POWER PLANTS

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Types of power plants

Based on various factors the power plants are classified as follows

1. ***On the basis of fuel used***
   - i. Steam Power Plant
     - a. condensing power plant
     - b. non-condensing power plant
   - ii. Diesel power plant
   - iii. Nuclear power plant
   - iv. Hydro electric power plant
   - v. Gas-turbine power plant
2. ***On the basis of nature of load***
   - i. Base load plant
   - ii. Peak load power plant
3. ***On the basis of location***
   - i. Central power station
   - ii. Captive power station
4. ***On the basis of service rendered***
   - i. Stationary
   - ii. Locomotive

In other way, the power plants can be classified on the basis of fuel resource type namely,

(i) Conventional power plants

(ii) Non-conventional power plants

Steam power plants

Steam Power Plant

- Steam is an important medium of producing mechanical energy.
- Steam has the advantage that it can be raised from water which is available in abundance it does not react much with the materials of the equipment of power plant and is stable at the temperature required in the plant.
- Steam is used to drive steam engines, steam turbines etc. Steam power station is most suitable where coal is available in abundance.
- Thermal electrical power generation is one of the major method.
- Out of total power developed in India about 60% is thermal.
- For a thermal power plant the range of pressure may vary from 10 kg/cm^2 to super critical pressures and the range of temperature may be from 250°C to 650°C.

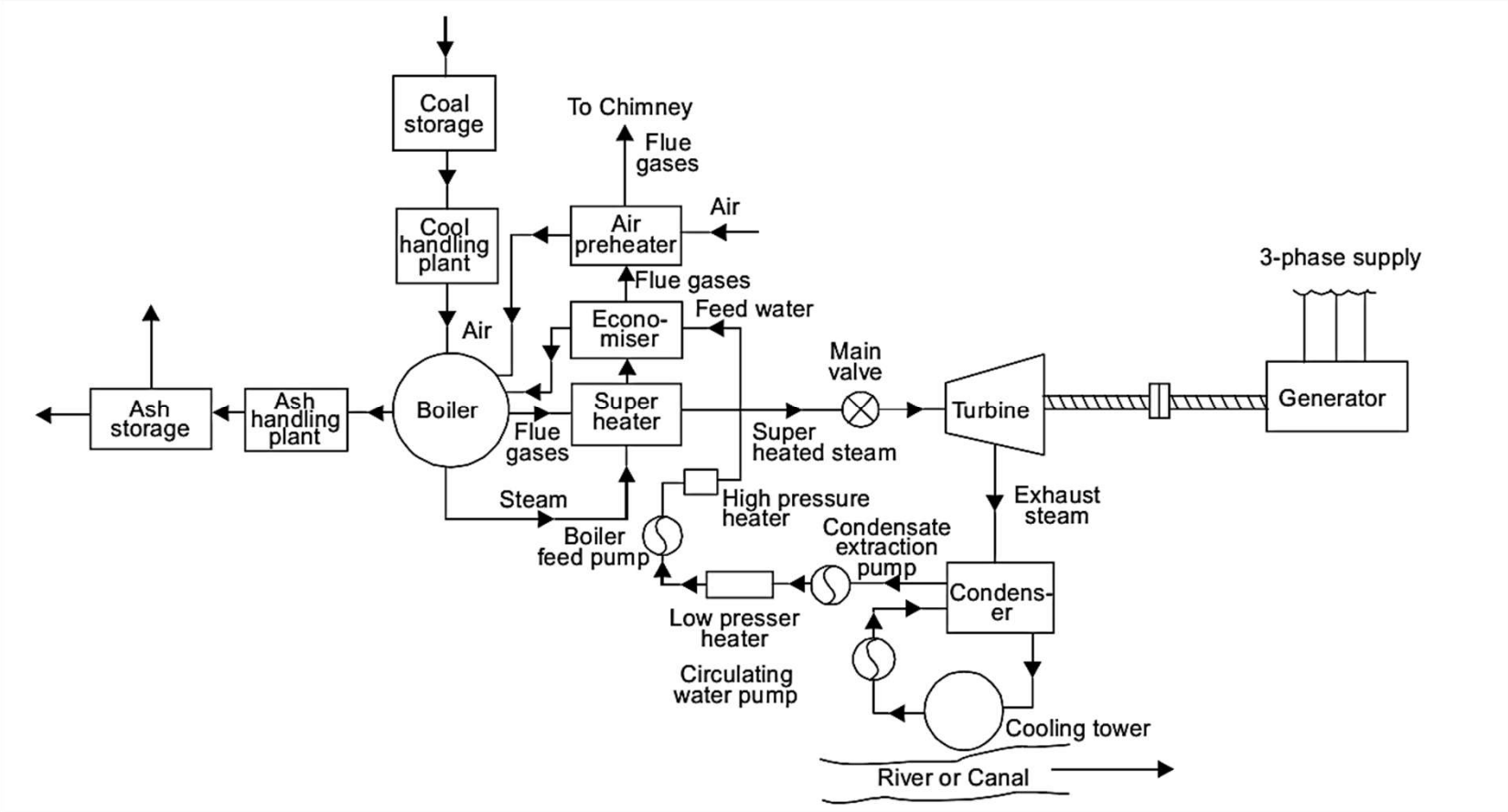
Steam Power Plant Equipment

The major equipment of the steam power plants are as follows

i. A furnace to burn the fuel.
ii. Steam generator or boiler containing water.
iii. Main power unit such as an engine or turbine to use heat energy of steam and perform work.
iv. Piping system to convey steam and water.

- In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.
- The flow sheet of thermal power plant consists of the following four main circuits
  a) Feed water and steam flow circuit
  b) Coal and ash circuit
  c) Air and gas circuit
  d) Cooling water circuit
- A steam power plant using steam as working substance works basically on Rankine cycle.

Steam Power Plant



Components of steam power plant

The different types of systems and components in steam power plant are as follows

- High pressure boiler
- Prime mover (steam turbines)
- Condensers and cooling towers
- Coal handling system
- Ash and dust handling system
- Draught system
- Feed water purification plant
- Pumping system
- Air preheater, economizer, super heater, feed heaters

Types of boilers

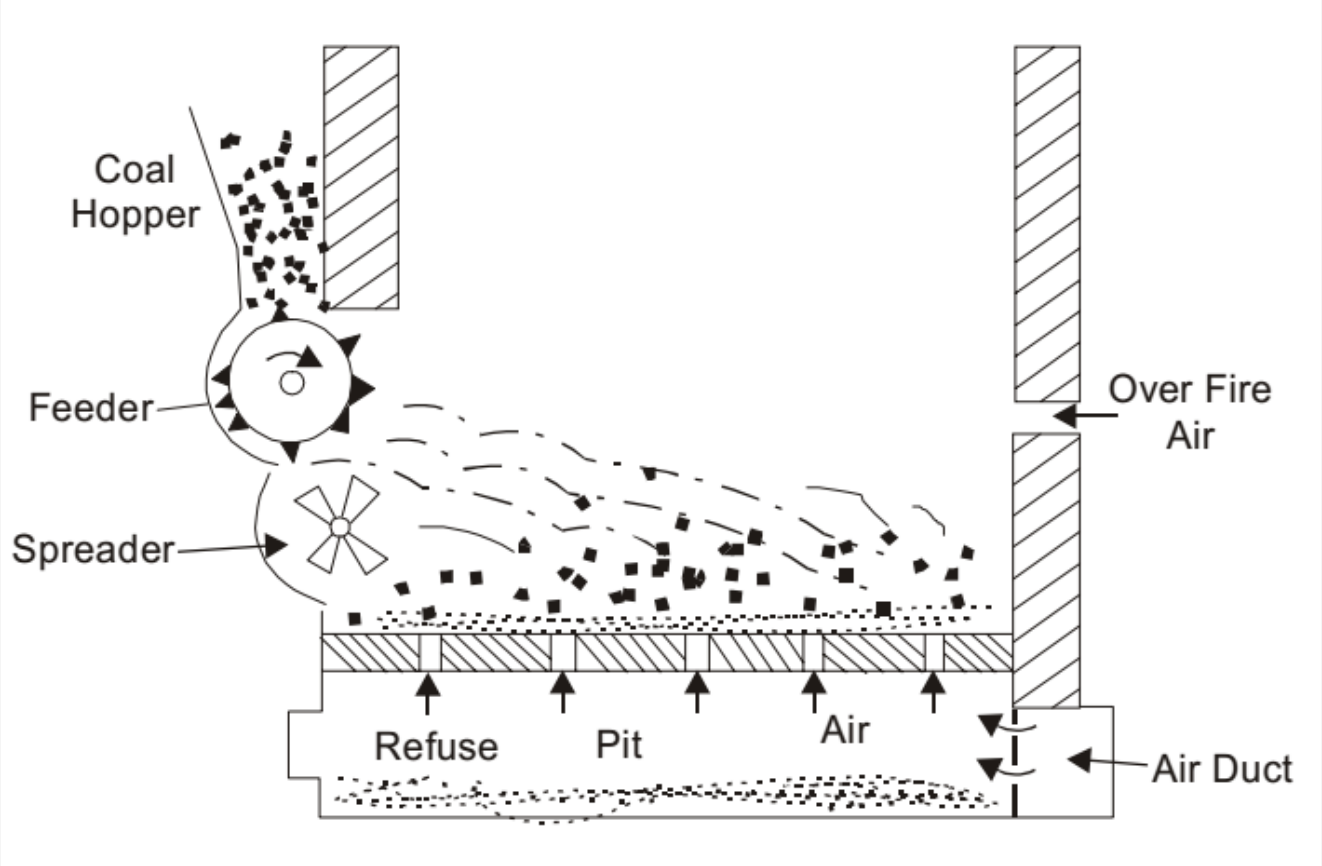
There are two general categories of boiler (***based on fluid in tube***) namely,

- Fire tube or "fire in tube"
- Water tube or "water in tube”

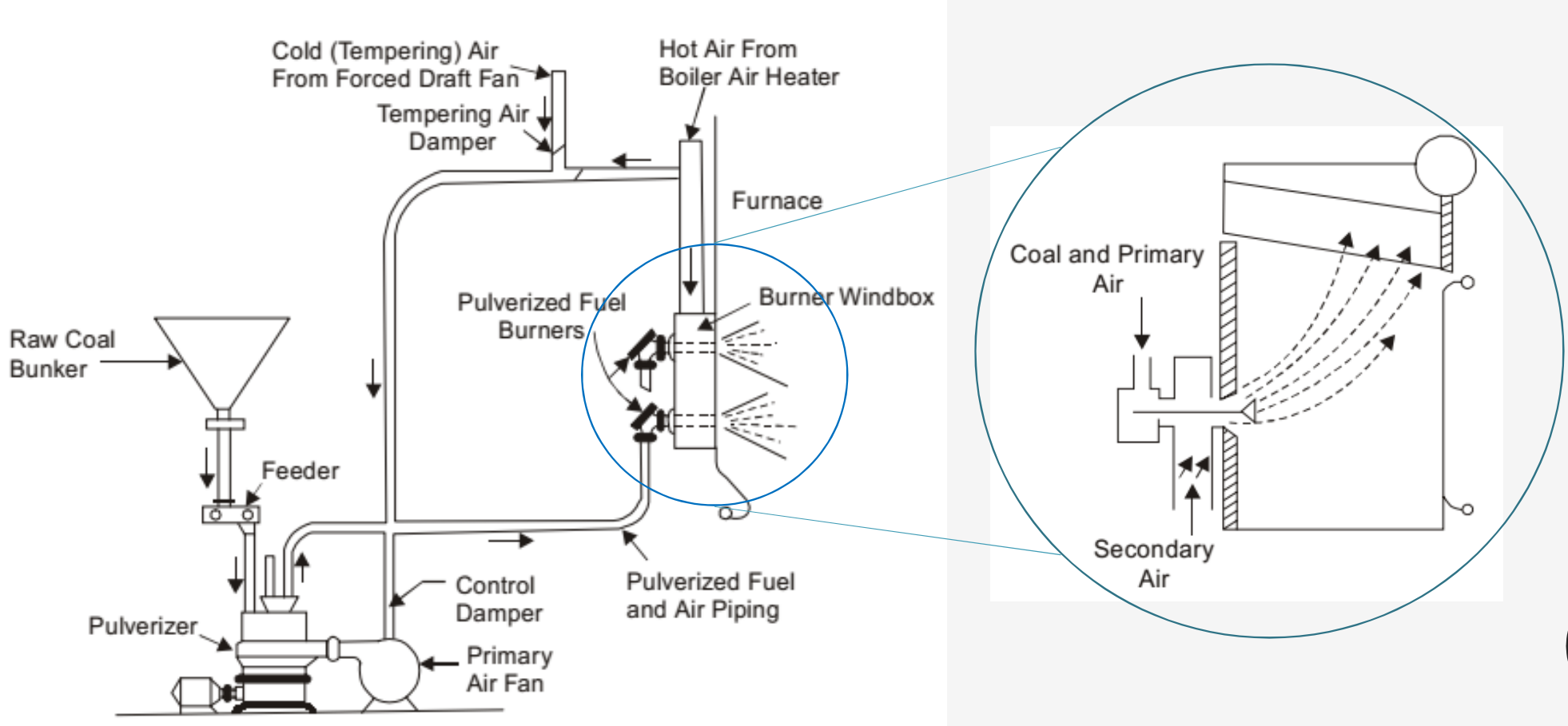
On the ***basis of feeding fuel*** to the furnace, boilers can be classified as

- Stoker fired boiler
- Pulverized fuel boiler
- Fluidised bed boiler

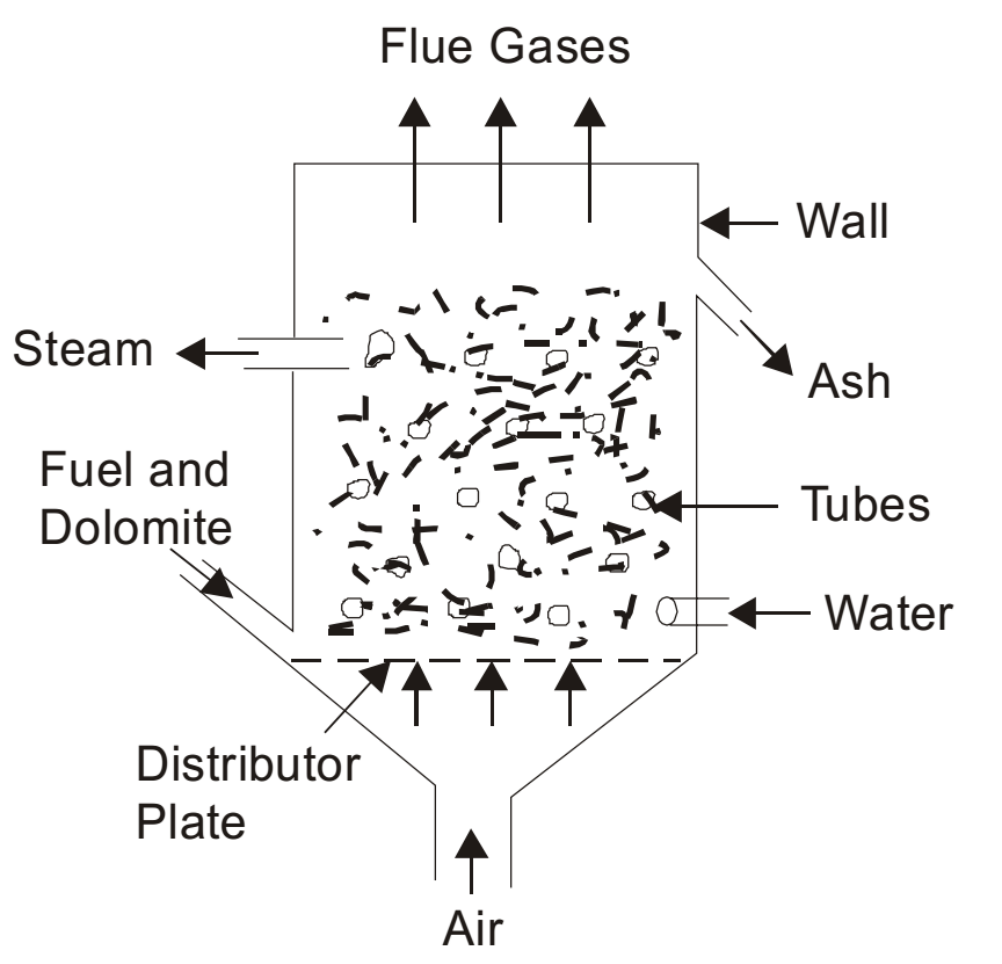
Stoker feed


Coal
Hopper
Feeder
Spreader
Over Fire
Air
Refuse
Pit
Air
Air Duct

Pulverised fuel boiler



Fluidised bed boiler



Power Plant Cycle

Power plant cycles are generally divided in to the following groups,

1. ***Vapour Power Cycle (used in steam power plants)***

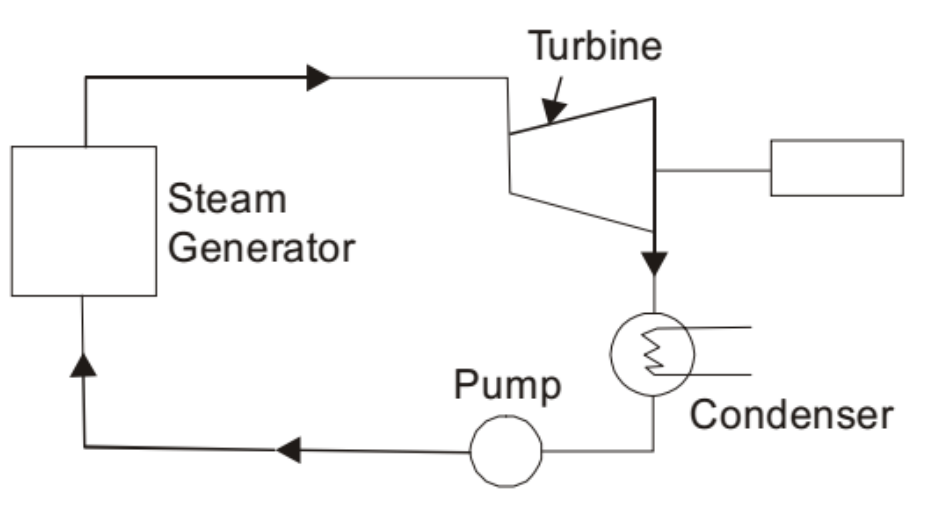
   Carnot cycle, Rankine cycle, Regenerative cycle, Reheat cycle, Binary vapour cycle

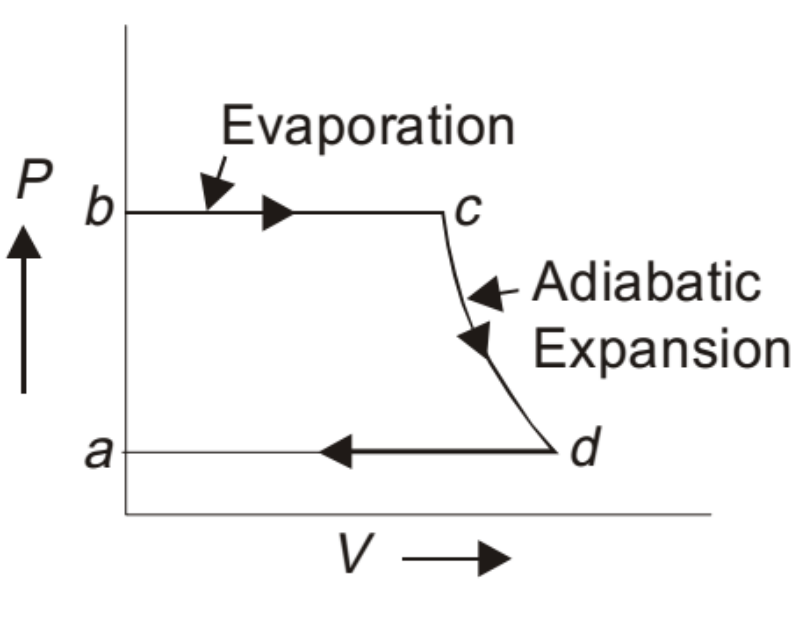
2. Gas Power Cycles

   Otto cycle, Diesel cycle, Dual combustion cycle, Gas turbine cycle

Rankine cycle – commonly used thermodynamic cycle

Steam engine and steam turbines in which steam is used as working medium follow Rankine cycle





Advantages of steam power plant

- The fuel (i.e., coal) used is quite cheap.
- Less initial cost as compared to other generating stations.
- It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
- It requires less space as compared to the hydroelectric power station.
- The cost of generation is lesser than that of the diesel power station.

Disadvantages of steam power plant

- It pollutes the atmosphere due to the production of large amount of smoke and fumes.
- It is costlier in running cost as compared to hydroelectric plant.
- It can only be used to supply the base load since it is slow to start and can not be used to cater for peak loads that generally occur for a short duration.

Start-up type	**Start-up time**
Very Hot start (<2 hours shutdown)	< 1 h
Hot start (2 to 8 hours shutdown)	1.5 – 2.5 h
Warm start (8 to 48 hours shutdown)	3 – 5 h
Cold start (>72 hours shutdown)	6 – 7 h

Diesel power plants

- The oil engines and gas engines are called Internal Combustion Engines.
- In IC engines, fuels burn inside the engine and the products of combustion form the working fluid that generates mechanical power.
- Whereas, in Gas Turbines the combustion occurs in another chamber and hot working fluid containing thermal energy is admitted in turbine.
- Usually diesel (oil) power plants are used as peak load supplement, being steam power plants as the base load supplier.

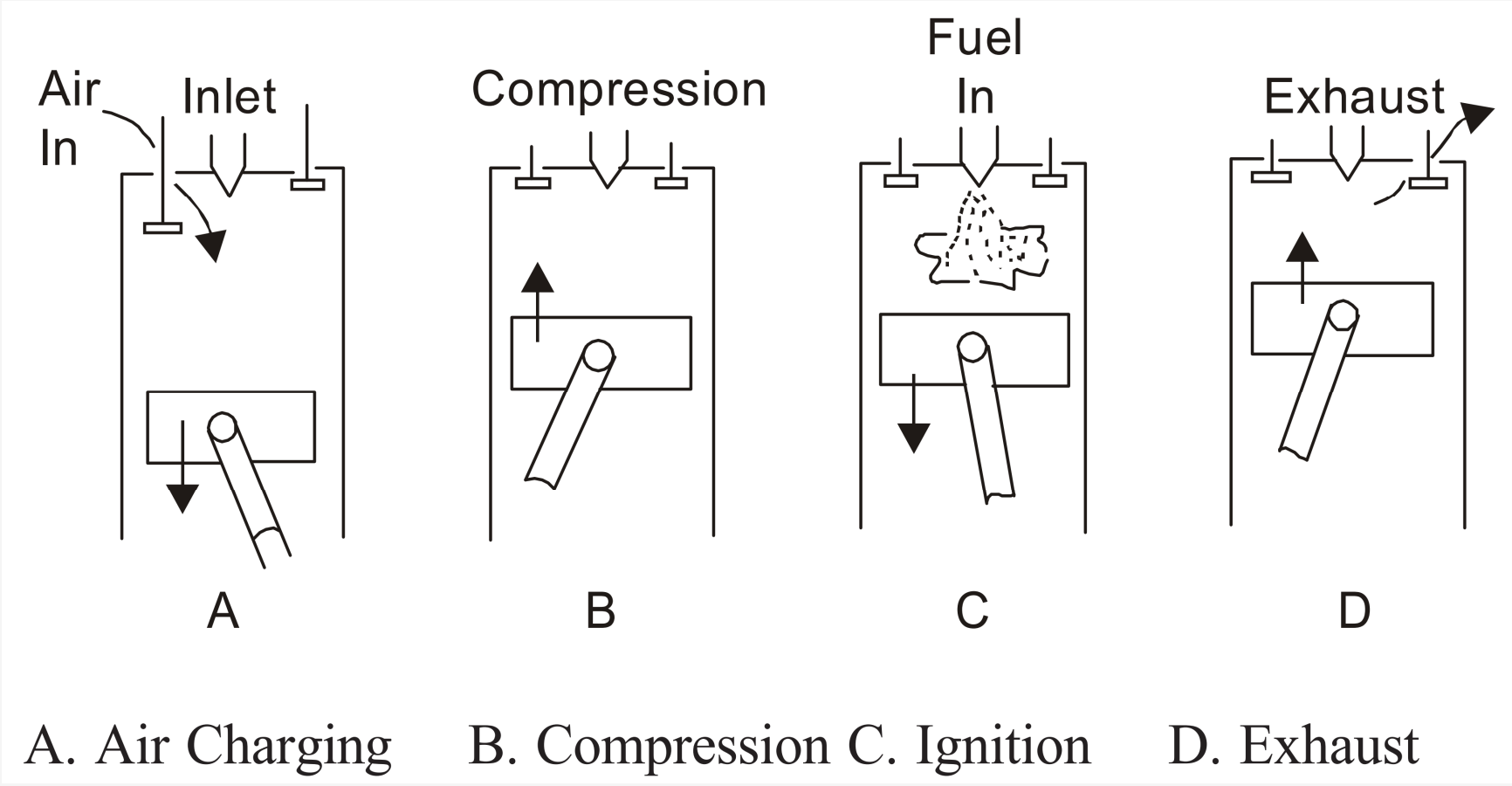
Application of diesel power plant

1. They are suitable for mobile power generation and are widely used in transportation systems consisting of railroads, ships, automobiles and aeroplanes.
2. They can be used for electrical power generation in capacities from 100 to 5000 H.P.
3. They can be used as standby power plants.
4. They can be used as peak load plants for some other types of power plants.
5. Industrial concerns where power requirement are small say of the order of 500 kW, diesel power plants become more economical due to their higher overall efficiency.

Working of a diesel (oil) engine

- The engines convert chemical energy in fuel into mechanical energy.
- A typical oil engine has:
    1. Cylinder in which fuel and air are admitted and combustion occurs.
    2. Piston, which receives high pressure hot products of combustion and the piston is forced to move in linear motion.
    3. Connecting rod, crankshaft linkage to convert reciprocating motion into rotary motion of shaft.
    4. Connected Load, mechanical drive, electrical generator.
    5. Suitable valves (ports) for control of flow of fuel, air, exhaust gases, fuel injection, and ignition systems.
    6. Lubricating system, cooling system
- In an engine-generator set, the generator shaft is coupled to the Engine shaft.

Operation of an I.C. Engine (4 stroke)



A. Air Charging B. Compression C. Ignition D. Exhaust

Advantage of diesel power plant

The advantages of diesel power plants are listed below.

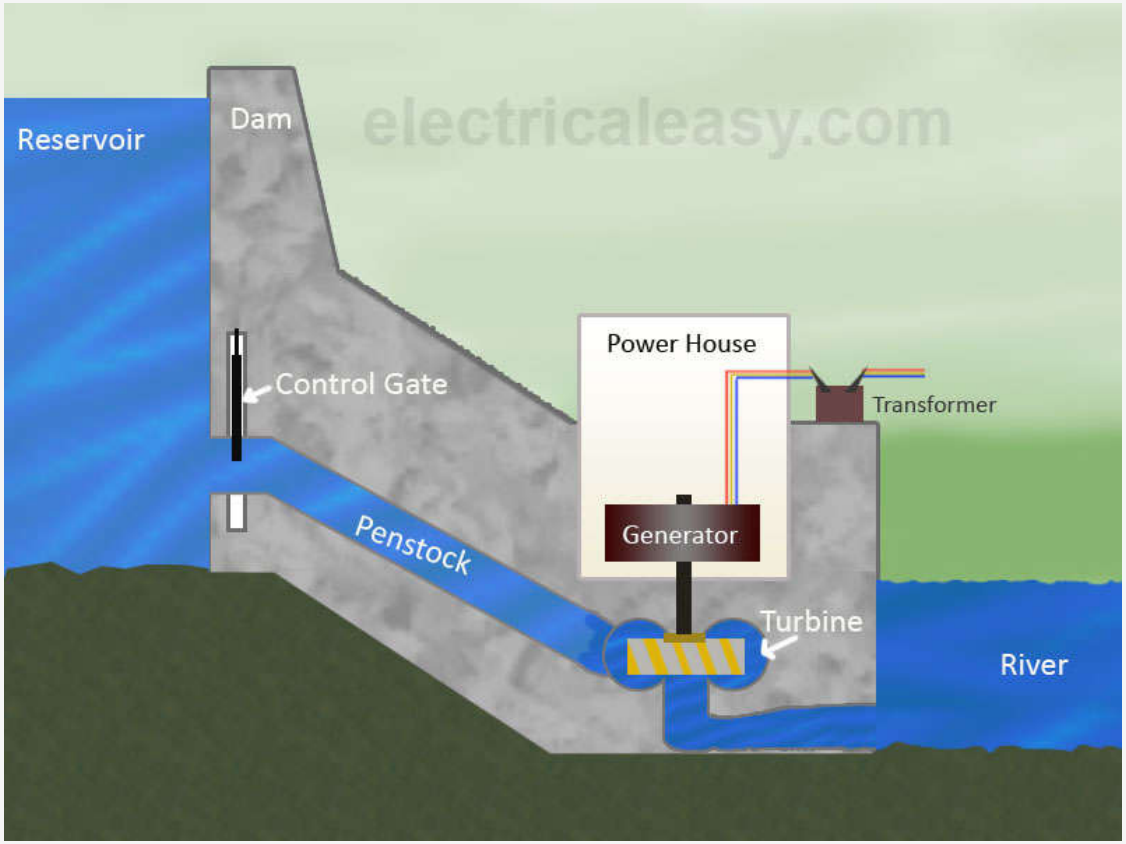
1. Very simple design also simple installation.
2. Limited cooling water requirement.
3. Quickly started and put on load.
4. Smaller storage is needed for the fuel.
5. Layout of power plant is quite simple.
6. There is no problem of ash handling.
7. Less supervision required.
8. For small capacity, diesel power plant is more efficient as compared to steam power plant.
9. They can respond to varying loads without any difficulty

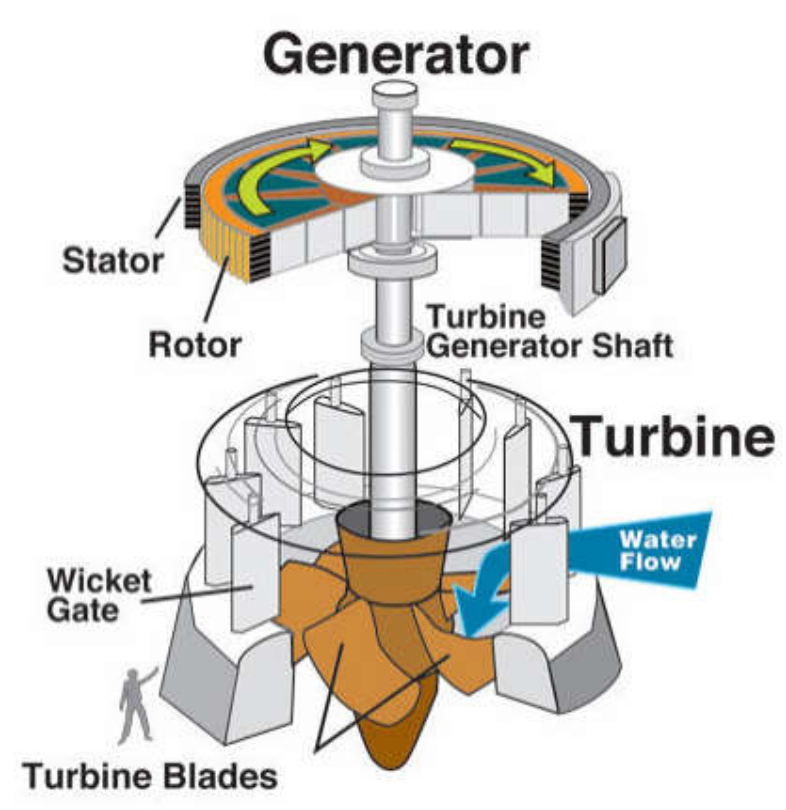
Disadvantage of diesel power plant

The disadvantages of diesel power plants are listed below.

1. High Maintenance and operating cost.
2. Fuel cost is more, since in India diesel is costly.
3. The plant cost per kW is comparatively more.
4. The life of diesel power plant is small due to high maintenance.
5. Noise is a serious problem in diesel power plant.
6. Diesel power plant cannot be constructed for large scale.

Hydro-power plant





Hydro-power plant

- Water surface in the storage reservoir is known as head race level or simply headrace.
- Penstocks or canals are used to bring water from the dam of the turbines fitted in the power house which is built at some lower level.
- Penstocks are made up of steel, wood or reinforced concrete.
- Water enters the turbine through the inlet valve.
- Hydraulic turbines convert the potential energy of water into mechanical energy.
- The mechanical energy developed by the turbine is used in running the electric generator which is directly coupled to shaft of the turbine.

Essential Feature or Elements of Hydro-electric Power Plant

The essential elements of hydro-electric power plant are as follows

I. Reservoir
II. Dam
III. Forebay
IV. Trash rack
V. Water way
VI. Draft tube
VII. Surge tank
VIII. Spill way
IX. Power house and equipment

Types of hydropower plant based on water supply

- **Run-of-river hydropower:**
  - a facility that channels flowing water from a river through a canal or penstock to spin a turbine.
  - used for continuous supply of base load
- **Storage hydropower:**
  - typically a large system that uses a dam to store water in a reservoir.
  - Electricity is produced by releasing water from the reservoir through a turbine, which activates a generator.
- **Pumped-storage hydropower:**
  - provides peak-load supply, harnessing water which is cycled between a lower and upper reservoir by pumps which use surplus energy from the system at times of low demand.
- **Offshore hydropower:**
  - a less established but growing group of technologies that use tidal currents or the power of waves to generate electricity from seawater

Types of hydro power plant based on capacity

- **Large Hydropower**

Although definitions vary, DOE defines large hydropower as facilities that have a capacity of more than 30 megawatts (MW).

- **Small Hydropower**

Although definitions vary, DOE defines small hydropower as projects that generate 10 MW or less of power.

- **Micro Hydropower**

A micro hydropower plant has a capacity of up to 100 kilowatts. A small or micro-hydroelectric power system can produce enough electricity for a home, farm, ranch, or village.

Types of hydropower based on water supply

Water power can be divided into two types as follows:
(i) Primary or firm power
(ii) Secondary or surplus power

- Primary power is the power corresponding to minimum stream flow with due consideration to the effects of pondage and load factor.
- It is the power always available to supply the load.
- The secondary power is available only when quantity of water and storage are sufficient.

Advantages of a hydroelectric power plant

- No fuel is required as potential energy is stored water is used for electricity generation
- Neat and clean source of energy
- Very small running charges - as water is available free of cost
- Serves other purposes too, such as irrigation
- Once a dam is constructed, electricity can be produced at a constant rate.
- If electricity is not needed, the sluice gates can be shut, stopping electricity generation.
- The water can be saved for use another time when electricity demand is high.
- Dams are designed to last many decades and so can contribute to the generation of electricity for many years / decades.
- The build up of water in the lake means that energy can be stored until needed, when the water is released to produce electricity.

Disadvantages of a hydroelectric power plant

- Dams are extremely expensive to build and must be built to a very high standard.
- High cost of transmission – as hydro plants are located in hilly areas which are quite away from the consumers
- The flooding of large areas of land means that the natural environment is destroyed.
- People living in villages and towns that are in the valley to be flooded, must move out.
- The building of large dams can cause serious geological damage by triggering earthquakes.
- Dams built blocking the progress of a river in one country usually means that the water supply from the same river in the following country is out of their control.
- This can lead to serious problems between neighbouring countries.
- Building a large dam alters the natural water table level and the constructions nearby.

Environmental impacts of hydropower project

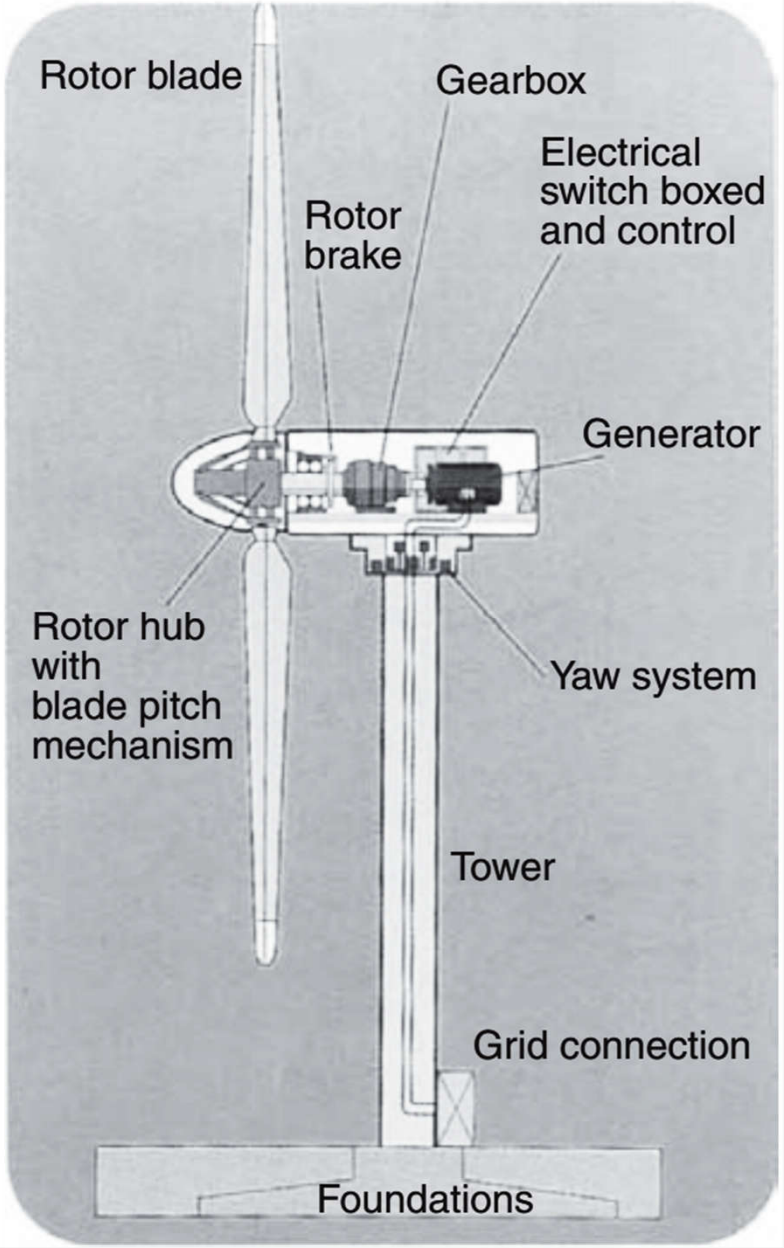
- Diverting large amounts of river water reduce river flows affecting water velocity and depth, minimizing habitat quality for fish and aquatic organisms; reduced flows can lead to excessively warm water for salmon and other fish in summer.
- New access roads and transmission lines can cause extensive habitat fragmentation for many species, making inevitable the introduction of invasive species and increases in undesirable human activities, like illegal hunting.
- Cumulative impacts – the sum of impacts caused not only by the project, but by roads, transmission lines and all other nearby developments – are difficult to measure.
- Cumulative impacts are an especially important consideration in areas where projects are clustered in high densities close to sources of electricity demand
- Water licenses – conflicts will arise over the water needed to both sustain aquatic life and generate power when river flow becomes more variable or decreases in the future

Wind power systems

Working of a wind turbine

- The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator.
- The turbine is mounted on a tall tower to enhance the energy capture.
- Numerous wind turbines are installed at one site to build a wind farm of the desired power generation capacity.

Horizontal axis wind turbine



Vertical axis wind turbine

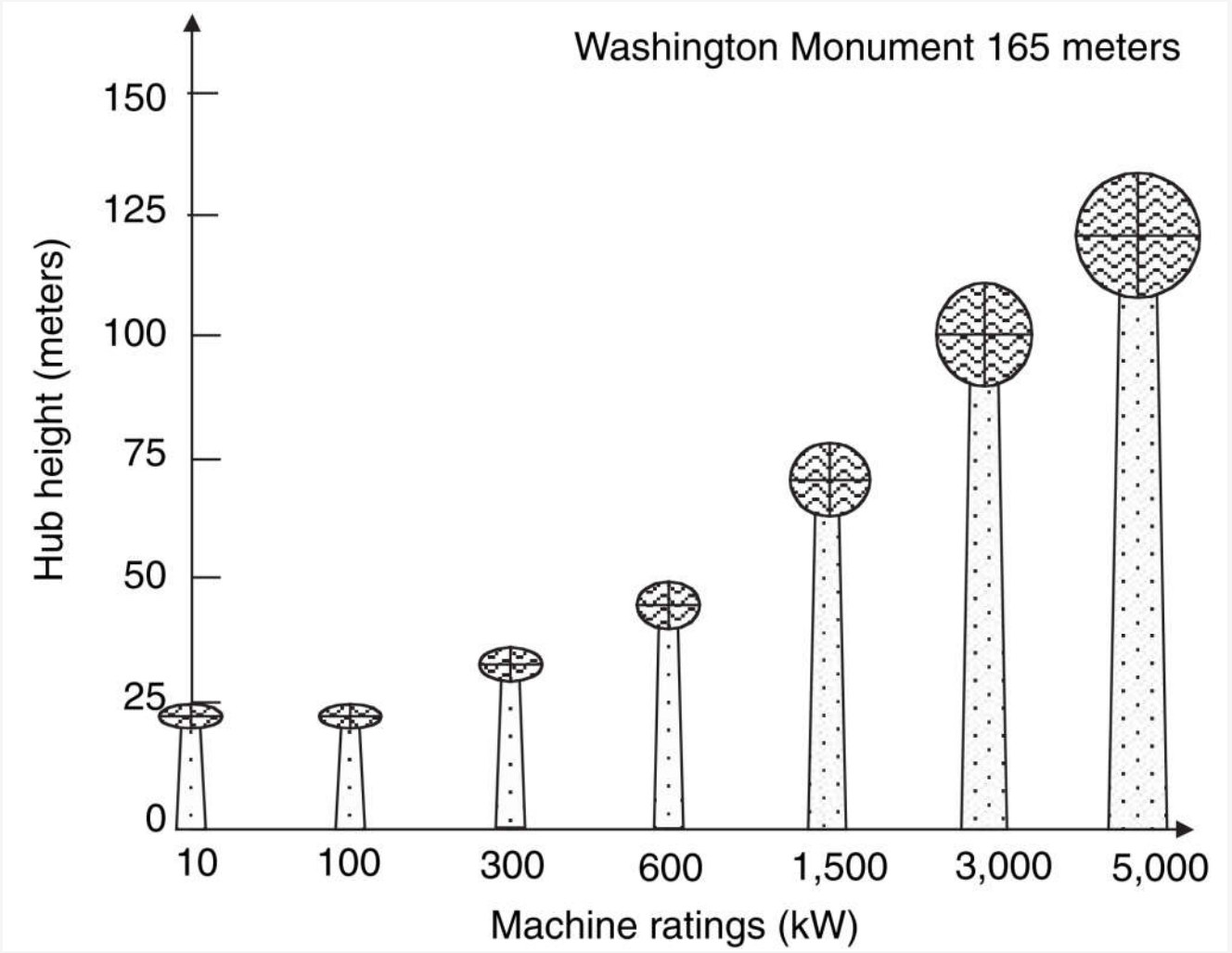
System components of a wind turbine

- Tower structure
- Rotor with two or three blades attached to the hub
- Shaft with mechanical gear
- Electrical generator
- Yaw mechanism, such as the tail vane
- Sensors and control

Additional components

- Anemometers, which measure the wind speed and transmit the data to the controller.
- Numerous sensors to monitor and regulate various mechanical and electrical parameters.
- A 1-MW turbine may have several hundred sensors.
- Stall controller, which starts the machine at set wind speeds of 8 to 15 mph and shuts off at 50 to 70 mph to protect the blades from overstressing and the generator from overheating.
- Power electronics to convert and condition power to the required standards.
- Control electronics, usually incorporating a computer.
- Battery for improving load availability in a stand-alone plant.
- Transmission link for connecting the plant to the area grid.

Tower heights and capacities of wind turbines



Speed control in wind turbines

- ***No speed control whatsoever:*** In this method, the turbine, the electrical generator, and the entire system are designed to withstand the extreme speed under gusty winds.
- ***Yaw and tilt control:*** The yaw control continuously orients the rotor in the direction of the wind. It can be as simple as the tail vane or more complex on modern towers. A controlled yaw is often required and used to reduce the noise generated during the tilt.
- ***Pitch control:*** This changes the pitch of the blade with changing wind speed to regulate the rotor speed. Large-scale power generation is moving towards variable-speed rotors with power electronics incorporating a pitch control.
- ***Stall control:*** At stall, the blades experience a high drag, thus lowering the rotor power output. This way, the blades are kept under the allowable speed limit in gusty winds. Once stalled, the turbine has to be restarted after the gust has subsided.

Comparison of fixed and variable speed systems

Fixed-Speed System	Variable-Speed System
Simple and inexpensive electrical system	Higher rotor efficiency, hence, higher energy capture per year
Fewer parts, hence, higher reliability	Low transient torque
Lower probability of excitation of mechanical resonance of the structure	Fewer gear steps, hence, inexpensive gear box
No frequency conversion, hence, no current harmonics present in the electrical system	Mechanical damping system not needed; the electrical system could provide damping if required
Lower capital cost	No synchronization problems
	Stiff electrical controls can reduce system voltage sags

Advantages of wind power systems

- First and foremost, wind is an unlimited, free, renewable resource.
- Wind is a natural occurrence and harvesting the kinetic energy of wind doesn't affect currents or wind cycles in any way.
- Wind energy is far more eco-friendly than the burning of fossil fuels for electricity, since they emit no air pollutants or greenhouse gases.
- Once turbines and energy centres have been installed, the cost of maintaining turbines and generating wind power is next to nothing.
- Another advantage of wind power is the ability to place turbines wherever necessary.
- Wind power locations are usually least populated or unpopulated (offshore wind turbines, for example).

Drawbacks of wind power systems

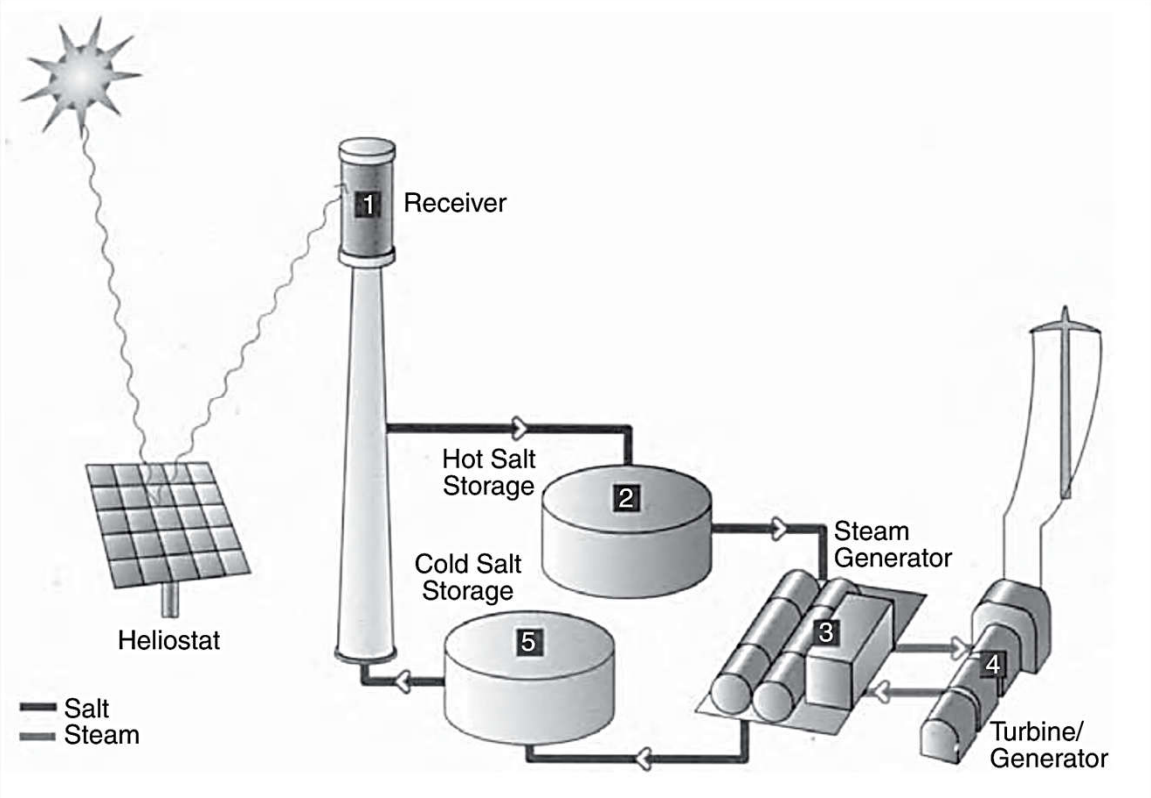
- Firstly, constructing turbines and wind facilities is extremely expensive.
- Payback time is longer than other power systems.
- Offshore wind energy produces more energy than onshore wind energy, but costs much more to establish.
- The second disadvantage is technology immaturity.
- New technology is needed to lower costs, increase reliability and energy production, solve regional deployment issues, expand the resource area, develop infrastructure and manufacturing facilities, and mitigate known environmental impacts.

Solar power plants

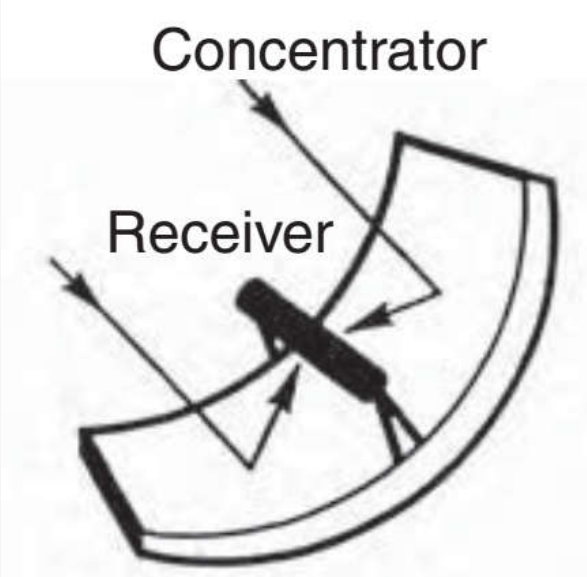
Solar power can be harnessed by the following installations

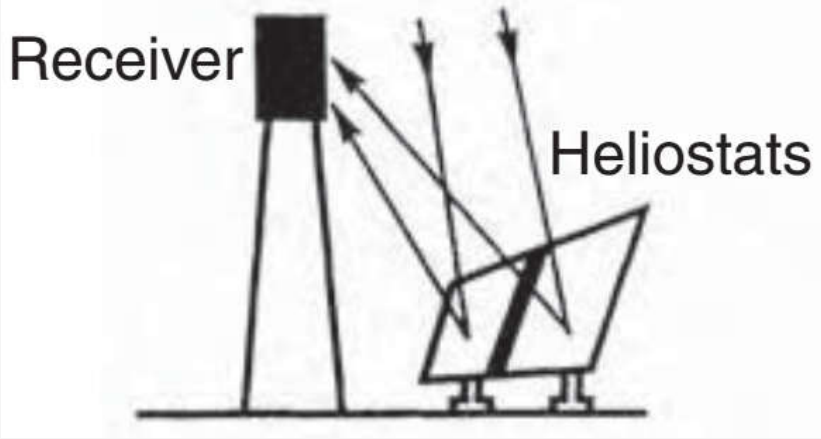
- Solar thermal power plants
- Photo-voltaic solar power plants

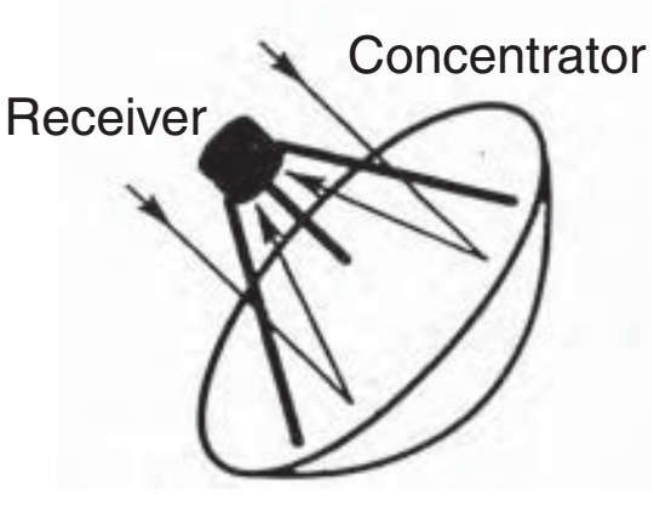
Solar thermal power plant



Types of energy collection technologies







(a) Trough **(b) Central Receiver** **(c) Dish**

Comparison of Alternative Solar Thermal Power System Technologies

Technology	Solar Concentration (x Suns)	Operating Temperature (Hot Side)	Thermodynamic Cycle Efficiency
Parabolic trough receiver	100	300–500°C	Low
Central receiver power tower	1000	500–1000°C	Moderate
Dish receiver with engine	3000	800–1200°C	High

Photovoltaic solar power systems

- Photovoltaic cells look similar to solar panels but they work in a different way.
- Solar panels are use to produce hot water or even steam.
- Photovoltaic panels convert the sunlight directly into electricity.
- Photovoltaic cells have been developed that will provide electrical power to pump drinking water from wells in remote villages.
- Often photovoltaic cells are used as a backup to conventional energy. If conventional fails the cells are used to produce electricity.
- Recently, numerus PV based solar power plants are being commissioned in large scales for commercial purposes.

Solar power plant (Hungary)

ADVANTAGES OF SOLAR POWER

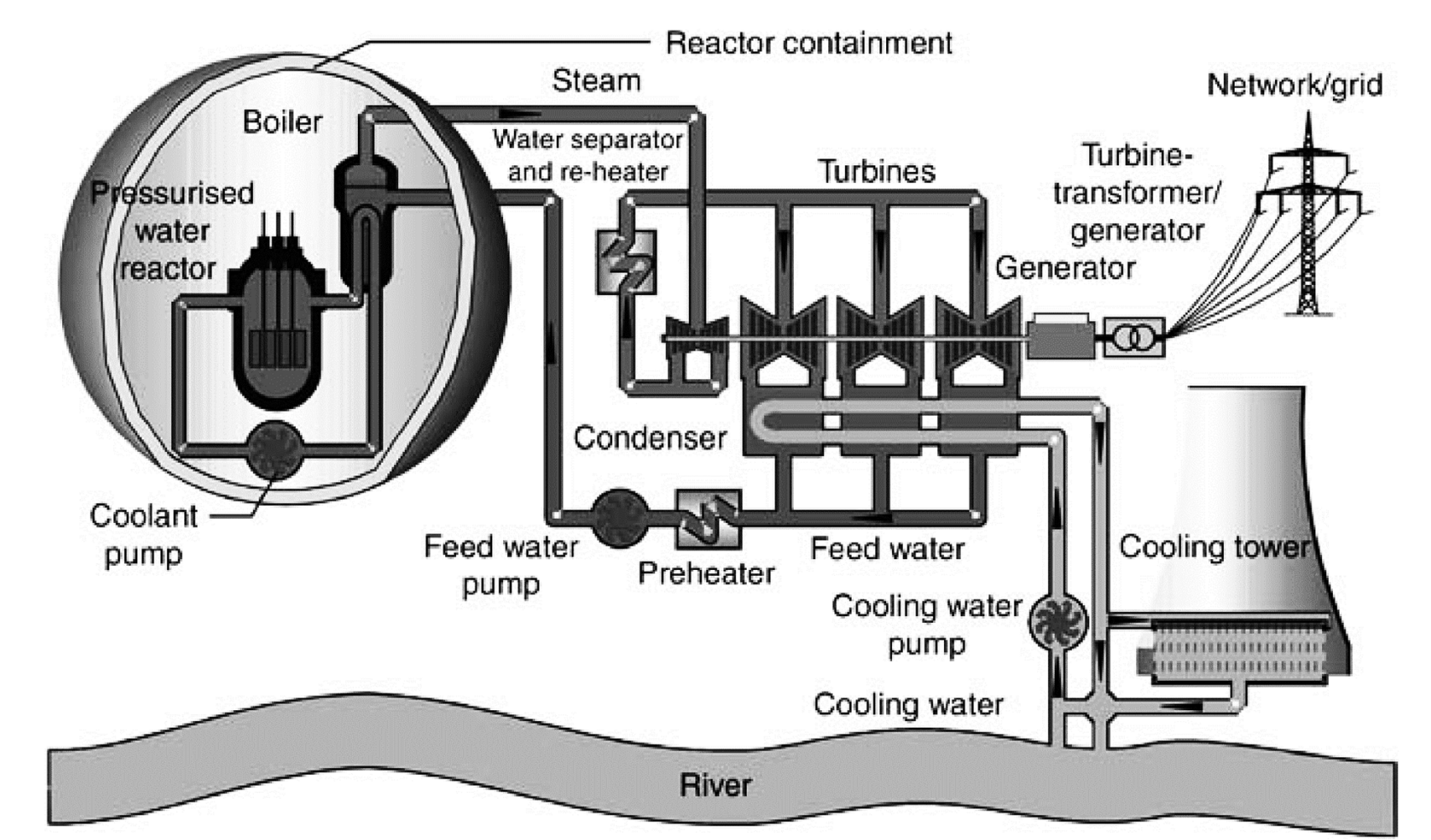
- Solar energy is free although there is a cost in the building of 'collectors' and other equipment required to convert solar energy into electricity or hot water.
- Solar power plants does not cause pollution.
- Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid.
- Reduced dependence on foreign oil and fossil fuels
- Renewable clean power that is available every day of the year, even cloudy days produce some power
- Return on investment unlike paying for utility bills
- Virtually no maintenance as solar panels last over 30 years
- Can be installed virtually anywhere; in a field or on a building

DISADVANTAGES OF SOLAR POWER

- Solar energy can only be harnessed when it is daytime and sunny.
- Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.
- Solar power stations can be built but they do not match the power output of similar sized conventional power stations.
- Large areas of land are required to capture the suns energy.
- Collectors are usually arranged together especially when electricity is to be produced and used in the same location.
- For the storage of solar power, large storage space is needed and they also need replacing from time to time.

NUCLEAR POWER PLANT

Nuclear power plant



Nuclear power plant

- A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction.
- Main components of a nuclear reactor are as follows
    I. Nuclear Fuel (Uranium, Thorium etc.)
    II. Moderator
    III. Control Rods
    IV. Reflector
    V. Reactors Vessel
    VI. Biological Shielding
    VII. Coolant

Moderator

- In the chain reaction the neutrons produced are fast moving neutrons.
- These fast moving neutrons are far less effective in causing the fission of U^{235} and try to escape from the reactor.
- To improve the utilization of these neutrons their speed is reduced.
- It is done by colliding them with the nuclei of other material which is lighter, does not capture the neutrons but scatters them.
- Each such collision causes loss of energy, and the speed of the fast moving neutrons is reduced.
- Such material which moderates the neutron speed is called Moderator.

Control rods

- Control rods in the cylindrical or sheet form are made of boron or cadmium.
- These rods can be moved in and out of the holes in the reactor core assembly.
- Their insertion absorbs more neutrons and damps down the reaction and their withdrawal absorbs less neutrons.
- Thus power of reaction is controlled by shifting control rods which may be done manually or automatically.

Reflector

- The neutrons produced during the fission process will be partly absorbed by the fuel rods, moderator, coolant or structural material etc.
- Neutrons left unabsorbed will try to leave the reactor core never to return to it and will be lost. Such losses should be minimised.
- It is done by surrounding the reactor core by a material called reflector which will send the neutrons back into the core.
- The returned neutrons can then cause more fission and improve the neutrons economy of the reactor.
- Generally the reflector is made up of graphite and beryllium.

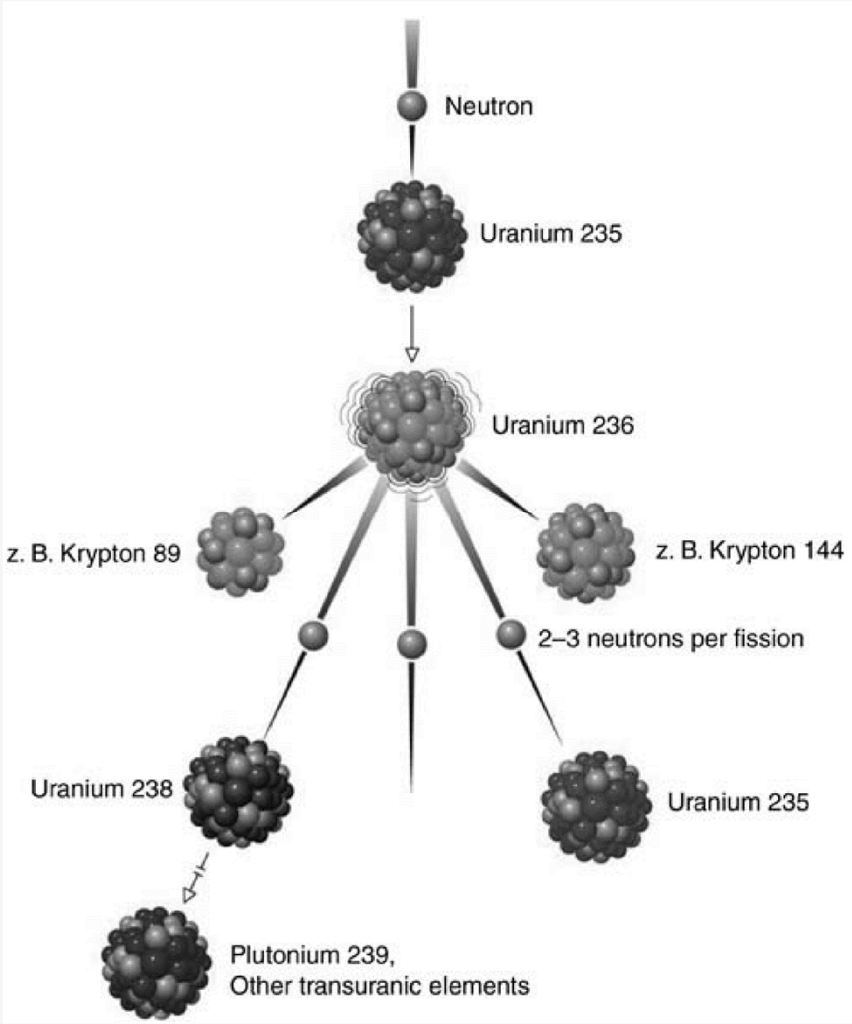
Biological Shielding

- Shielding the radioactive zones in the reactor from possible radiation hazard is essential to protect, the operating men from the harmful effects.
- During fission of nuclear fuel, alpha particles, beta particles, deadly gamma rays and neutrons are produced.
- Out of these, neutrons and gamma rays are of main significance and a protection must be provided against them.
- Thick layers of lead or concrete are provided all round the reactor for stopping the gamma rays.
- Thick layers of metals or plastics are sufficient to stop the alpha and beta particles.

Chain reaction in nuclear reactor

- The chain reaction producing a constant rate of heat energy can continue only if the neutron liberated by fission, balance the disposal of neutrons by different ways listed below
    1. Escape of neutrons from the fissionable materials.
    2. Fission capture by U^{235}, and Pu^{239} and U^{233}.
    3. Non-fission capture by moderator, control rods, fission fragments and by impurities etc.
- If the neutrons produced in the chain reaction are less than the neutrons disposed off in different ways, the chain reaction will stop.

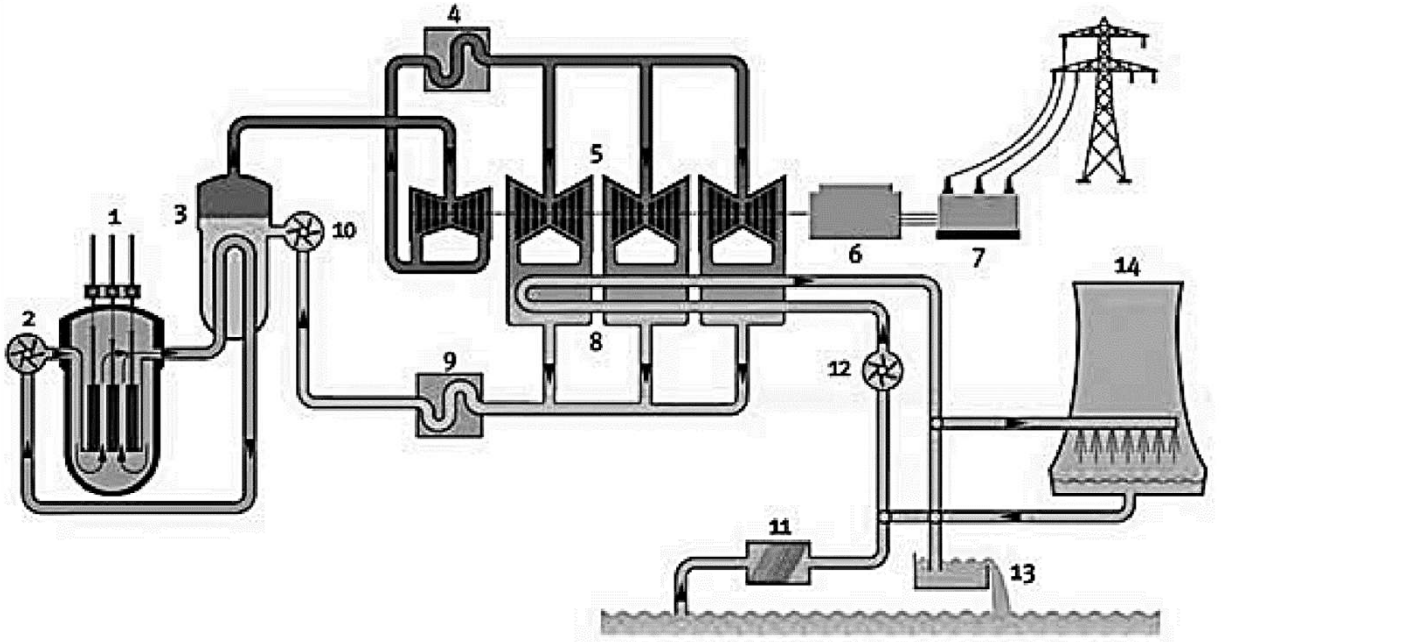
Nuclear fission



Working of a nuclear power plant

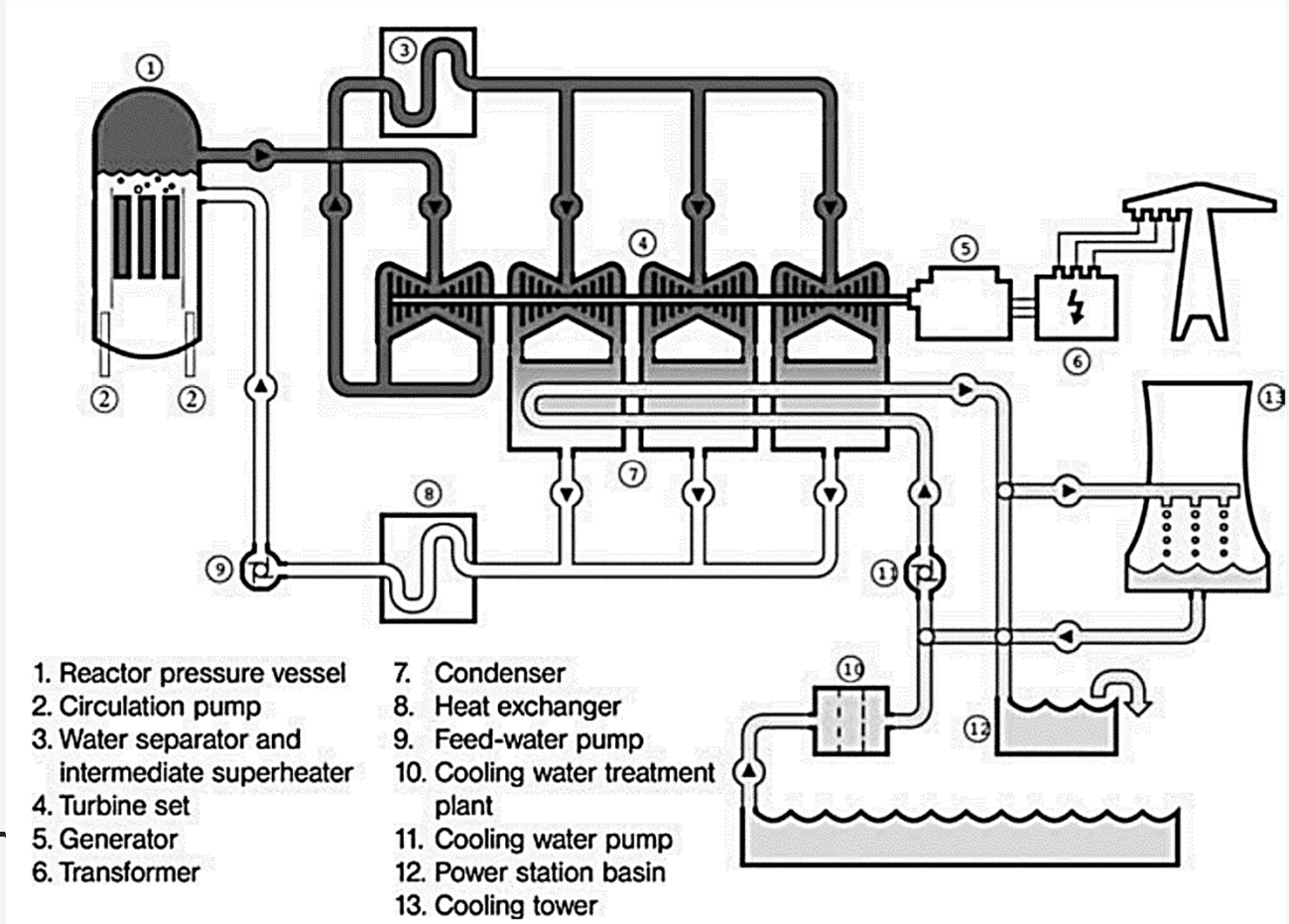
- Nuclear fission inside the reactor pressure vessel generates heat, which heats water until it vaporises, turning thermal energy into latent energy in steam.
- This steam, which is under high pressure, then drives the turbines (converting to mechanical energy), which turn the generators connected to them, generating electrical energy, like a bicycle dynamo.
- Condensing the steam required to drive the turbines is done either by direct flow or seawater cooling or via a cooling system using a cooling tower.

Nuclear power plant with pressurised water reactor



1. Reactor pressure vessel
2. Circulation pump
3. Boiler
4. Water separator and intermediate superheater
5. Turbine set
6. Generator
7. Transformer
8. Condenser
9. Heat exchanger
10. Feed-water pump
11. Cooling water treatment plant
12. Cooling water pump
13. Power station basin
14. Cooling tower

Nuclear power plant with boiling water reactor



Advantages of Nuclear Power

- The main advantage to nuclear energy is that is it relatively low-cost and consistently runs on its full potential, making it the ideal source to power national grids
- In addition, nuclear energy by far has the lowest impact on the environment since it does not release any gases like carbon dioxide or methane, which are largely responsible for the greenhouse effect.
- As a result, this differentiates nuclear energy from fossil fuels in that it does not produce negative carbon externalities as a byproduct, though some greenhouse gases are released while transporting fuel or extracting energy from uranium.
- The factor of scarcity is not of concern when it comes to the reactors fuel source, which is primarily uranium.

Disadvantages of Nuclear Power

- The future implementations of nuclear power projects are limited because although nuclear energy does not produce CO_2, toxic byproducts are produced from uranium-fueled nuclear cycles: radioactive fission waste.
- 1 tonne of fresh fuel rod waste from a nuclear reactor would give you a fatal dose of radiation in 10 seconds if placed 3 meters away.
- Plutonium is also of concern, as it increases an exposed person's potential in developing liver, bone, or lung cancer.
- There is also a negative political perception associated with nuclear plants and nuclear weapons, so expansive growth of nuclear energy is difficult to accomplish.
- Any accident would could cause a widespread radiation catastrophe.

Biomass power

- Biomass power plants could be built similar to coal power plants.
- But the sourcing of biomass and continuous supply limits the large scale plants.
- But decentralised biomass power systems are useful to local communities where biomass resource is rich.
- Biomass power can be directly obtained from gasification and combustion units, whereas energy can be indirectly generated using biogas plants and bio-alcohol plants.

Advantages of biomass power

- It is renewable
- Biomass reduces carbon emissions because the fuel is a natural part of the carbon cycle, unlike oil and other fossil fuels.
- Less dependency on fossil fuels
- Biomass energy is also amongst the most versatile alternatives available. It can be converted into many different fuel sources, each of which has varied applications.
- Low cost in comparison to fossil fuels

Disadvantages of biomass power

- While biomass is a carbon neutral fuel source, it is not completely clean.
- High costs in comparison to other alternatives (renewables)
- Possible deforestation while sourcing biomass stock.
- A large amount of space is needed to grow the materials that are used in biomass energy.
- An often unseen disadvantage of biomass energy is the amount of water needed in production.
- While biomass fuels are natural, they are also not as efficient as processed fossil fuels, like petroleum and gasoline.

Tidal power

- Tidal power is one of the major renewable energy sources, but also one of the most infantile.
- Using the power of the tides, energy is produced from the gravitational pull from both the moon and the sun, which pulls water upwards, while the Earth's rotational and gravitational power pulls water down, thus creating high and low tides.
- This movement of water from the changing tides is a natural form of kinetic energy.
- All it takes is a steam generator, tidal turbine or the more innovative dynamic tidal power (DTP) technology to turn kinetic energy into electricity.

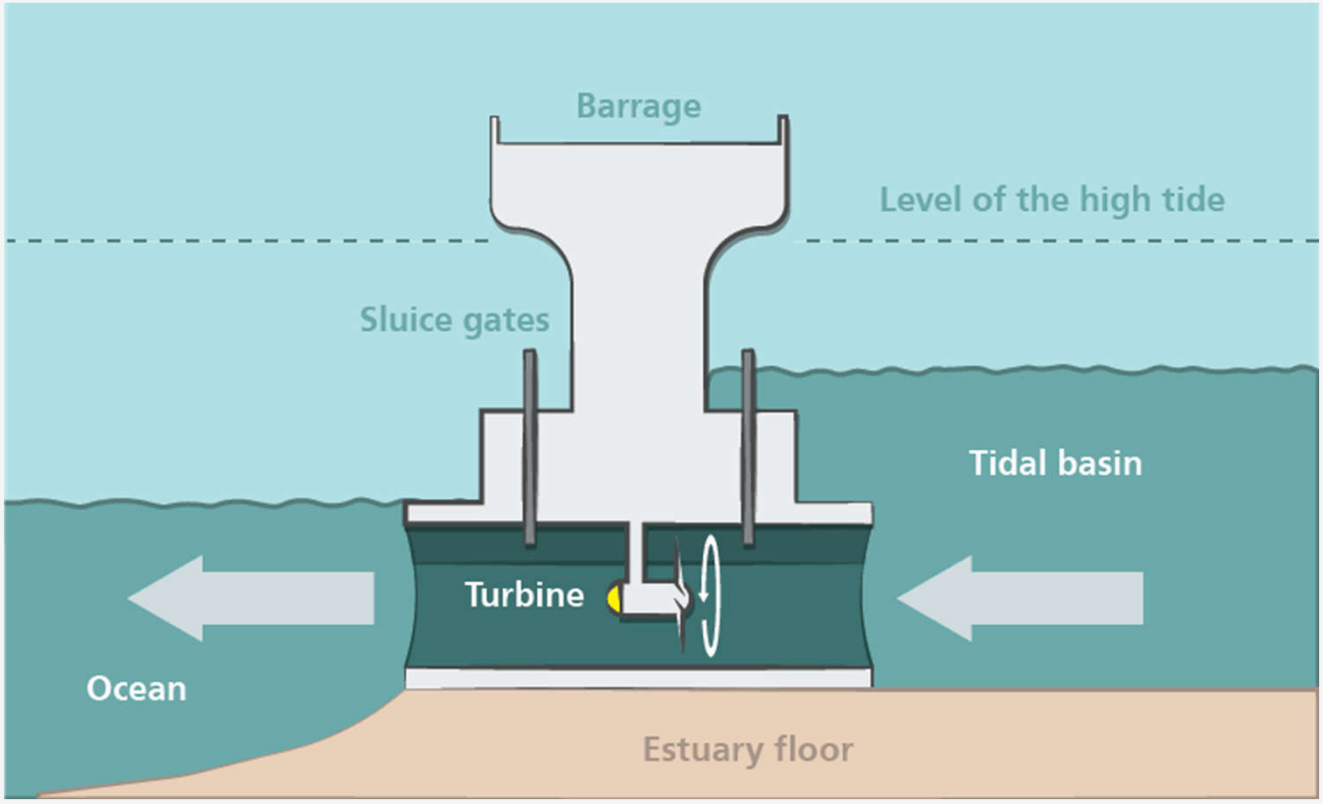
Types of tidal power generating units

- Tidal barrages
- Tidal current turbines
- Dynamic tidal power plants

Tidal barrages

- Utilize potential energy
- Tidal barrages are typically dams built across an estuary or bay.
- Consist of turbines, sluice gates, embankments, and ship locks.
- Two types are
  - Single basin system
  - Double-basin system

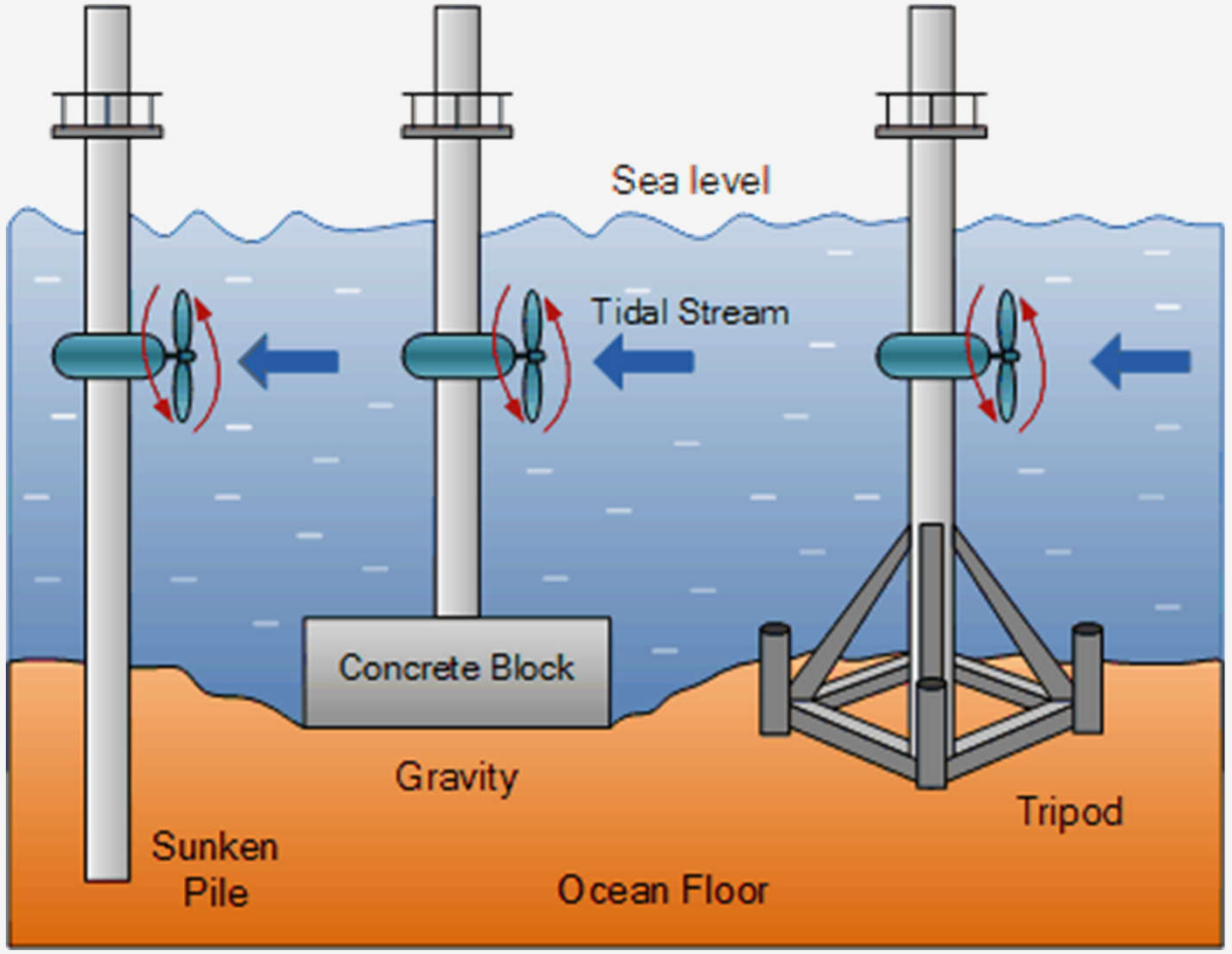
Tidal barrage



Tidal barrages – operation

- ***Ebb generation***
  - During flood tide basin is filled and sluice gates are closed, for trapping water. Gates are kept closed until the tide has ebbed sufficiently and thus turbines start spinning and generating electricity.
- ***Flood generation***
  - The basin is filled through the turbine which generate at flood tide.
- ***Two way generation***
  - Sluice gates and turbines are closed until near the end of the flood tide when water is allowed to flow through the turbines into the basin creating electricity.
  - At the point where the hydrostatic head is insufficient for power generation the sluice gates are opened and kept open until high tide when they are closed.
  - When the tide outside the barrage has dropped sufficiently water is allowed to flow out of the basin through the turbines again creating electricity.

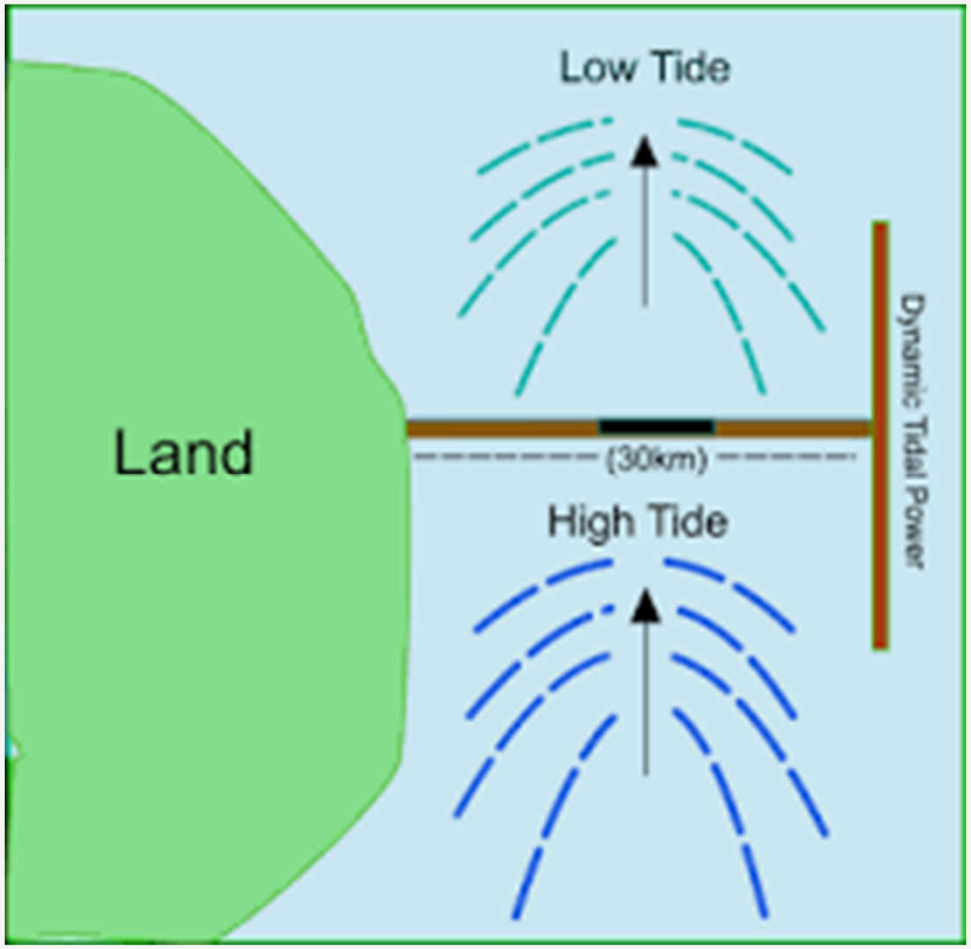
Tidal current turbines



Tidal current turbines

- Make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use wind to power turbines.
- Operate during flood and ebb tides.
- Consists of a rotor, gearbox, and a generator.
- These three parts are mounted onto a support structure.
- There are three main types:
  - Gravity structure
  - Piled structure
  - Floating structure

Dynamic tidal power



Dynamic tidal power

- Dynamic tidal power or DTP is a new and untested method of tidal power generation.
- It would involve creating large dam-like structure extending from the coast straight to the ocean, with a perpendicular barrier at the far end, forming a large 'T' shape.
- A single dam can accommodate over 8 GW (8000 MW) of installed capacity.

Tidal power projects - global

Station	Capacity (MW)	Country
Annapolis Royal Generating Station	20	Canada
Jiangxia Tidal Power Station	3.2	China
Kislaya Guba Tidal Power Station	1.7	Russia
Rance Tidal Power Station	240	France
Sihwa Lake Tidal Power Station	254	South Korea
Uldolmok Tidal Power Station	1.5	South Korea
Eastern Scheldt Barrier Tidal Power Plant	1.25	The Netherlands

Advantages of tidal power

- Tidal power is a known green energy source, at least in terms of emitting zero greenhouse gases.
- It also doesn't take up that much space.
- Tidal power is also relatively prosperous at low speeds, in contrast to wind power.
- Water has one thousand times higher density than air and tidal turbines can generate electricity at speeds as low as 1m/s, or 2.2mph
- It's a very predictable energy source and typically offsets the intermittency of solar and wind – balancing the grid with a low levelised cost of energy.
- Tidal power plants can last much longer than wind or solar farms, at around four times the longevity.

Drawbacks with tidal energy

- While the true effects of tidal barrages and turbines on the marine environment have not been fully explored, there has been some research into how barrages manipulate ocean levels and can have similar negative effects as hydroelectric power.
- Electro-magnetic emissions might also disrupt the sensitive marine life.
- While long-term generation costs are relatively good compared to other renewable energy systems, the initial construction cost makes investing in tidal energy a particularly risky venture.

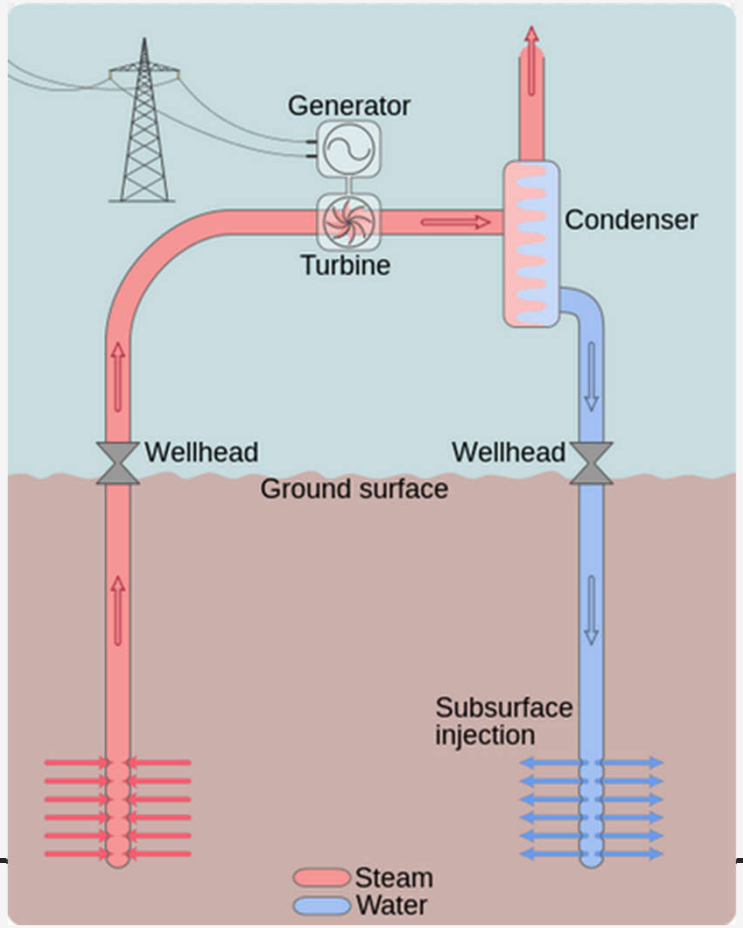
Geothermal power plants

- Geothermal power plants are used in order to generate electricity by the use of geothermal energy (the Earth's internal thermal energy)
- They essentially work the same as a coal or nuclear power plant, the main difference being the heat source.
- With geothermal, the Earth's heat replaces the boiler of a coal plant or the reactor of a nuclear plant.
- Hot water or steam is extracted from the Earth through a series of wells and feeds the power plant.
- In most geothermal plants the water pulled up from the ground is returned back to the subsurface.
- The rate of water used is often larger than the rate of water returned, so make-up water supplies are generally needed.

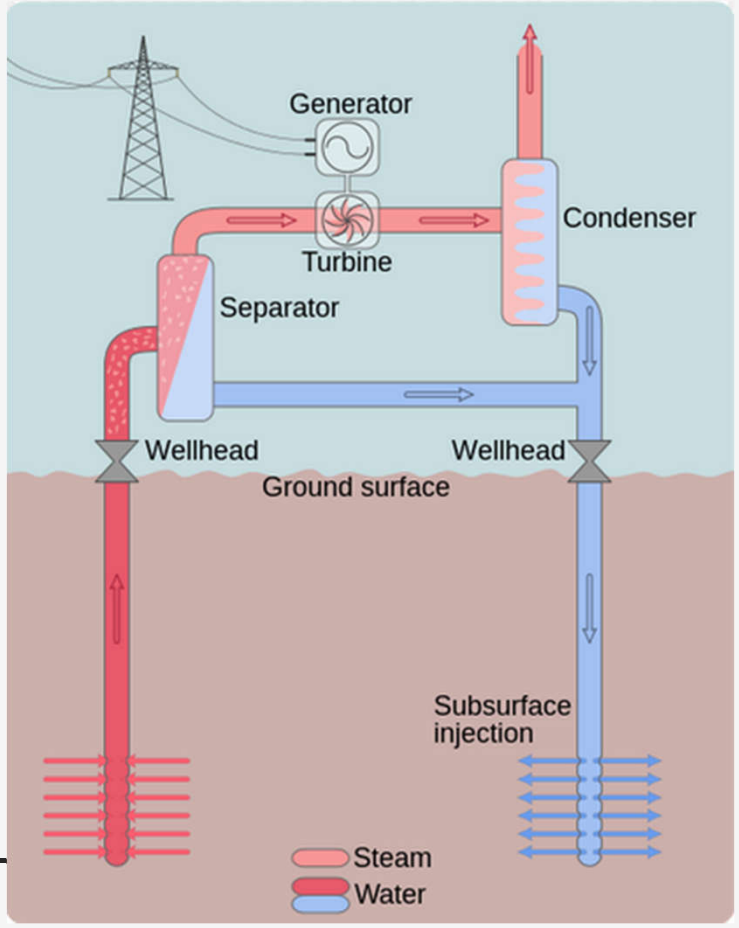
Types of geothermal power plants

- There are 3 main types of geothermal power plants, with the flash cycle being the most common. The types are,
  - Dry steam plants
  - Flash cycle steam plants
  - Binary cycle plants
- The choice of plant depends on how much geothermal energy is available, and how hot the resource is.
- The hotter the resource, the less fluid needs to flow from the ground to take advantage of it, the more useful it is.

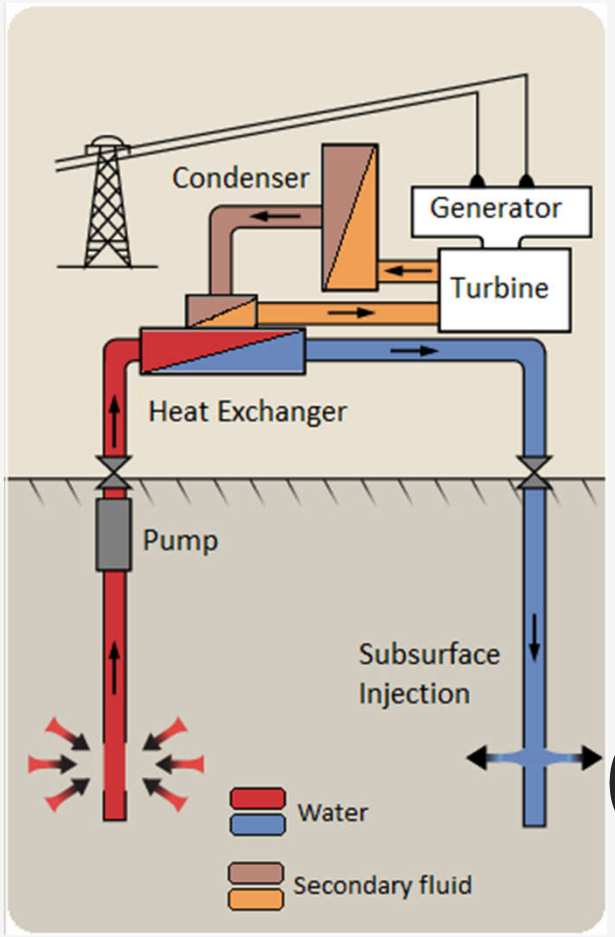
Dry steam cycle



Flash steam cycle



Binary cycle



Advantages of geothermal power

- Environmental friendly – only one-eighth of the CO_2 emissions associated with typical coal power plants.
- A renewable resource – Geothermal reservoirs are naturally replenished.
- Potential capacity – Estimates for the potential of geothermal power plants vary between 0.035 to 2 TW.
- A stable resource – The power output of a geothermal plant can be accurately predicted and is of less-fluctuating nature.
- Can provide base load or peak power.
- Great for Heating/Cooling – There is significant growth in the number of homeowners utilizing geothermal heating/cooling over the last couple of years.
- No fuel required and smallest land footprint of any major power source.

Disadvantages of geothermal power

- Surface Instability – Construction of geothermal power plants can affect the stability of land.
- High cost for electricity and if there is a predictable return-on-investment, it will not happen quickly.
- Location Specific – Good geothermal reservoirs are hard to come by and prime sites are often far from population centres.
- Distribution costs – If geothermal energy is transported long distances, cost can become prohibitive.
- Sustainability questions – Some studies show that reservoirs can be depleted if the fluid is removed faster than replaced.
- Cost of Powering the Pump – Geothermal heat pumps need a power source.
- May Run Out of Steam

Pollution aspects of various power plants

Impacts on Natural Resources - Air

- Operating power plants that burn coal, oil, or natural gas emit air pollutants into the atmosphere requiring the plant be fitted with pollution control equipment to reduce emissions.
- Major air pollutants include air pollutants include
  - Carbon dioxide (CO_2)
  - Sulphur dioxide (SO_2)
  - Nitrogen oxides (NOx)
  - Carbon monoxide (CO)
  - Ozone (O_3)
  - Particulate matter ($PM_{2.5}$ or PM_{10})
  - hazardous elements like lead (Pb), mercury (Hg) or cadmium (Cd) and compounds like acetaldehyde (CH_3CHO) or hydrochloric acid (H_2SO_4).

Carbon Dioxide (CO2)

- CO_2 was thought of as a product of combustion and not as a pollutant.
- CO2 is a major greenhouse gas from fossil fuel based thermal power plants
- Kyoto protocol, effects of Green House gases and global warming issues have changed the way we look at CO_2.

Sulphur Dioxide (SO2)

- This is a product of combustion and depends on the amount of Sulphur in coal, also referred to as SOx.
- Power plants are the largest emitters of SO_2.
- SO2 has been a cause of acid precipitation, commonly known as "acid rain," which can damage vegetation and acidify lakes.
- Species vulnerable to acidic conditions have trouble reproducing and, in some cases, die.
- Use of low Sulphur coals is the best ways to reduce the SO2 emissions.
- Desulphurisation plants downstream of the boilers also reduce emissions.
- Fluidized bed combustion of coal is another effective method to reduce SO_2 emissions.

Nitrogen Oxides (NOx)

- Nitrogen in fuel and in the air reacts with Oxygen at high temperatures to form various oxides of Nitrogen collectively called NO_X.
- Fossil fuel power plants are the second largest emitter of NO_X.
- This is a hazardous pollutant creating visual and respiratory problems.
- Also NO_X combines with water to form acid rain, smog, and ground ozone.
- Design changes in combustion technology have helped in reducing the NO_X emissions.
- Methods like Selective Catalytic Reactors are used in power plants to meet the emission regulations.

Mercury and other heavy metals

- Mercury (Hg) is naturally present in small quantities in the environment.
- Human activities have greatly increased the concentration of this pollutant in the air and water
- Coal-fired power plants are the biggest category of mercury emitters.
- Mercury is very volatile and can travel around the world in the atmosphere, repeatedly being deposited and re-emitted into the atmosphere.
- While mercury is a pollutant with global consequences, the local impacts of mercury emissions from power plants also remain a serious concern.
- Other heavy metals like Cd, Cu, Pb, Cr, Mo, Zn, As, Ni, Ba are also emitted from coal combustion, which have severe health hazards as a consequence of long-term exposure.

Ash

- Ash is the residue after the combustion.
- A 500 MW coal fired power plant burning Coal with around 20 % Ash, collects ash to the tune of Two Million Tons in Five years.
- Ash contains toxic elements that can percolate into the drinking water system.
- The wind, breach of dykes or ash spills can carry away the ash particles to surrounding areas causing harm to humans and vegetation.
- Cement plants may utilize a small portion of the ash. Disposing bulk of it on a long term basis can raise major environmental issues.
- Considering the life of a power plant is 20 years, great foresight , planning and commitment is required to dispose the ash in an eco friendly way.

Particulate Matter

- Particulate matter (PM) includes dust and smaller particles with a maximum particle diameter of 10 microns (PM10).
- In addition to PM10 emission standards, there are federal standards for PM2.5, extremely small particles with a diameter between 2.5 and 10 microns.
- Small particulates have been shown to cause respiratory problems because they can penetrate deeper into the lungs than the larger particulates.
- Only a relatively small amount of fine particulates are directly emitted from combustion sources.

List of 15 Most Polluted Cities Across The World

By PM2.5 (µg/m^3) concentration*

(Source: WHO)

airveda

* *Figures represent annual mean concentration of PM2.5 in the city*

www.airveda.com

24-Hour $PM_{2.5}$ Standard ($\mu g/m^3$)

$PM_{2.5}$	Air Quality Index	$PM_{2.5}$ Health Effects	Precautionary Actions
0 to 12.0	**Good 0 to 50**	Little to no risk.	None.
12.1 to 35.4	**Moderate 51 to 100**	Unusually sensitive individuals may experience respiratory symptoms.	Unusually sensitive people should consider reducing prolonged or heavy exertion.
35.5 to 55.4	**Unhealthy for Sensitive Groups 101 to 150**	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
55.5 to 150.4	**Unhealthy 151 to 200**	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion.
150.5 to 250.4	**Very Unhealthy 201 to 300**	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
250.5 to 500.4	**Hazardous 301 to 500**	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

NATIONAL AMBIENT AIR QUALITY STANDARDS (Notified on18th November, 2009)

CPCB is asked to lay down standards for the quality of air under section 16(2)(h)

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Govt)	
1	Dioxide (SO_2), µg/m³	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m³	Annual*	40	30	1. Modified Jacob & Hochheiser (Na-Arsenite) 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m³	Annual*	60	60	1. Gravimetric 2. TOEM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m³	Annual*	40	40	1. Gravimetric 2. TOEM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m³	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m³	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m³	8 Hours **	02	02	Non dispersive Infra Red (NDIR) Spectroscopy
		1 Hour**	04	04	
8	Ammonia (NH_3), µg/m³	Annual*	100	100	1. Chemiluminescence 2. Indophernol blue method
		24 Hour**	400	400	
9	Benzene (C_6H_6) , µg/m³	Annual *	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP)-particulate phase only, ng/m³	Annual*	01	01	Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m³	Annual*	06	06	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m³	Annual*	20	20	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.

** 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring. NOTE: Whenever and wherever monitoring results on two consecutives days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

Impacts on water

- Pollution and pollutants discharged to surface water from power plants can result in adverse water quality effects
- Ground water contamination is likely to happen when ash or other waste chemical dump yards are leached away by rain water or water logging.
- Discharge locations range from streams or lakes to local municipal sewer systems that eventually discharge into streams or lakes.
- To handle the discharge, surface waters or sewer treatment systems must be able to absorb water that has been altered by the addition of heat, acids, or salts.
- Larger water bodies or streams might be able to accept more of this altered water because of their size and volume or because they have water containing solutes that can buffer the added chemicals, or they might not.

Warm water discharge

- Some power plants use "once-through cooling."
- In once-through cooling, cooling water is drawn from the lake or river and used to condense the steam for recycling through the plant.
- The water used for cooling picks up heat from the steam and is then returned to the lake or river at a warmer temperature.
- Impacts of this technology could include the warming of the lake or river near the discharge point, potentially affecting temperature-sensitive plants, fish, microbial activities, or chemical and physical reactions in the water.
- Even with cooling towers instead of once-through cooling, discharged process water that is warmer than ambient water temperatures can alter the local fishery composition, aquatic macroinvertebrate (bugs) communities, and aquatic plant communities.

Wetlands

- Power plants with a large construction footprint often require the filling or draining of some wetlands.
- Even if a wetland is not filled or drained, construction activities near wetlands can damage wetlands in several ways.
- Heavy machinery can crush wetland vegetation, especially that growing on cassocks.
- Wetland soils, especially very peaty soils, can be easily compacted, increasing runoff, and reducing the wetland's water holding capacity.
- The construction of power plant access roads through wetlands can change the quantity or direction of water flow, causing permanent damage to wetland soils and vegetation.

Land and Soil

- Contamination of land and soil with toxic chemicals will degrade the soil quality.
- The polluted land/soil will become unusable for agriculture purposes.
- The suitability of soil for other construction activities may also be affected, when soil loses its property.
- Conflict of interest for land space could occur, when land occupied by large agricultural lands or residential area or commercial establishments are required for power plant construction.

Impacts on vegetation

Vegetation impacts can be of two basic kinds:

(a) Direct impacts of vegetation removal or damage during construction.

(b) Indirect impacts on vegetation from air pollution or surface water impacts caused by the power plant.

- The vegetation communities at any site depend largely on: (1) soil quality and fertility, (2) relative elevations and slopes, (3) moisture availability, (4) solar radiation, and (5) the degree and type of disturbance in the area.
- A new power plant could affect the vegetation communities by eliminating them or by altering one or more of these five factors, which could weaken the communities (for example, by shading them or by redirecting runoff away so that a vegetative community receives less water.)

Impacts on vegetation

- Power plants emit air pollutants and water vapor as fog into the atmosphere that could affect the growth and survival of certain vegetation communities.
- Some pollutants are toxins or promote diseases that damage or kill plants.
- Conversely, the pollutants could provide nutrients to the plants, like fertilizer from the air.
- Fog from cooling towers could change the moisture regime so that some plants have a competitive advantage over others from differences in the ability to utilize the moisture or to resist fungal disease.
- Vegetation in surface waters could also be affected, or lost, by construction of water intake or discharge facilities, by the removal of water (intake) for power plant processes, or by the nature of waste water discharged by the power plant into the waterbody.

Impacts on Wildlife and endangered species

- Impacts on local or migrating wildlife could occur when their habitat and source of food is removed or damaged.
- The food source could be the vegetation itself or bugs, animals, birds, or organisms that rely on the vegetation for food. Nesting and den areas would be destroyed.
- Construction of a new power plant could displace certain species of wildlife and attract other species.
- Species that relied specifically on the original natural habitat might not survive or might need to leave the area.
- Migratory species that depended on the original local habitat for resting, feeding, or reproduction would have to find new places for these activities.
- Loss of feeding, resting, or reproductive habitat could harm a river or lake species' ability to survive.

Social impacts - Agriculture

- Farmlands, particularly prime farmlands (areas having more fertile soils), are a valuable resource.
- Construction of power plant facilities on local farmlands would permanently take those fields out of agricultural production and could affect the economic viability of the farm and, indirectly, the local farm community.
- Farm fields outside the proposed power plant property could also be affected, at least temporarily, by construction of ancillary facilities like natural gas or water pipelines or electric transmission lines.
- The fog or salts from water vapor from cooling towers and air pollutants from an operating power plant stack could be deposited and affect the yield or quality of nearby crops.
- It is also possible that noise or light from a power plant could disturb farm families or reduce the productivity of local farm animals.

Environmental impacts specific to other power plants

- Hydro power
  - Formation of wetland
  - Loss of habitat for people and wildlife
  - Risk of earthquake and alteration of local water table
- Nuclear
  - Leaching of radioactive wastes into air or waterbodies pose a severe threat to health of all sorts of life.
- Solar
  - Indirectly, solar panel production industry cause severe air and water pollution with heavy metals.
- Tidal
  - Affect marine life in terms of habitat loss, change in water temperature etc.