00
All India (Total)	**184**	**606**	**39623.40**

Cost factor in Hydropower



Advantages

1) No fuel required
2) Cost of electricity is constant
3) No air-pollution is created
4) Long life
5) Cost of generation of electricity
6) Can easily work during high peak daily loads
7) Irrigation of farms
8) Water sports and gardens
9) Prevents floods

Disadvantages

1) Disrupts the aquatic ecosystems
2) Disruption in the surrounding areas
3) Requires large areas
4) Large scale human displacement
5) Very high capital cost or investment
6) High quality construction
7) Site specific
8) Effects on environment
9) Safety of the dams

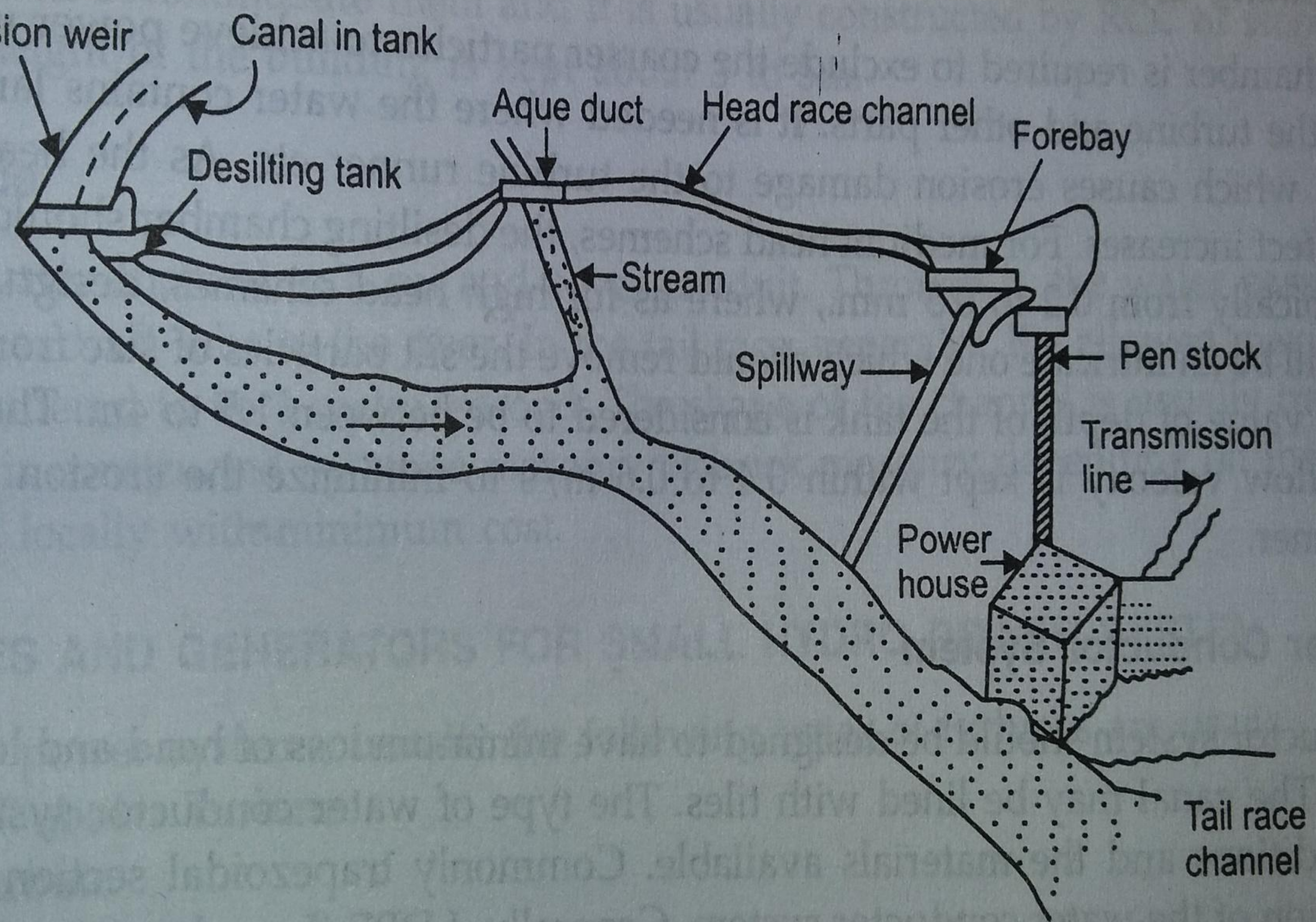


Fig. 8.3.1: Typical Arrangement of Small Hydro Power Station

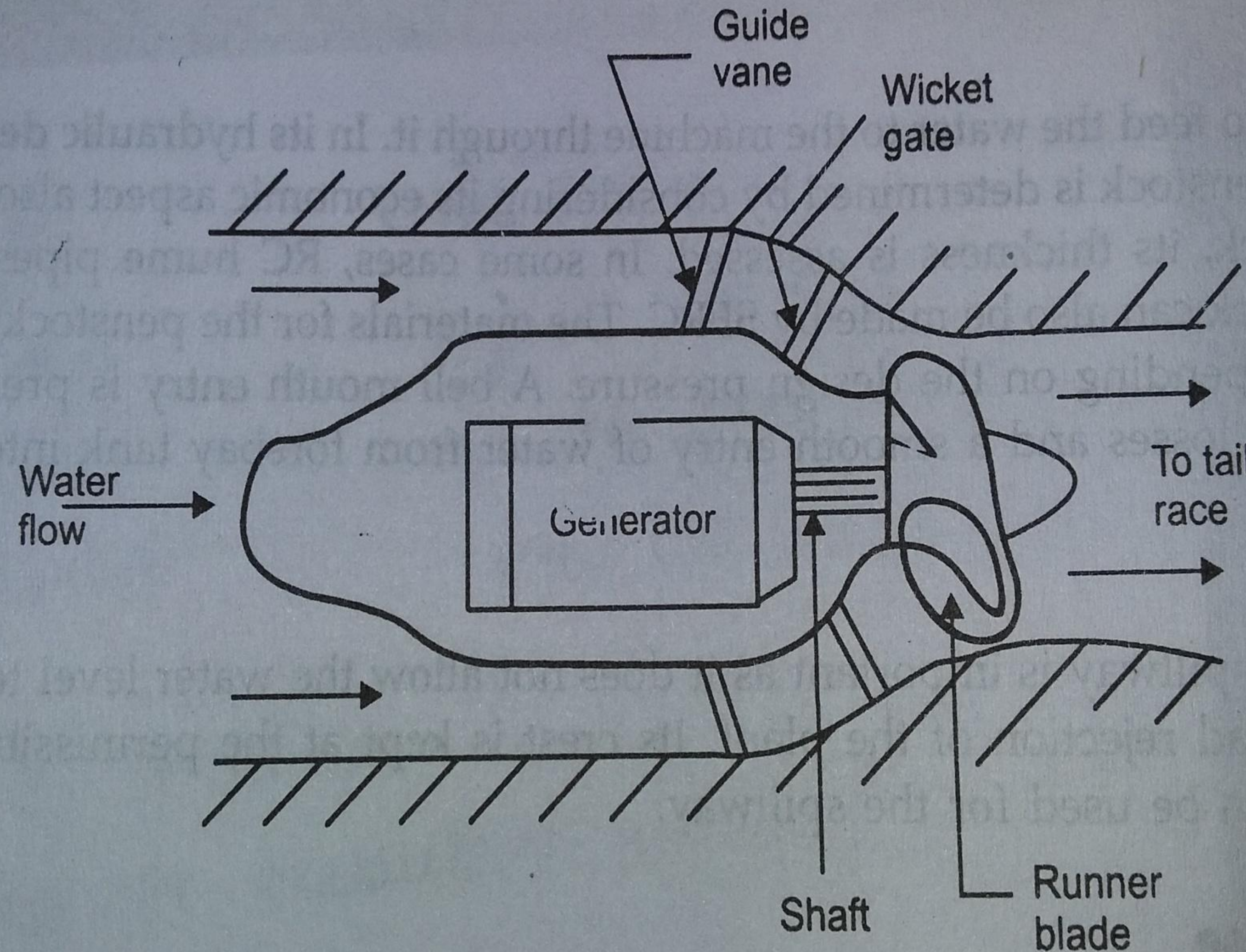


Fig 8.4.1: Bulb Turbine

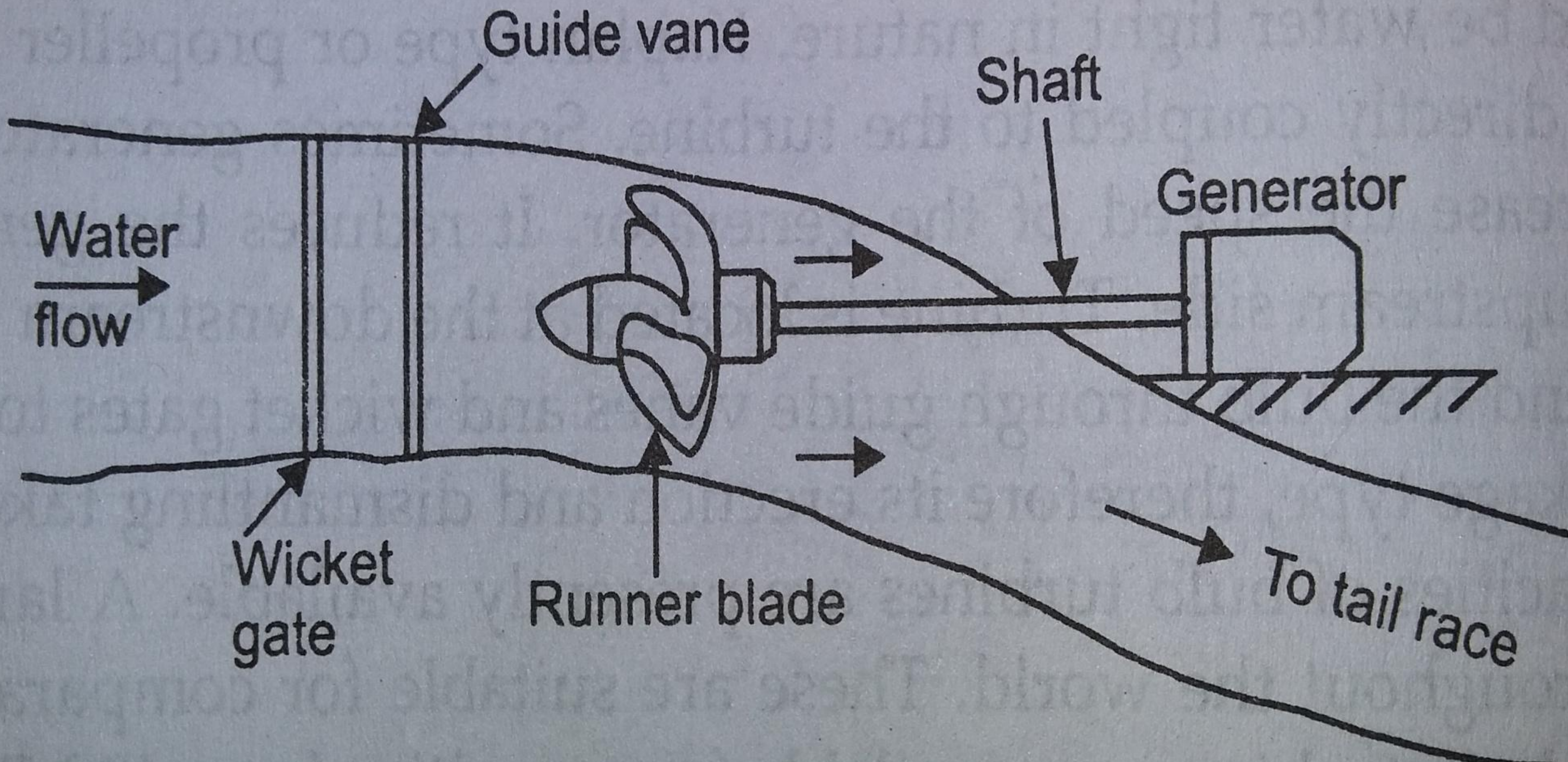


Fig. 8.4.2: Tube Turbine