UNIT-IV

TIDAL ENERGY,
OTEC,
HYDEL,
GEOTHERMAL ENERGY

TIDAL ENERGY

- Tide :
  - Spring Tides
  - Neap Tides
  - Tidal Range
  - Tidal Power
- Types of Tidal Power Plant:
  - Single and Double basin Schemes
  - Requirements in Tidal Power Plant
- Ocean Thermal Energy Conversion (OTEC)
  - Open and Closed OTEC Cycle
- Hydel Energy :
  - Micro Hydro
- Geothermal Energy:
  - Geothermal Energy Sources
  - Geothermal Power Plant
  - Environmental Issues

Ocean Energy

The ocean energy types:

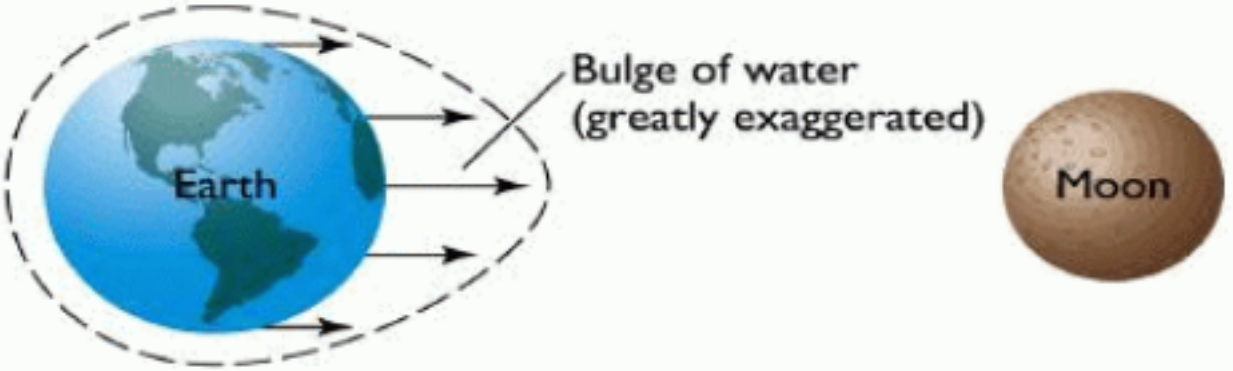
- 1. Wave Energy
- 2. Tidal Energy
- 3. Ocean Thermal Energy

Tidal Energy

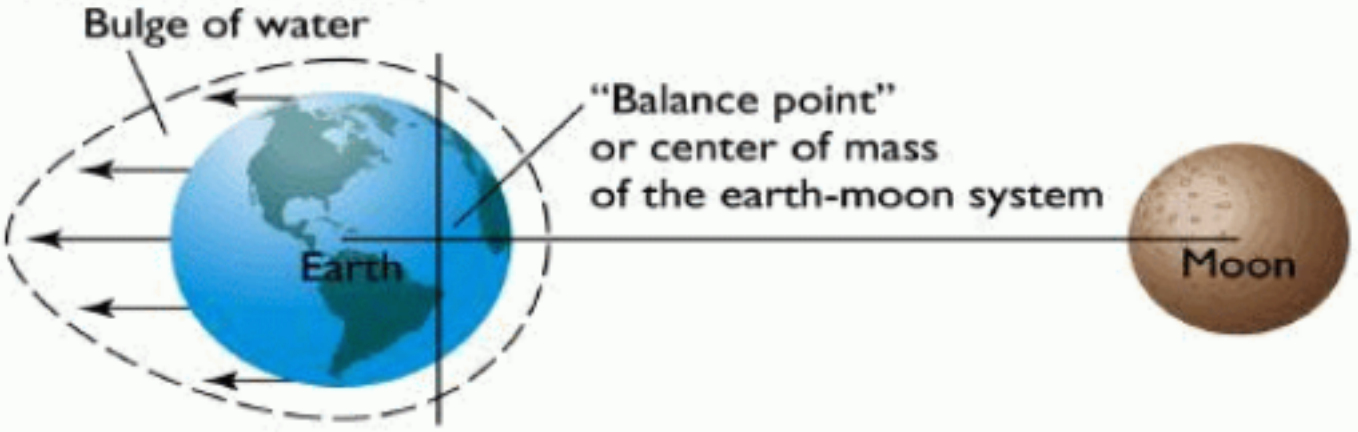
Basics of tides

- Tidal energy is the energy due to the water waves created in the ocean. The tidal energy is also called hydropower.
- It is a hydropower due to raise and fall of water wave in ocean. The raise and fall of water wave is due to the gravitational forces of the moon and sun as well as the revolution of the earth
- The raising and falling *waves* are used to *rotate the turbines* and hence the electricity is produced.
- Gravitational pull of the sun and moon and the pull of the centrifugal force of rotation of the earth-moon system.
- When a landmass lines up with the earth-moon system, the water around it is at high tide

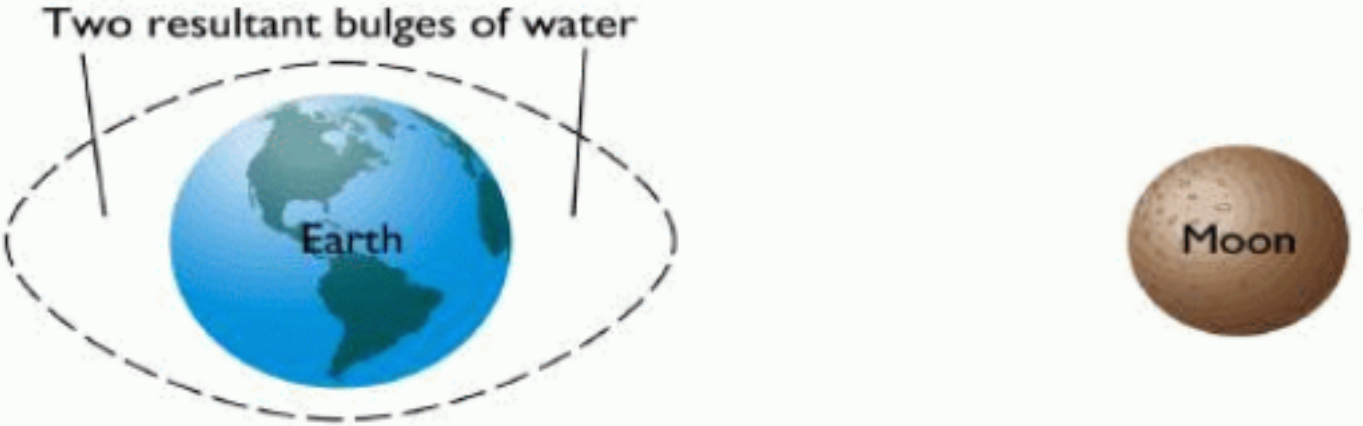
- When a landmass is at 90° to the earth-moon system, the water around it is at low tide.
- There are two high tides and two low tides during each period of rotation of the earth.
- Spring and Neap tides depend on the orientation of the sun, moon, and the earth.
- **High spring tides** occur when the sun and moon line up with the earth. This occurs whether they are either on same or opposite side.
- **Low neap tides** occur when the sun and moon line up at 90° to each other. Flood Currents: currents moving in the direction of the coast. Ebb Currents: the current receding from the coast



(a) GRAVITATIONAL FORCE



(b) CENTRIFUGAL FORCE

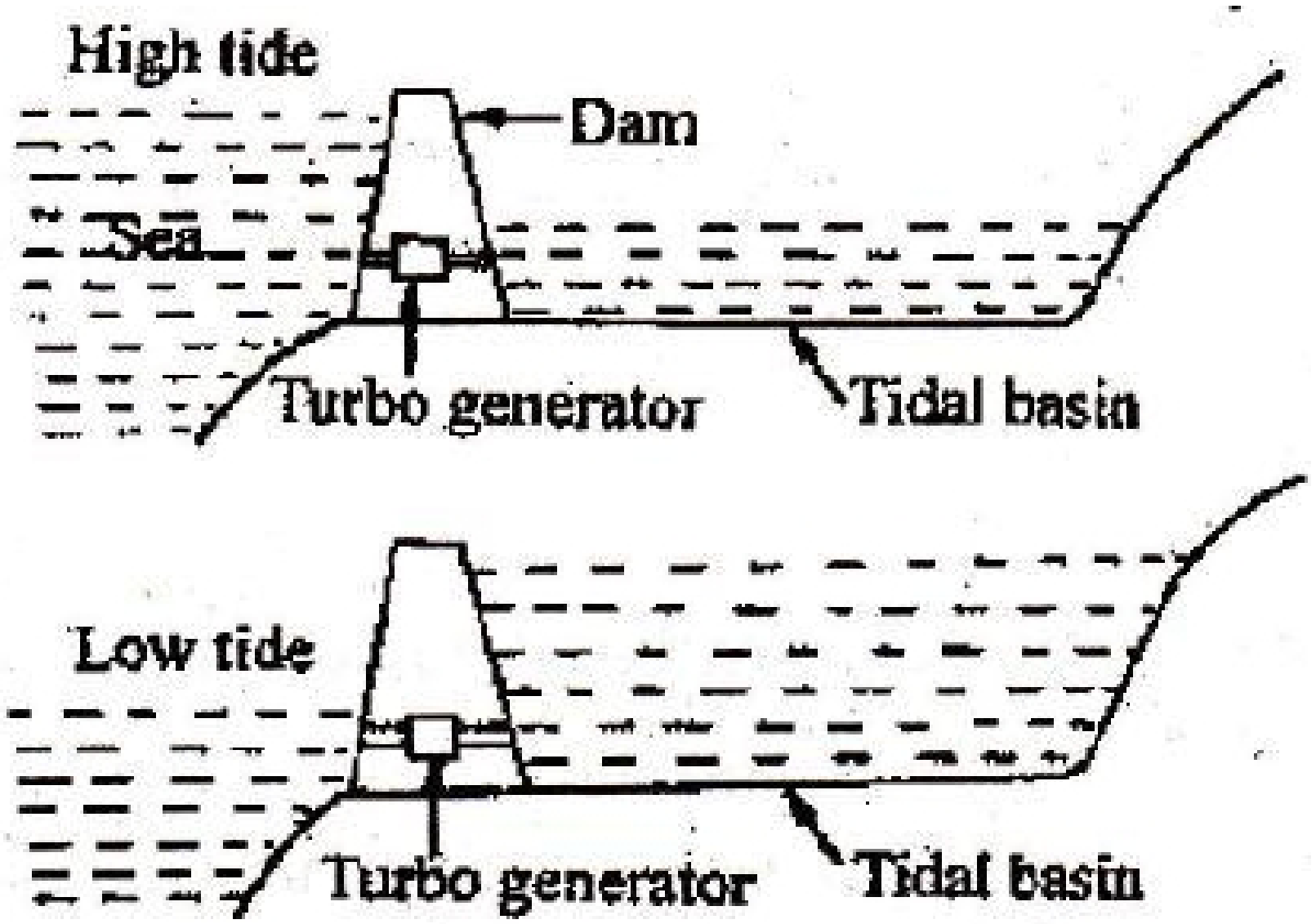


(c) GRAVITATIONAL AND CENTRIFUGAL FORCE

TIDAL ENERGY

- The tidal energy is due to moon's attraction on the earth.
- Normally lesser tidal waves occur per day (around 2 tides).
- The amplitude of tidal waves is around 10 m. The tidal energy is harvested by tidal power plants where the high tides are allowed
- to run an axial turbine during water f bws from sea to tidal basin as well as water f bws from basin to sea due to the water level difference between the sea and basin.
- High & Low Tide Tidal Power Plant

TIDAL ENERGY CONCEPT



Tidal power

- Tidal power generators derive their energy from movement of the tides.
- Obviously requires large bodies of water nearby. Not viable on the prairies for example.
- 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

- The interaction of the Moon and the Earth results in the oceans bulging out towards the Moon (Lunar Tide). The sun’s gravitational field pulls as well (Solar Tide)
- As the Sun and Moon are not in fixed positions in the celestial sphere, but change position with respect to each other, their influence on the tidal range (difference between low and high tide) is also effected.
- If the Moon and the Sun are in the same plane as the Earth, the tidal range is the superposition of the range due to the lunar and solar tides. This results in the maximum tidal range (spring tides). If they are at right angles to each other, lower tidal differences are experienced resulting in neap tides.
- ional effect of the Moon and, to a lesser extent the Sun on the world's oceans. The Earth's rotation is also an effect.

BASICS

•Cause of tides: gravitational force of sun, moon and earth's rotation

• Two tidal cycles

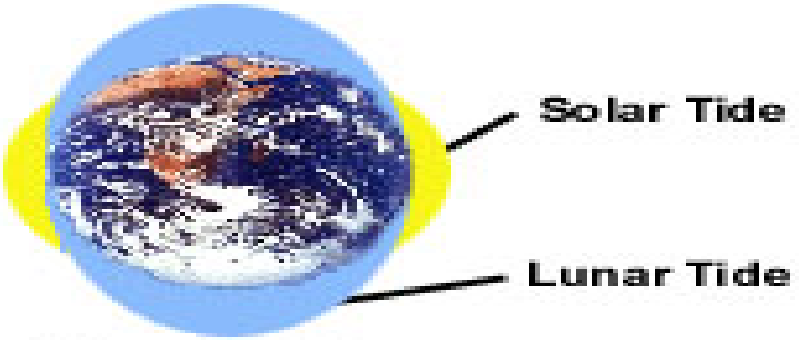
• **Tidal range** – large at coastal regions with high depth gradient

• Water can be stored in an estuary during high tide

• Release during low tide, through turbines

Tides

Moon
(quarter phase)



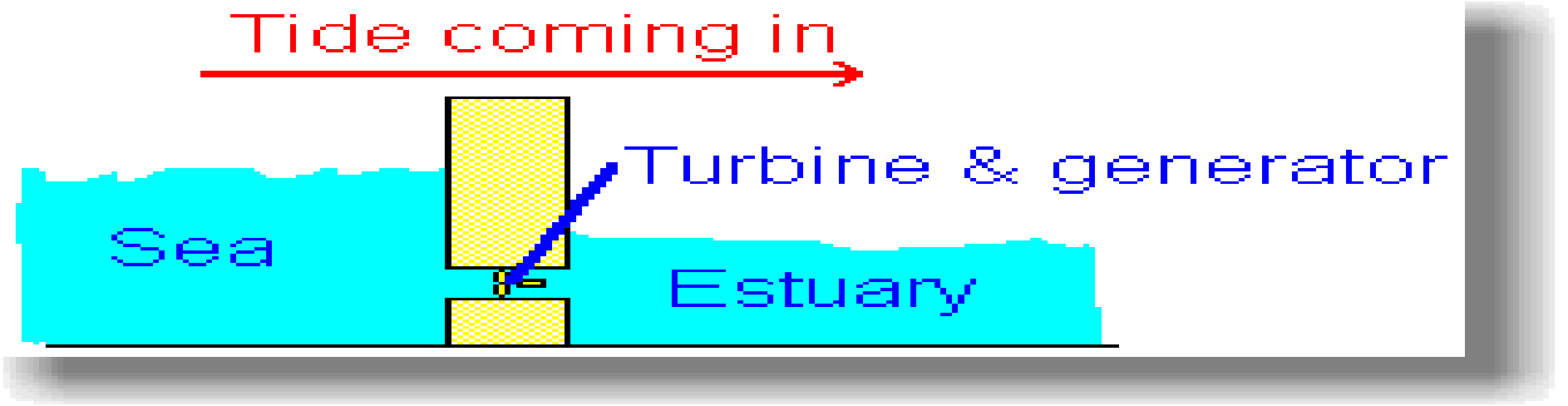
Neap Tides

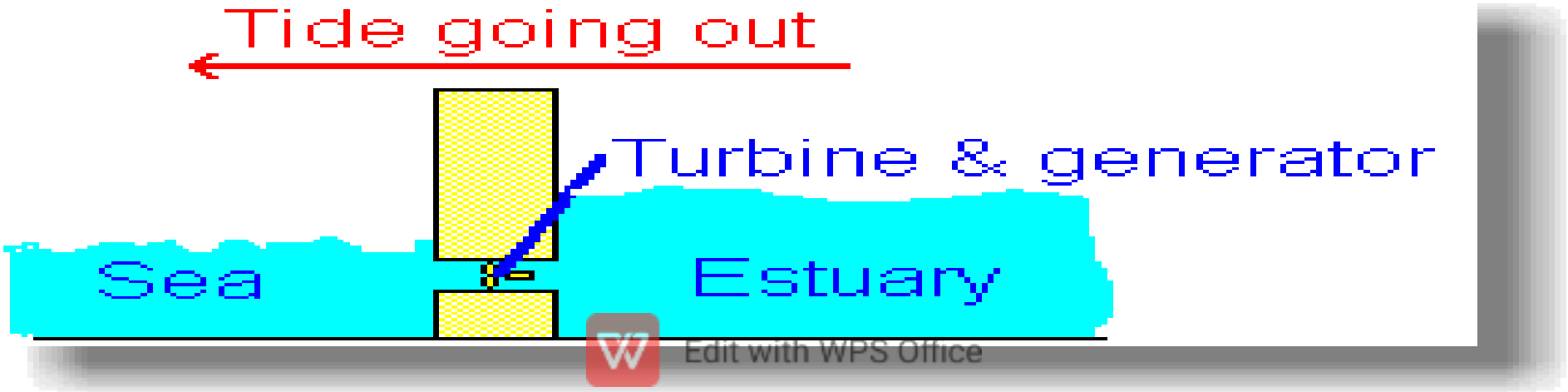
Moon
(full or new)

Spring Tides

THE TIDAL BARRAGE

• It's a huge dam built across a river estuary. When the tide goes in and out, the water flows through tunnels in the dam.





- Tidal range has to be in excess of 5 meters for tidal power to be feasible.
- The purpose of this dam or barrage is to let water flow through it into the basin as the tide comes in. As the tide recedes, gates in the barrage that contain turbines are opened, the hydrostatic head causes the water to come through these gates, driving the turbines and generating power.
- Power can be generated in both directions through the barrage but this can affect efficiency and the economics of the project

- Components of barrage
  - Caissons
  - Turbines

The **energy of the tide wave** contains two components, namely, potential and kinetic. The potential energy is the work done in lifting the mass of water above the ocean surface. This energy can be calculated as:

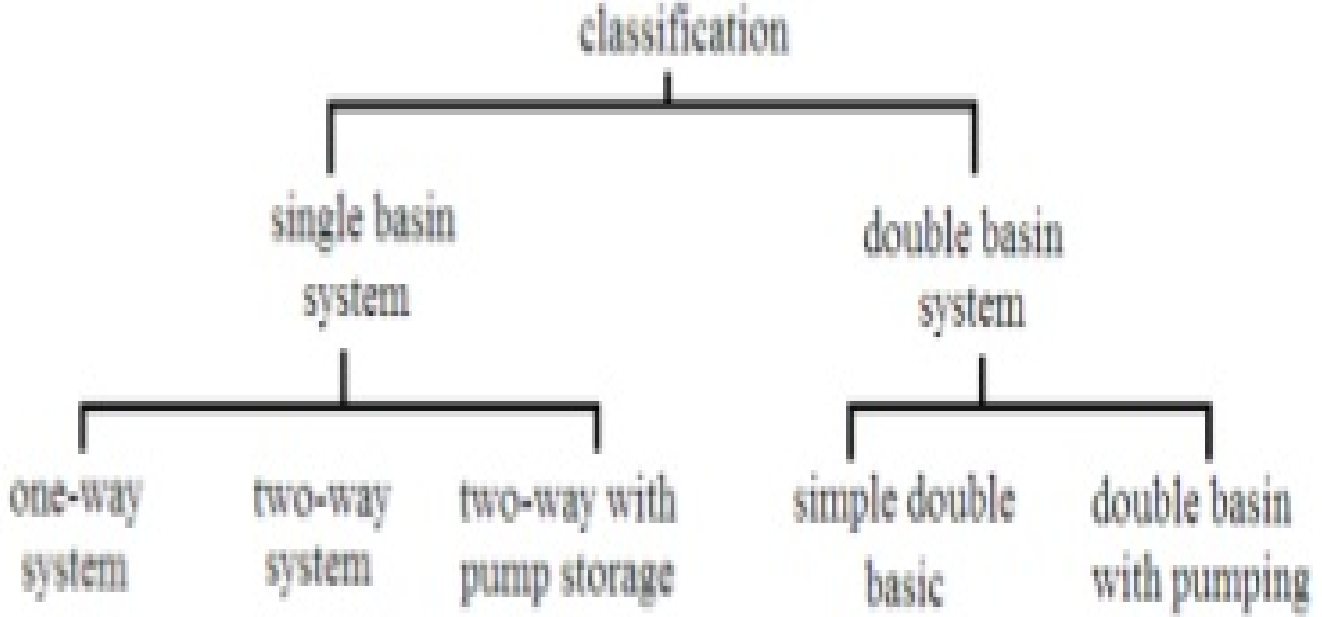
$$E = g\,\rho A \int P\,z\,dz = 0.5\,g\,\rho\,A\,h^2$$

where *E is the energy,* ***g is acceleration of gravity,*** o is the seawater density, which equals its mass per unit volume, *A is the sea area under consideration, z is a vertical coordinate of the ocean surface and h is the tide amplitude.*

(**for seawater, one can obtain** for a tide cycle per square meter of ocean surface: $E=1.4\,h^2$ *watt-hour* or $E=5.04h^2$, *kilojoule* The kinetic energy *T of the water mass m is its* capacity to do work by virtue of its velocity *V. It is* denoted by *T=0.5mV2. The total tide energy equals* the sum of its potential and kinetic energy components. Knowledge of the potential energy of the tide is important for designing conventional tidal power plants using water dams for creating arti Rcial upstreamwater heads.

Classification of tidal Power Plants

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation.



Working of different tidal power plants

Single basin-One-way cycle

This is the simplest form of tidal power plant. In this system, a basin is allowed to get filled during flood tide and during the ebb tide. The water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration during ebb tide.

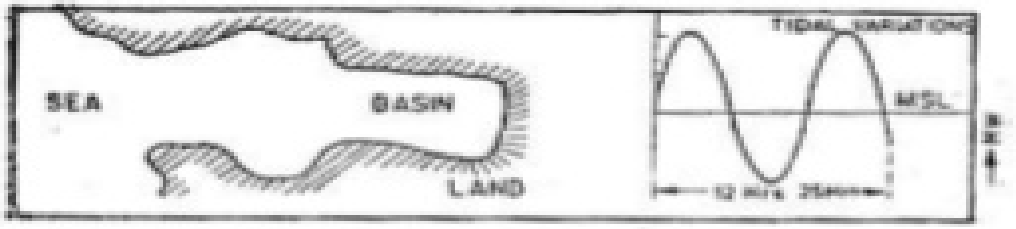
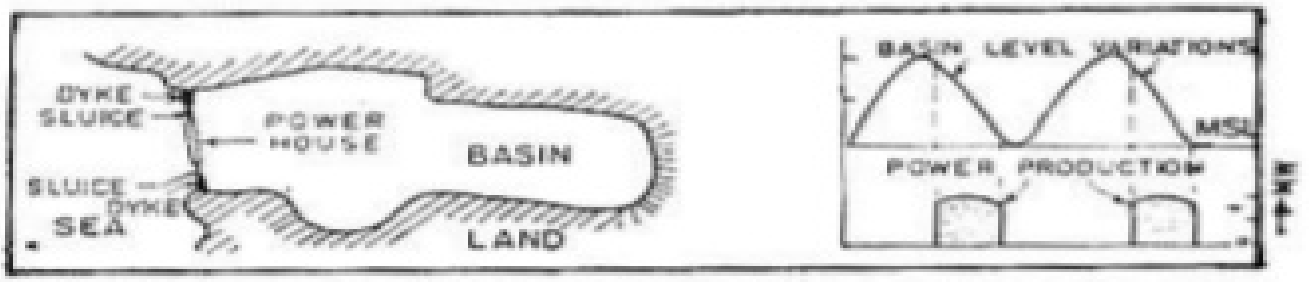


Fig1. Single basin Tidal Power Plant

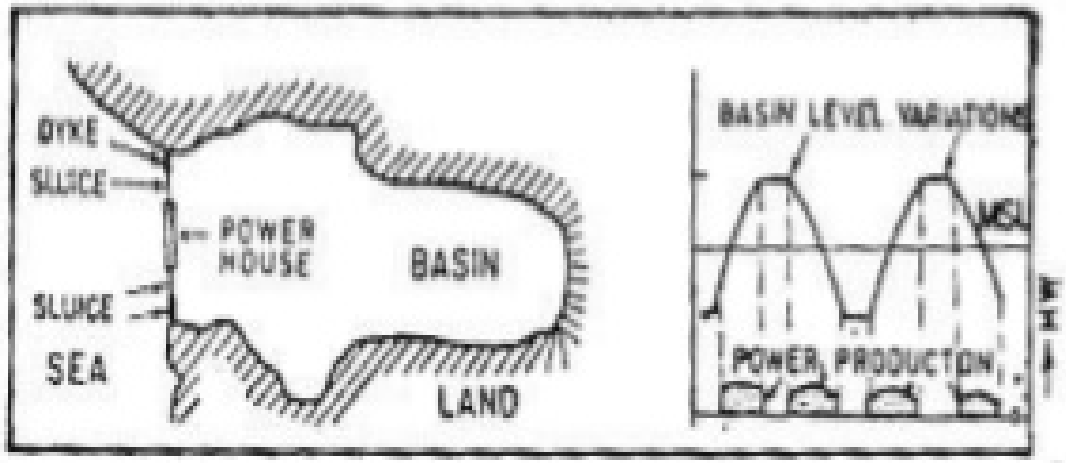
Fig1. Shows a single tide basin before the construction of dam and Fig.2 shows the diagrammatic representation of a dam at the mouth of the basin and power generation during the falling tide.



(b) Single basin, one-way tidal power plant.

Single-basin two-way cycle

In this arrangement power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However the peak power obtained is less than the one-way cycle. The arrangement of the basin and the power cycle is shown in Fig.3.

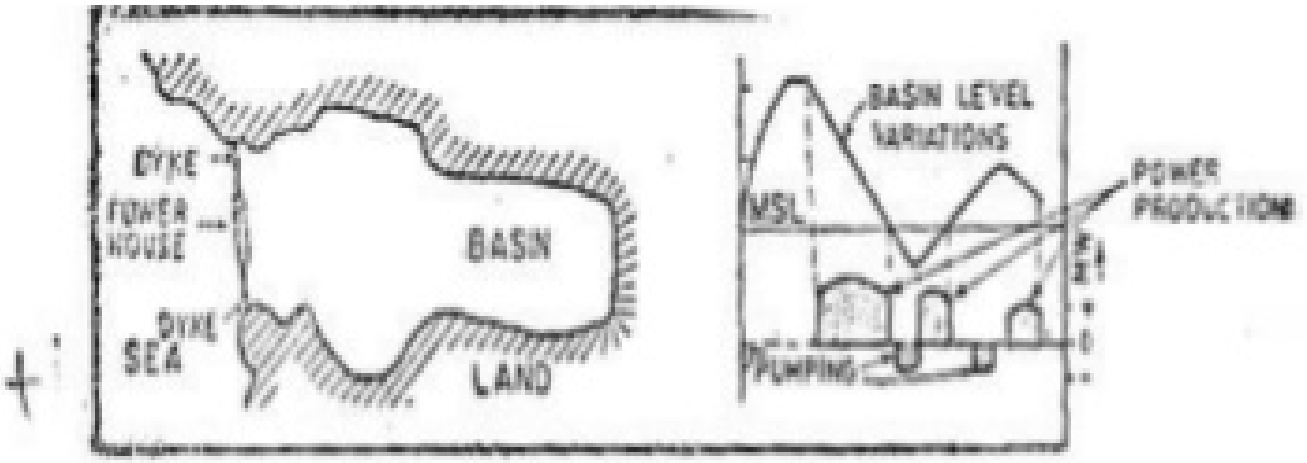


Single-basin two-way tidal power plant.

The main difficulty with this arrangement, the same turbine must be used as Prime mover as ebb and tide flows pass through the turbine in opposite directions. Variable pitch turbine and dual rotation generator are used for such schemes.

Single-basin two-way cycle with pump storage

The Rance tidal power plant in France uses this type of arrangement. In this system, power is generated both during flood and ebb tides. Complex machines capable of generation Power and Pumping the water in either direction are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and the sea at any time of the tide and this is done by pumping water into the basin up or down. The period of power production with this system is much longer than the other two described earlier. The cycle of operation is shown in Fig 5.4.



Single-basin, two-way tidal plant coupled with pump storage system.

How do tides changing = Electricity?

- As usual, the electricity is provided by spinning turbines.
- Two types of tidal energy can be extracted: kinetic energy of currents between ebbing and surging tides and potential energy from the difference in height (or *head*) between high and low tides.
- The potential energy contained in a volume of water is

$$E = x\,Mg$$

- where x is the height of the tide, M is the mass of water and g is the acceleration due to gravity.
- Therefore, a tidal energy generator must be placed in a location with very high-amplitude tides. Suitable locations are found in the former USSR, USA, Canada, Australia, Korea, the UK and other countries

How do tides changing = Electricity Contd…?

- The generation of electricity from tides is very similar to hydroelectric generation, except that water is able to flow in both directions and this must be taken into account in the development of the generators.

- The simplest generating system for tidal plants, known as an ebb generating system, involves a dam, known as a barrage across an estuary.

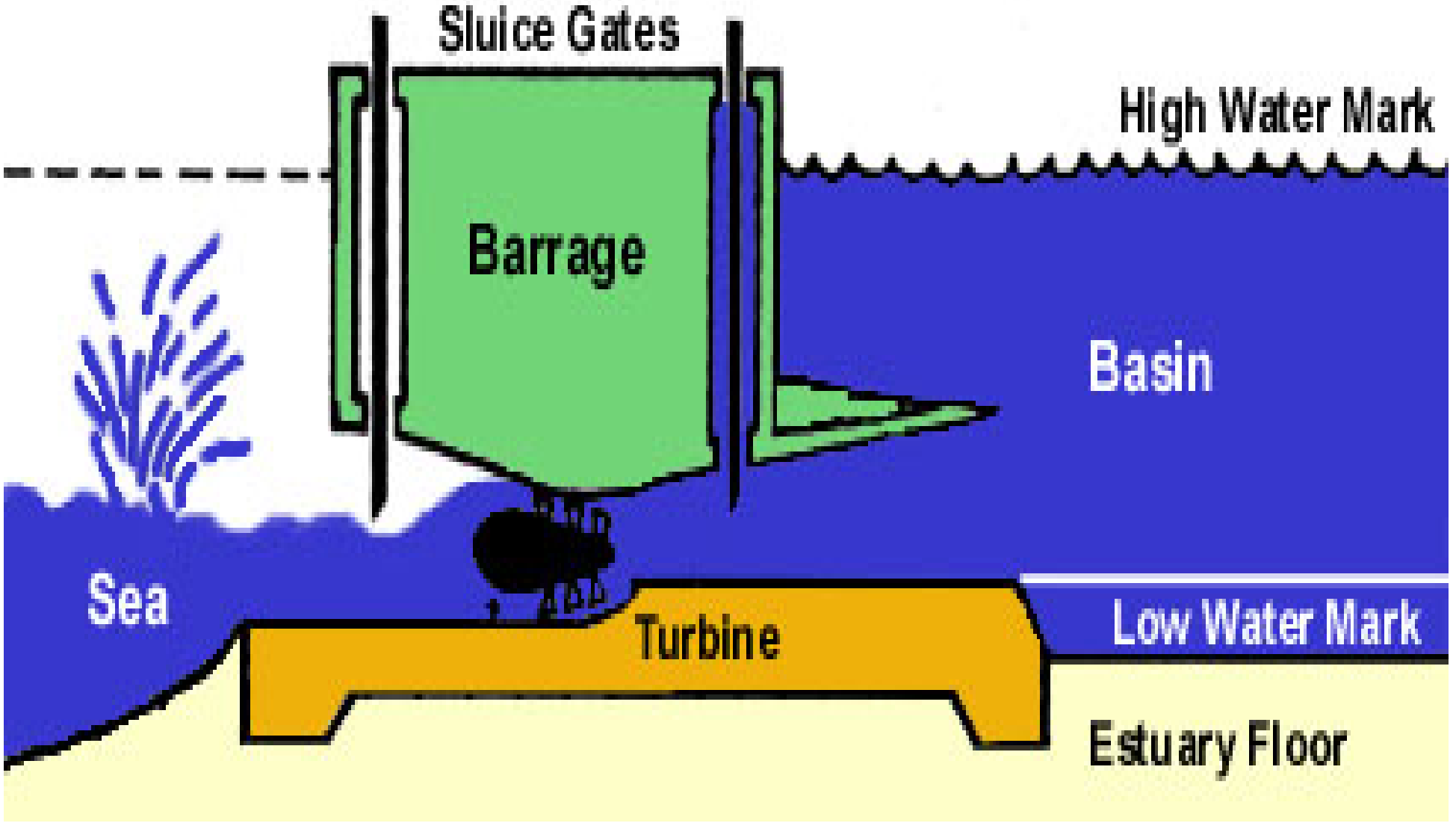
- Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides and to exit through the turbine system on the outgoing tide (known as the ebb tide).

- Alternatively, flood-generating systems, which generate power from the incoming tide are possible, but are less favored than ebb generating systems

Ebb Generation

- The basin is filled through the sluices and freewheeling turbines until high tide. Then the sluice gates and turbine gates are closed.
- They are kept closed until the sea level falls to create sufficient head across the barrage and the turbines generate until the head is again low. Then the sluices are opened, turbines disconnected and the basin is filled again.
- The cycle repeats itself.
- Ebb generation (also known as outflow generation) takes its name because generation occurs as the tide ebbs.

Ebb Generation



Requirements of Tidal Energy

- Tidal mills built on inlets branching off tidal estuaries
- Average Tidal range : the higher, the better
- Feasibility of plant construction & basin closure
- Environmental consequences

What is OTEC?

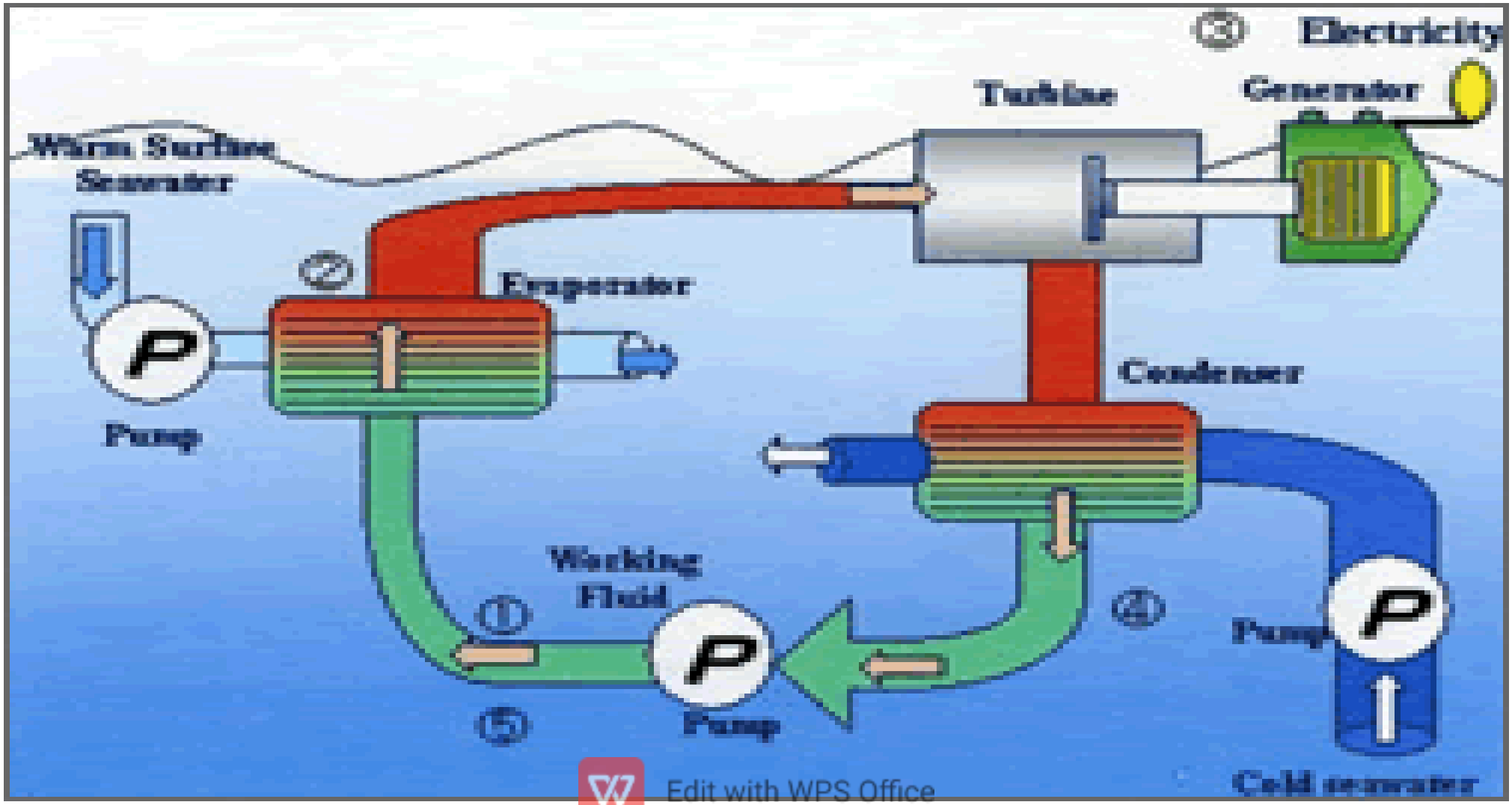
- Manifestation of solar energy
- Top layers of ocean receive solar heating
- Bottom layers receive water from polar regions
- Natural temperature gradient
- Use in Thermodynamic cycle – Generate electricity
- OTEC utilizes the ocean's 20°C natural thermal gradient between the warm surface water and the cold deep sea water to drive a Rankin 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.

OCEAN THERMAL ENRGY CONVERSION (OTEC)

✔Ocean Thermal Energy Conversion is working based on the temperature gradient of the sea water.
✔The surface water temperature is around 20-25°C and deep water temperature isaround 5-10°C.
✔This small temperature range is capable of operating low temperature power cycle.
✔The organic fluids of low boiling point (e.g. NH3 = - 33° C). The hot surface water isused in the evaporator to generate vapour out of working fluid and it drives a vapor turbine and then its condensed in the condenser which is operated by the deep see cold water.

OTEC PLANT

Closed-Cycle OTEC

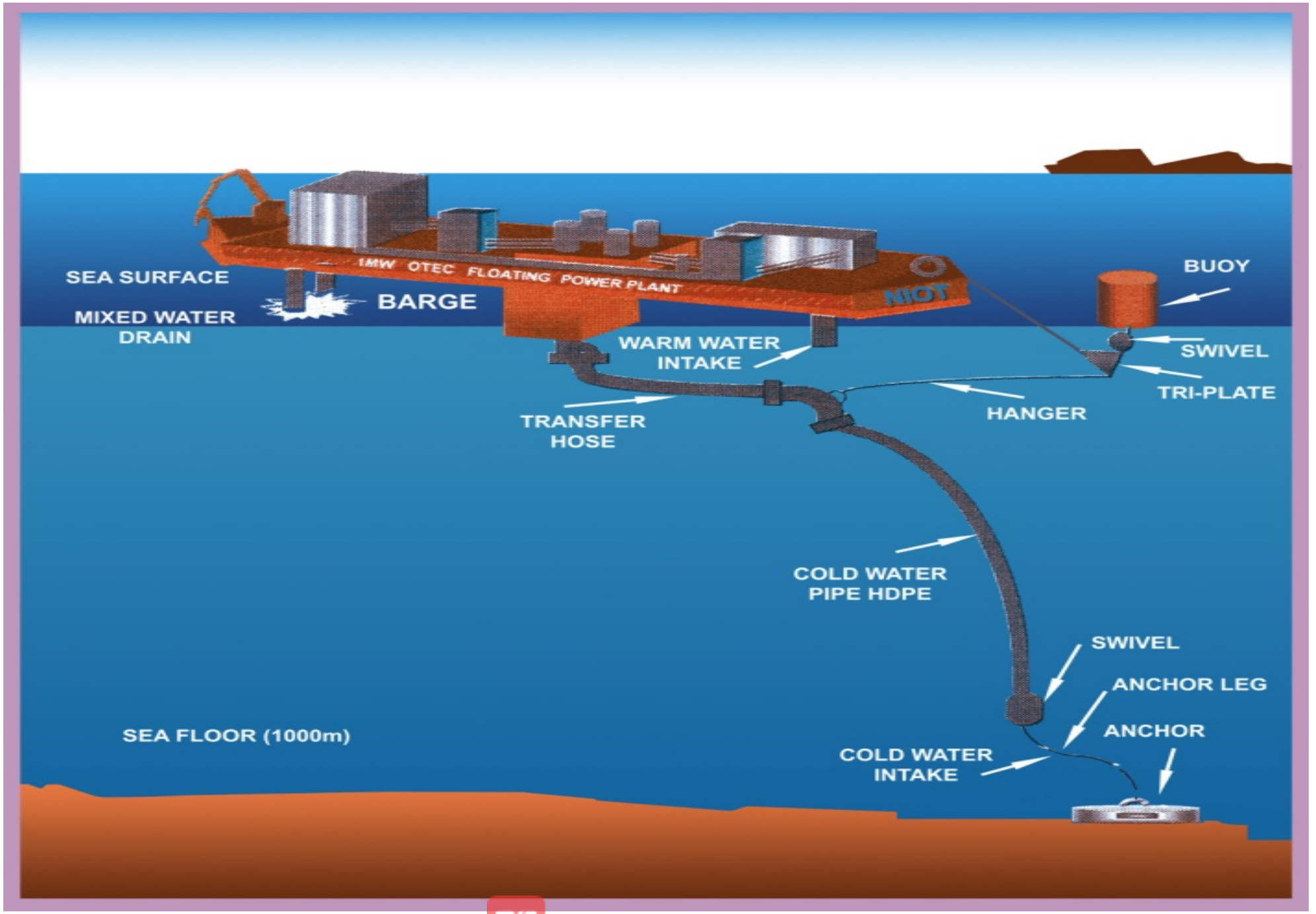


PLANT LOCATION

1. **Land based** - Favored locations : narrow shelves (volcanic islands), steep (15-20 deg) offshore slopes, and relatively smooth sea floors.

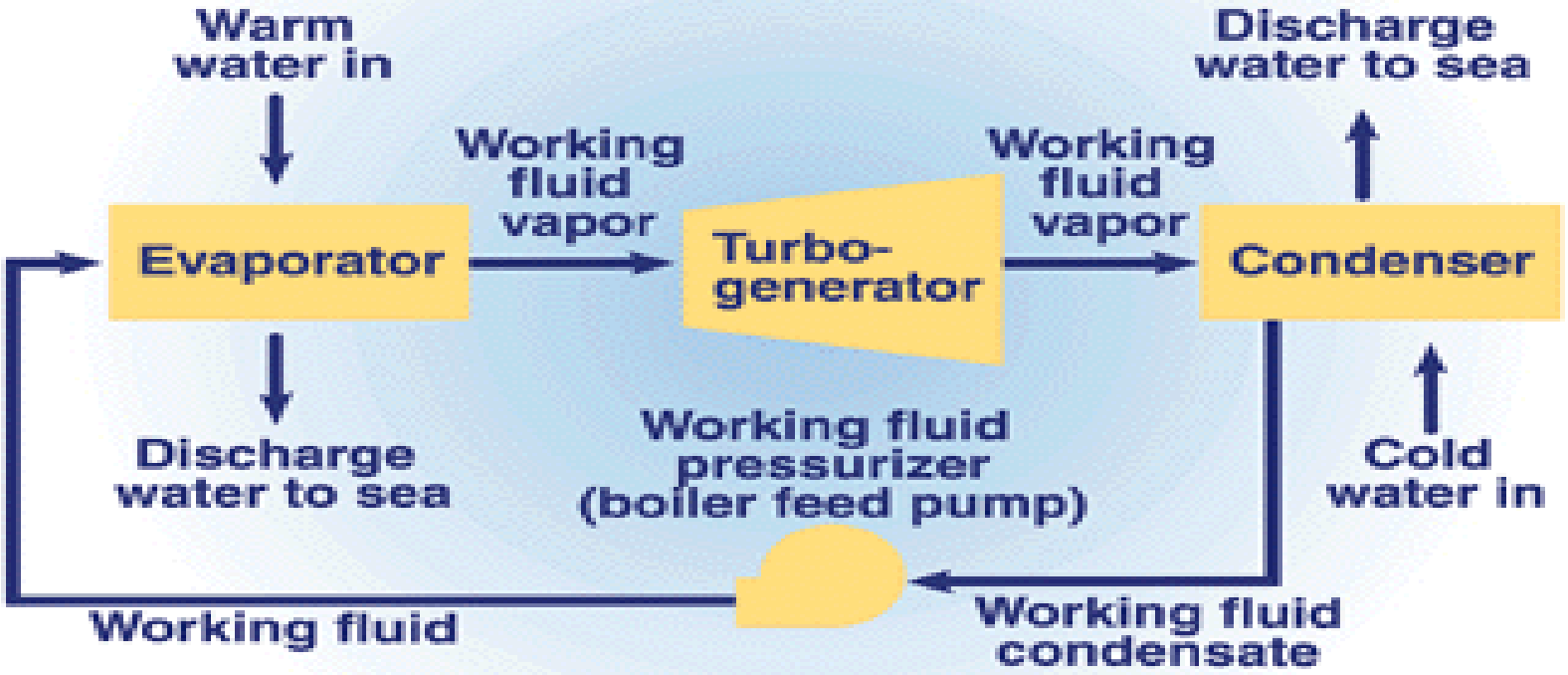
2. **Shelf mounted** - OTEC plants can be mounted to the continental shelf at depths up to 100 meters. A shelf-mounted plant could be built in a shipyard, towed to the site, and fixed to the sea bottom.

3. Off shore **floating** plants



ELECTRICITY PRODUCTION

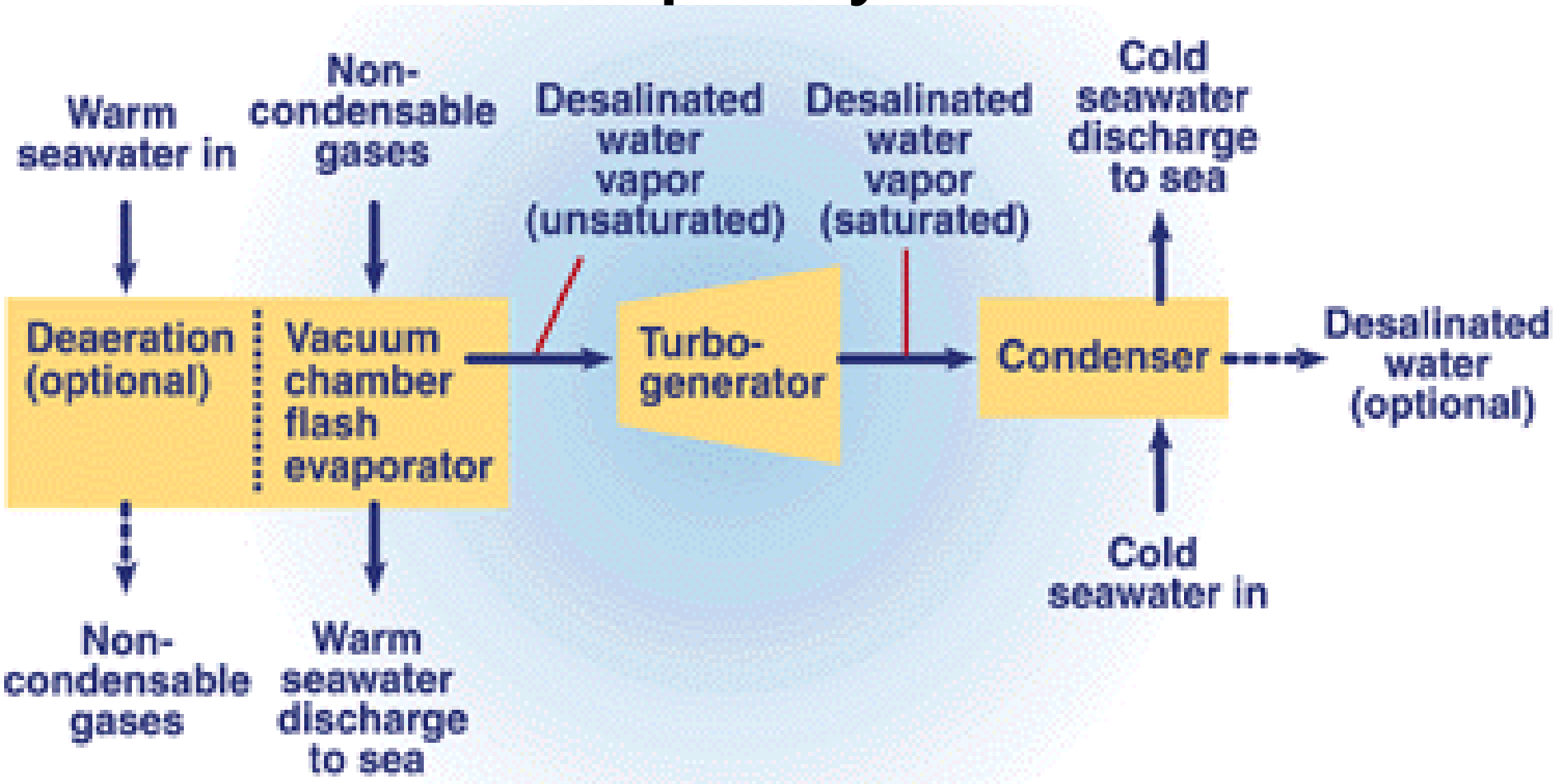
1. Closed cycle



- Ammonia can be used as a working fluid

ELECTRICITY PRODUCTION

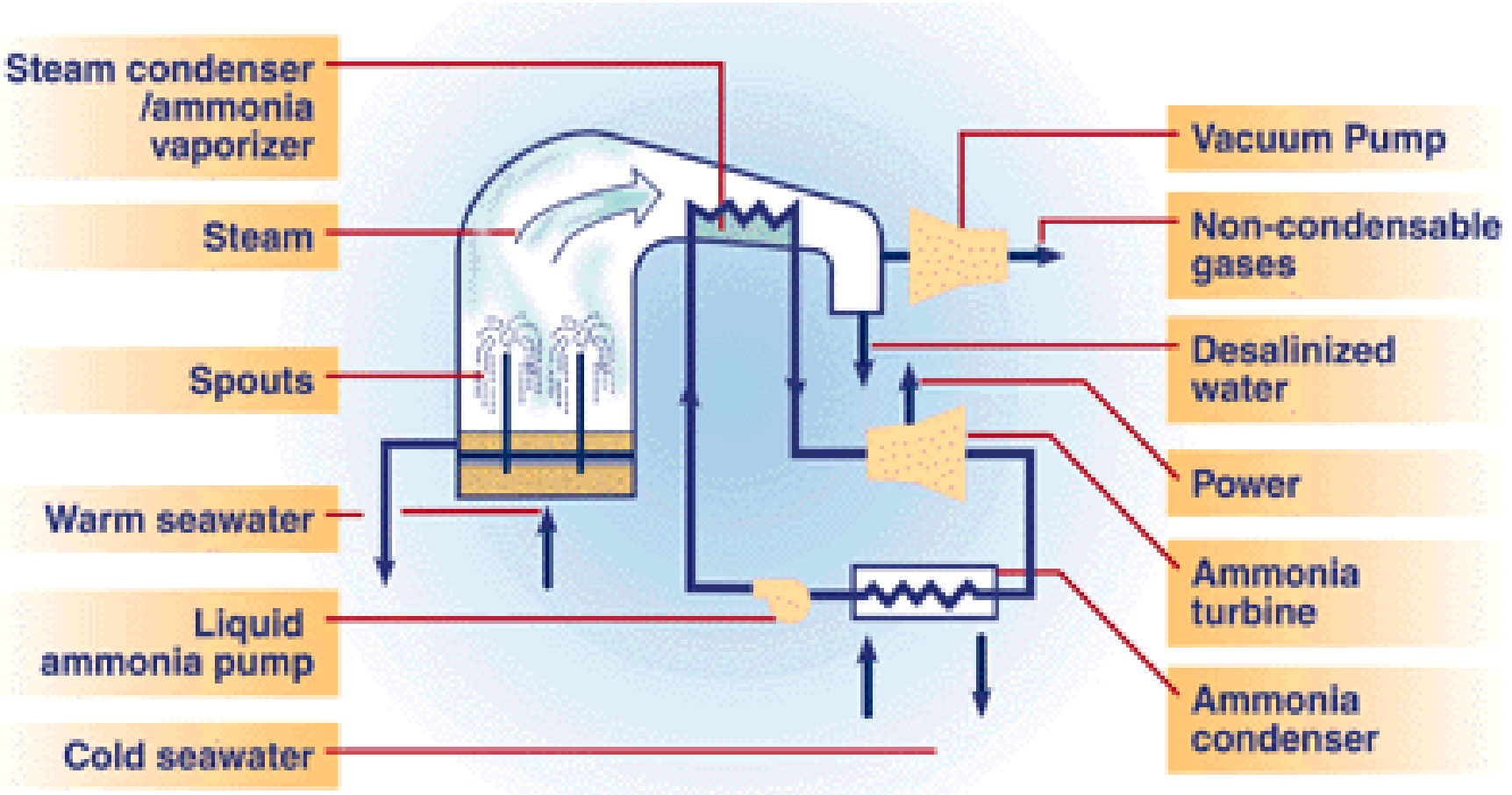
2. Open cycle



- Water is the working fluid
- Desalinated water can be produced

ELECTRICITY PRODUCTION

3. Hybrid cycle



- Ammonia is the working fluid
- Warm sea water is flashed and is then used to vaporize ammonia

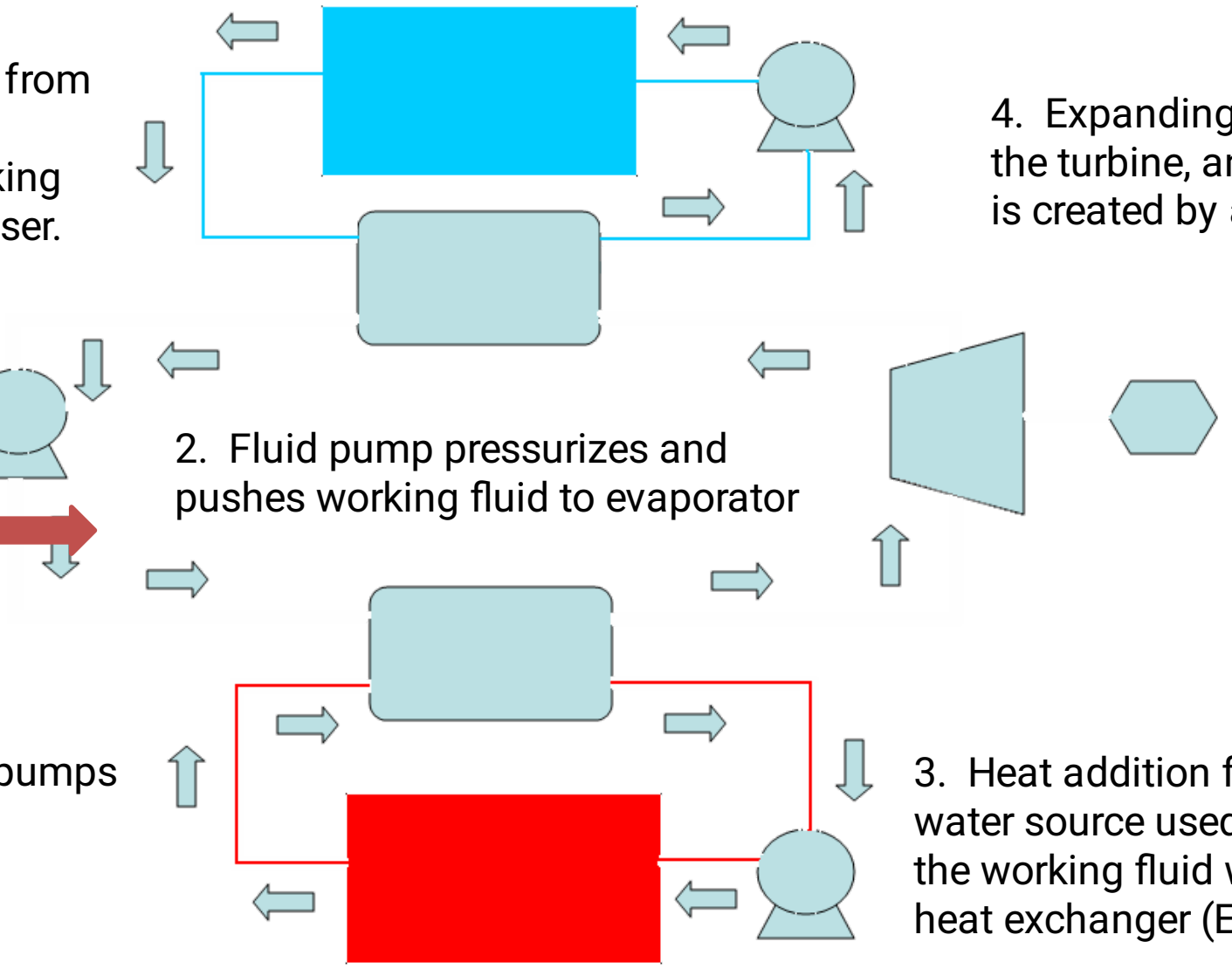
OTEC Process

5. Heat extraction from cold-water sink to condense the working fluid in the condenser.

4. Expanding vapor drive the turbine, and electricity is created by a generator

Cycle begins again
Return to step 2

2. Fluid pump pressurizes and pushes working fluid to evaporator



1. Power input to pumps to start process

3. Heat addition from the hot-water source used to evaporate the working fluid within the heat exchanger (Evaporator)

MAIN COMPONENTS OF AN OTEC SYSTEM

- Evaporators
- Condensers
- Cold-water pipe
- Turbines

POTENTIAL

- Equatorial, tropical and sub-tropical regions i.e.
- 20 °N to 20 °S, have favorable temperature profile
- Total estimated potential – 577000 MW
- 99 nations and territories have access to the
- OTEC thermal resource:
- Americas—Mainland - 15
- Americas—Island - 23
- Africa—Mainland - 18
- Africa—Island - 5
- Indian/Pacific Ocean—Mainland - 11
- Indian/Pacific Ocean—Island - 27

Potential in India

- **Ongoing projects**: The 1 MW barge research and demonstration facility being developed by the National Institute of Ocean Technology, **India** (NIOT) with technical support from Institute of Ocean Energy, Saga University (IOES)

- Identified sites:
  - ➤Kavaratti
  - ➤Kulasekarapattinam
  - ➤Andaman & Nicobar Islands

Requirements of OTEC System

Factors to be considered while choosing a site:

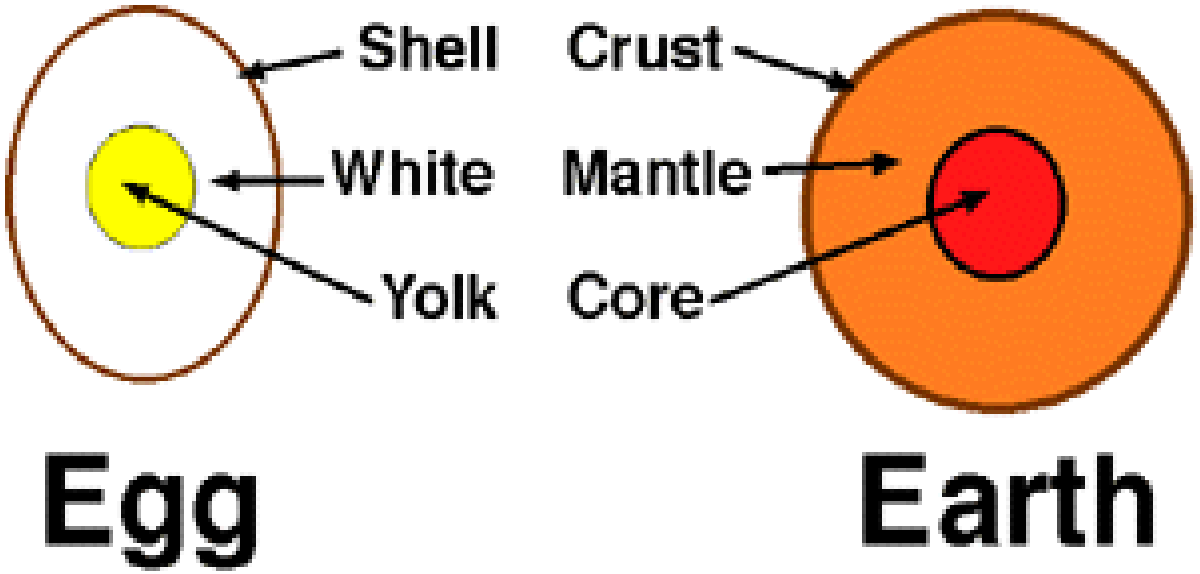
- Thermal gradient in the ocean
- Topography of the ocean floor
- Meteorological conditions – hurricanes
- Seismic activity
- Availability of personnel to operate the plant
- Infrastructure – airports, harbors, etc.
- Local electricity and desalinated water demand.
- Political, ecological constraints
- Cost and availability of shoreline sites

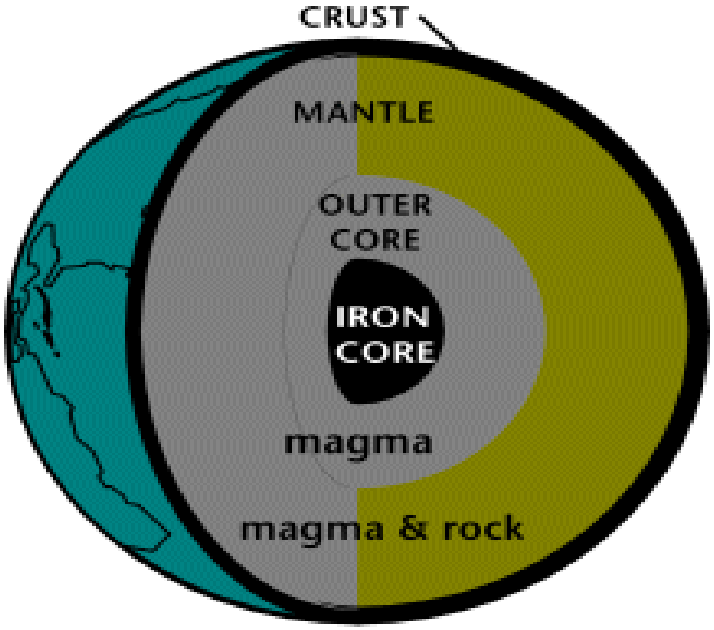
GEOTHERMAL ENERGY

GEOTHERMAL ENERGY

- The word **geothermal** comes from the Greek words geo (earth).and thermal (heat). So, geothermal energy is heat from within the earth.
- We can use the steam and hot water produced inside the earth to heat buildings or generate electricity.
- The geothermal energy is the heat energy available inside the earth.
- The thermal gradient is 1°C per 40 m depth (**25-30 Deg.C/km depth).**
- **The water is sent in the bore wells and** the steam out of it used to drive a steam turbine power cycle. The types of this plant can be wet steam and dry steam type.

The earth can be compared with egg. The outer layer of the earth is called crest and the center layer is called Mantle and inner layer is called Core (Iron).





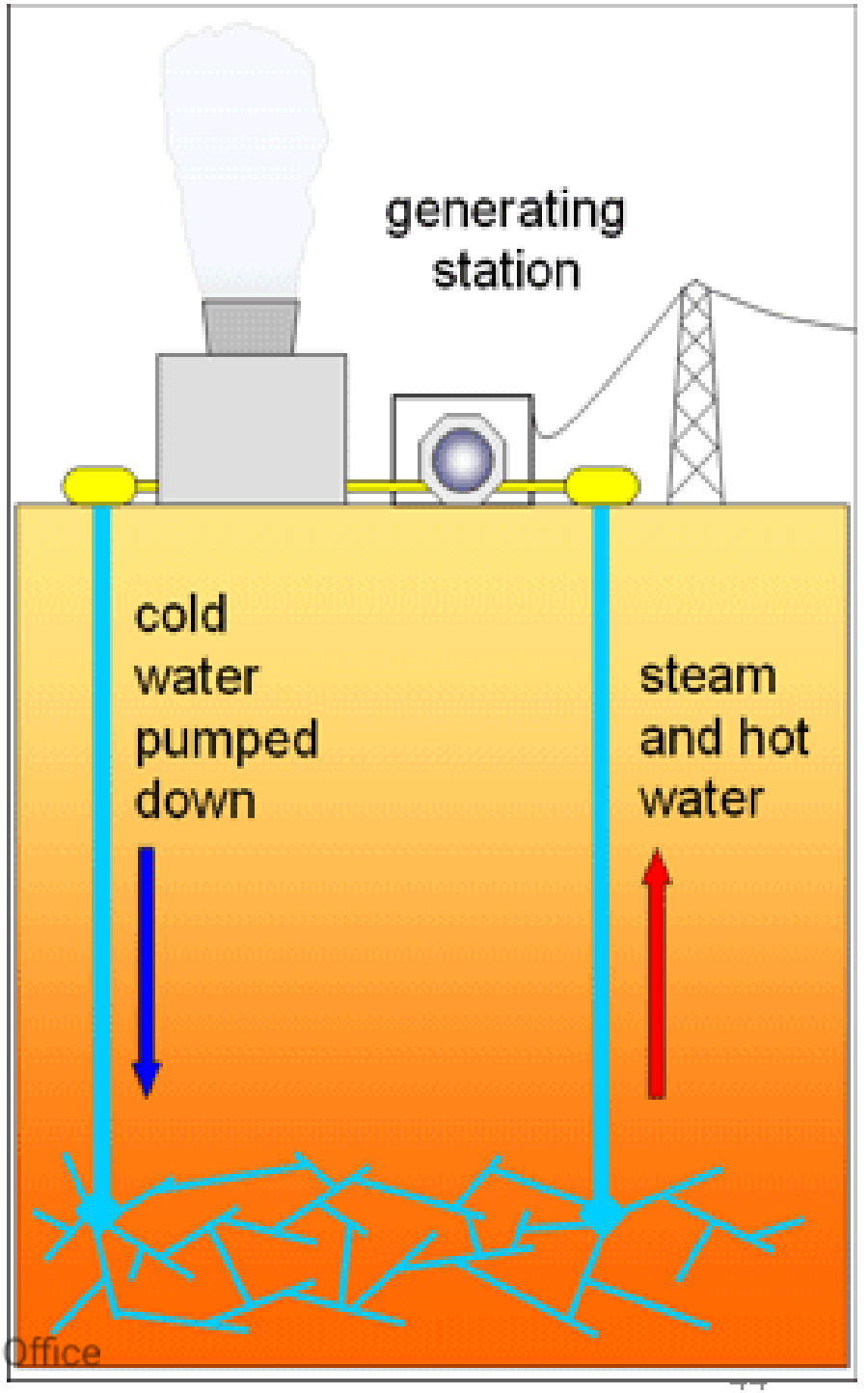
THE EARTH'S INTERIOR

- Below the crust of the earth, the top layer of the *mantle* is a hot liquid rock called magma.
- The crust of the earth f bats on this liquid magma mantle.

- For every *100 meters* you go below ground, the temperature of the rock increases about 3 degrees Celsius.
- So, if you went about *10,000 feet below ground*, the temperature of the rock would be hot enough to boil water.
- Deep under the surface, water *close to the hot rock* can reach temperatures of more than *148°C*.

➤This is hotter than boiling water (100°C). It doesn't turn into steam because it is not in contact with the air.

➤ When this *hot water* comes up through a crack in the earth, we call it a hot spring and it is used to *rotate the turbines and the electricity is produced*.



Types of Geothermal Resources?

- Geothermal Sources are Classified Based on: (1) Temperature, (2) Physical State of H_20 (i.e. water or steam), and (3) Type of Energy Usage
- Primary Classification is Resource Temperature:
  - Low Temperature Reservoir: 50-200 °F (10-94 °C)
  - High Temperature Reservoir: >200 °F

- The most active *geothermal resources* are usually *found* along major plate boundaries where *earthquakes and volcanoes* are concentrated.
- Most of the geothermal activity in the world occurs in an area called the *Ring of Fire.*

Sources of Earth's Internal Energy

- 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.

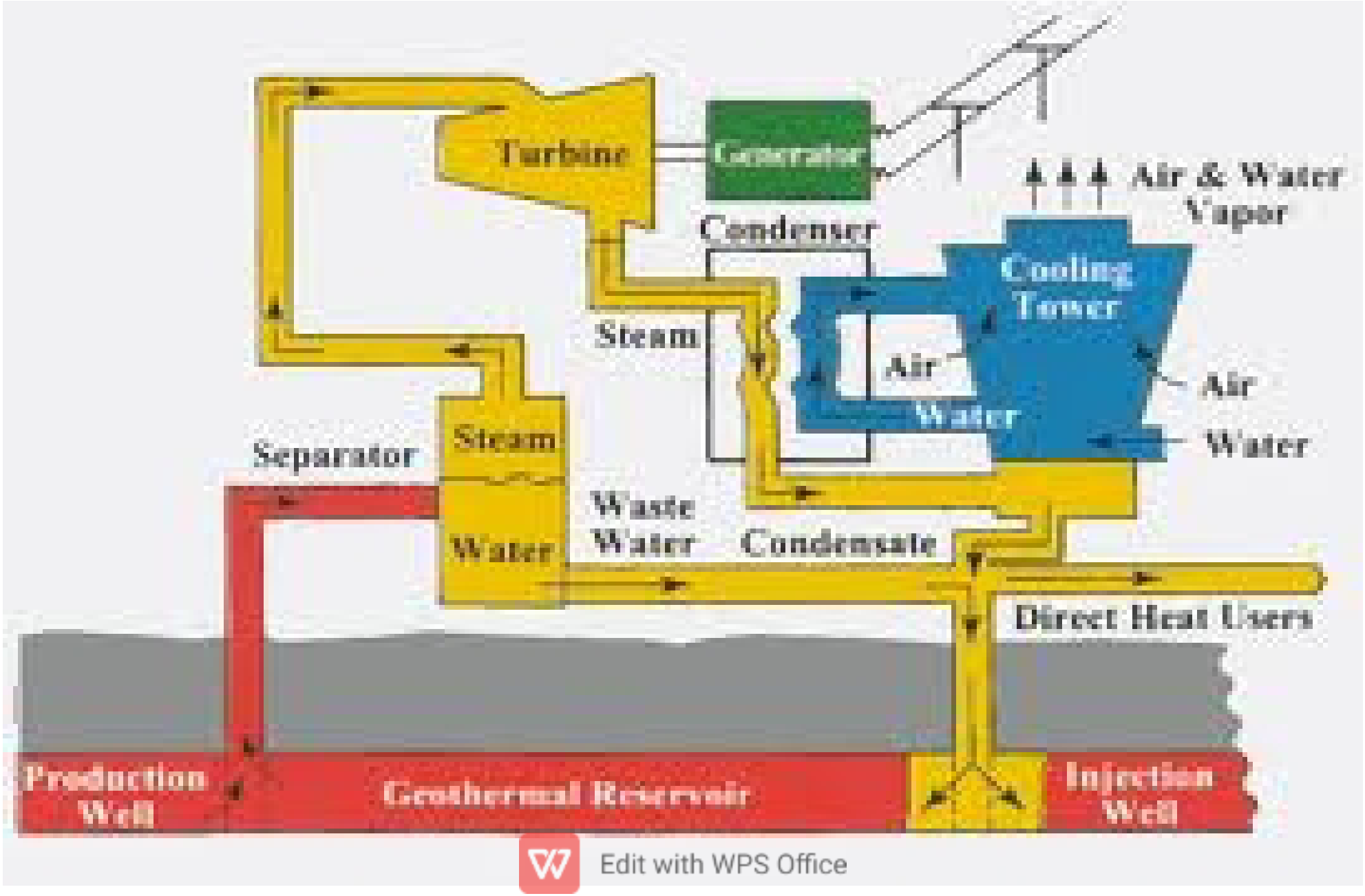
Different Geothermal Energy Sources

- **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 Contd..

- **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 190^0C 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 40^0C/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.

GEOTHERMAL POWER PLANT



Limitations of geothermal energy

- Drilling wells and Maintenance of underground piping systems, contaminations of
- working fluids and treatment of working fluids.

Direct uses of geothermal energy is appropriate for sources below 150^0C

- space heating
- air conditioning
- industrial processes
- drying
- Greenhouses
- Aguaculture
- hot water
- resorts and pools
- melting snow

Crop dehydration plant in Nevada.

A fish farm in Colorado

Greenhouse in Colorado

How Direct Uses Work

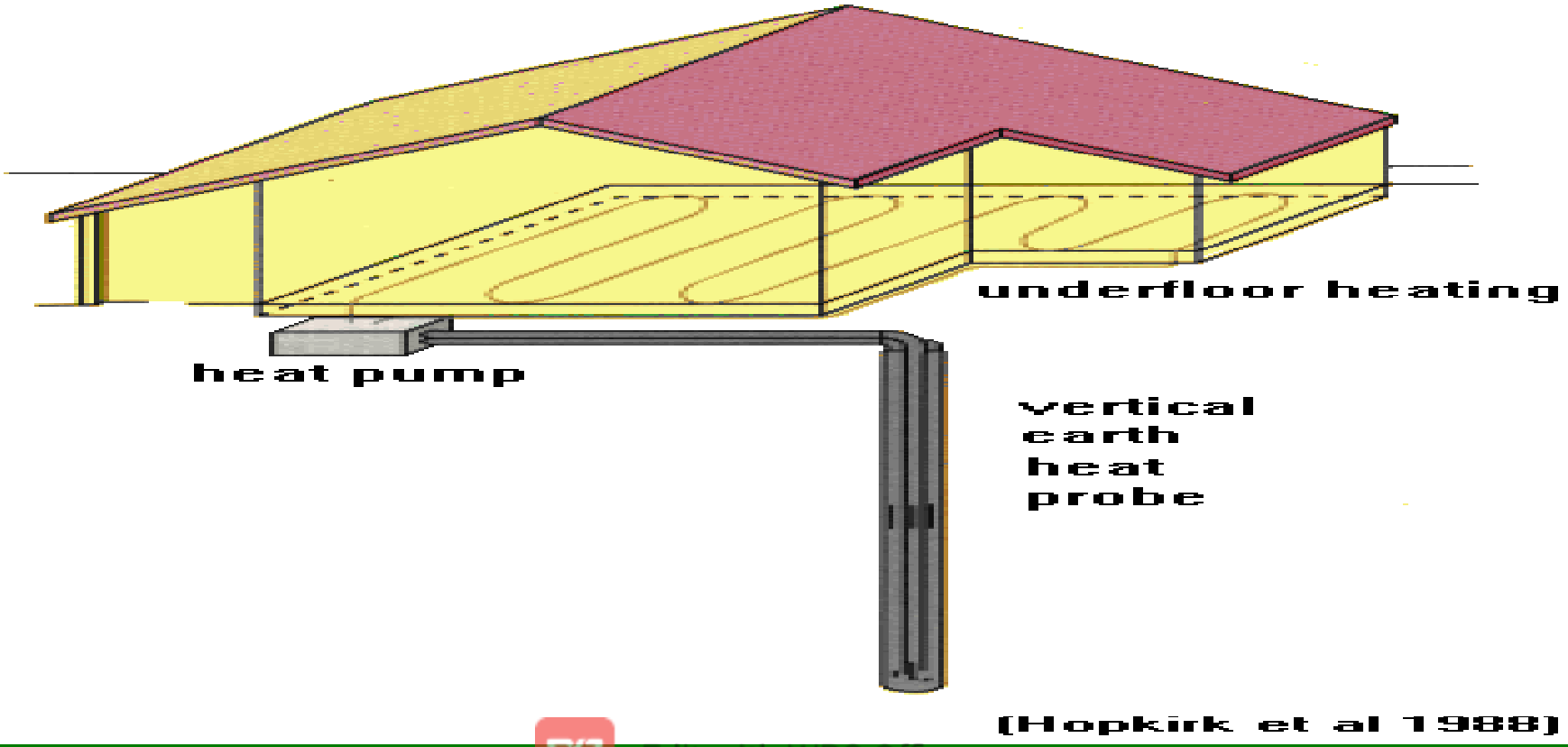
- Direct Sources function by sending water down a well to be heated by the Earth's warmth.
- Then a heat pump is used to take the heat from the underground water to the substance that heats the house.
- Then after the water it is cooled is injected back into the Earth.

Ground Heat Collectors

This system uses horizontal loops filled with circulating water at a depth of 80 to 160 cm underground.

Borehole Heat Exchange

This type uses one or two underground vertical loops that extend 150 meters below the surface.



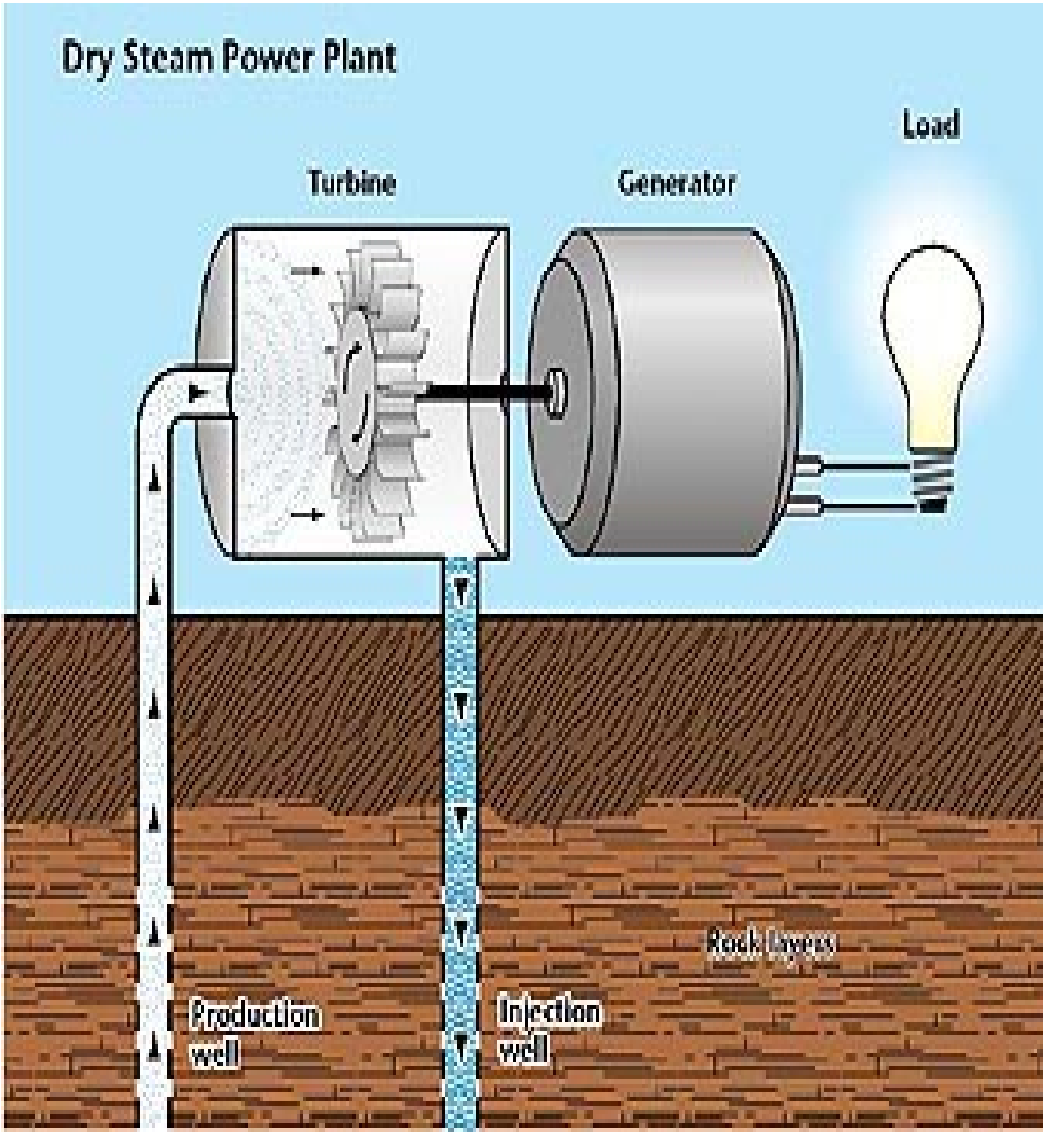
Schema of a U tube system installed in a small diameter well

TYPES OF GEOTHERMAL POWER PLANTS

- Different Types of Plants are Required to Take Advantage of the Particular Characteristics of Each Specific Geothermal Site
- Main Types of Geothermal Power Plants:
  1. **Dry Steam**
  2. **Flash Steam**
  3. **Binary Cycle**

Dry Steam Geothermal Plants

- Uses Steam From Geothermal Reservoir Directly
- Only Requires Removal of Rock Fragments From Steam Prior to Entering Turbines
- Only Emissions Are Water Vapor

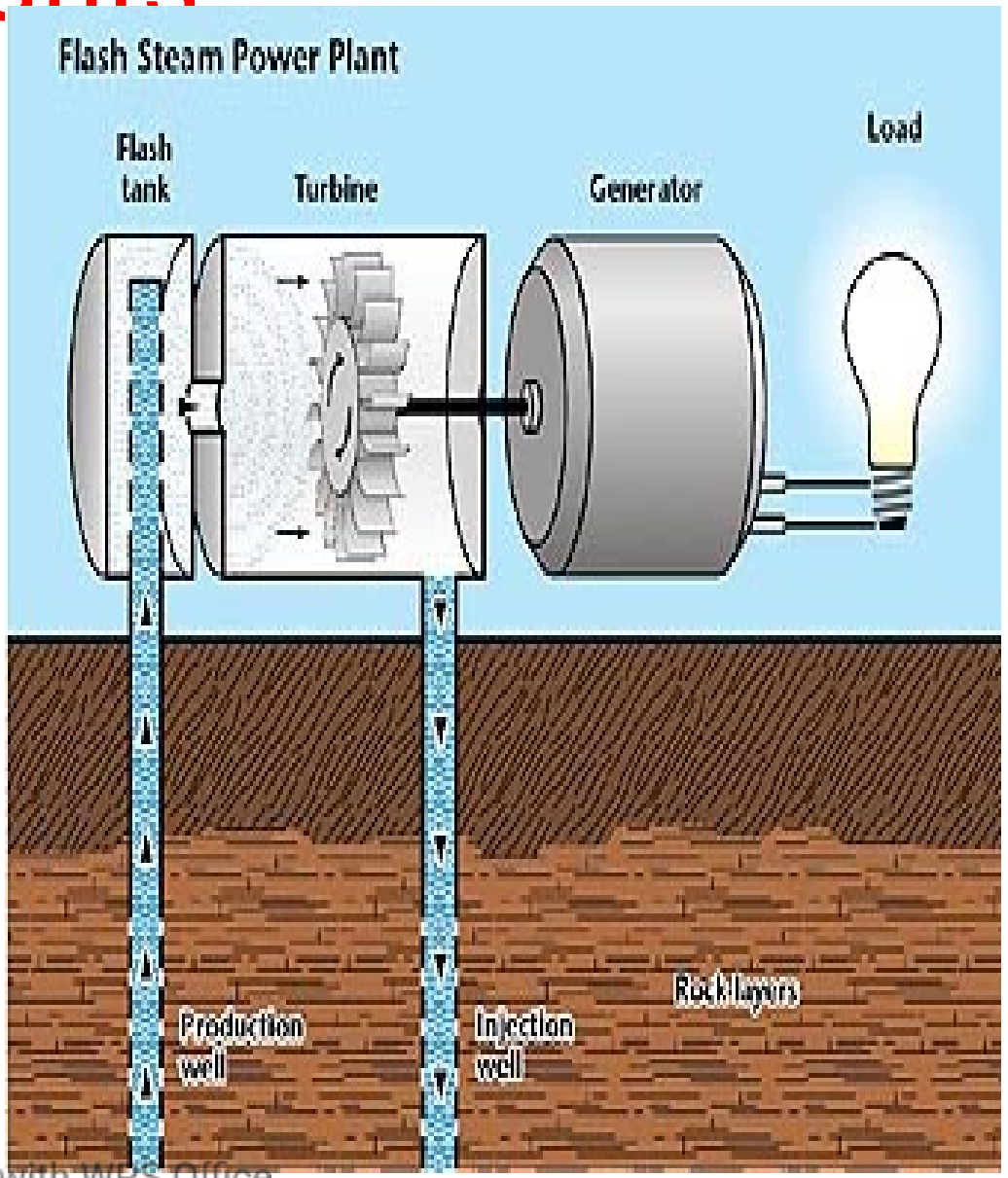


Dry Steam Geothermal Plants

- The “Geysers” in CA
  - Opened in 1960
- After 30 yrs. – temp. remains constant; pressure drop from 3.3 to 2.3 MPa near wells
- Output–2700 MW; enough for San Francisco (pop. 780,000)[1]

Flash Steam Geothermal Power Plants

- Injection of Deep, High-pressure Water Into Low-pressure Tanks; Water “Flashes” to Steam Used to Drive Turbines
- Excess Water Returned to Maintain Pressure in Reservoir

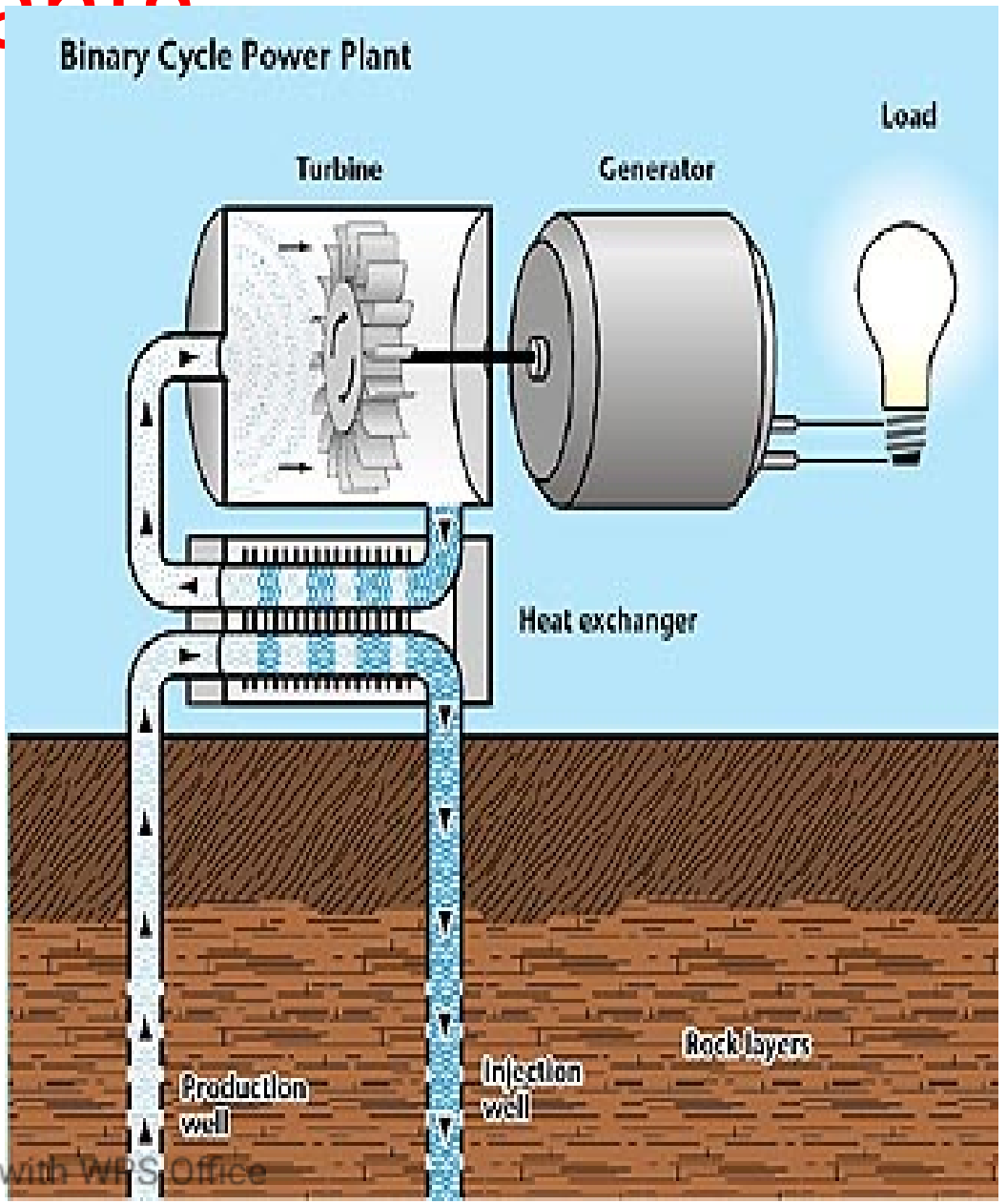


Flash Steam Plants Cont'd

- Steamboat Springs, NV Plant
- Initial Conditions – Liquid H_2O @ 240°C, Pressures of 24 MPa (hydrostatic pressure)

Binary Cycle Geothermal Power Plants

- Moderately Hot Water (<175 °C) Passed Through Heat Exchanger
- Heat Transferred to Secondary Fluid (Low B.P. Fluids (i.e., Propane or Isobutane) Which Is Vaporized ("Flashed")



Binary Cycle Plants Cont'd

- Higher Capital Cost
  - Needs High Efficiency Equip.
- Water Never Contacts Turbine/generator Unit
- Water Returned Directl to Reservoir
- No Plant Emissions!

Why Haven't We Built More Dry Steam Geothermal Plants?

- Pro:
  - **Lowest Technology Required – Lowest Capital Costs**

- Con:
  - **Ideal Conditions Required**
    - **Few Sites Available (Very Rare) in U.S.**

Geothermal Harmful Effects and Environmental Issues

- Brine can salinate soil if the water is not injected back into the reserve after the heat is extracted.
- 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.
- One well "blew its top" 10 years after it was built, and this threw hundreds of tons of rock, mud and steam into the atmosphere.

- There is the fear of noise pollution during the drilling of wells

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. Geothermal plants can be online 100%-90% of the time. Coal plants can only be online 75% of the time and nuclear plants can only be online 65% of the time.
- Flash and Dry Steam Power Plants emit 1000x to 2000x less carbon dioxide than fossil fuel plants, no nitrogen oxides and little SO_2.
- Geothermal electric plants production in 13.380 g of Carbon dioxide per kWh, whereas the CO_2 emissions are 453 g/kWh for natural gas, 906g g/kWh for oil and 1042 g/kWh for coal.
- Binary and Hot Dry Rock plants have no gaseous emission at all.
- Geothermal plants do not require a lot of land, 400m^2 can produce a gigawatt of energy over 30 years.

➤Geothermal Heat Pumps:

- produces 4 times the energy that they consume.

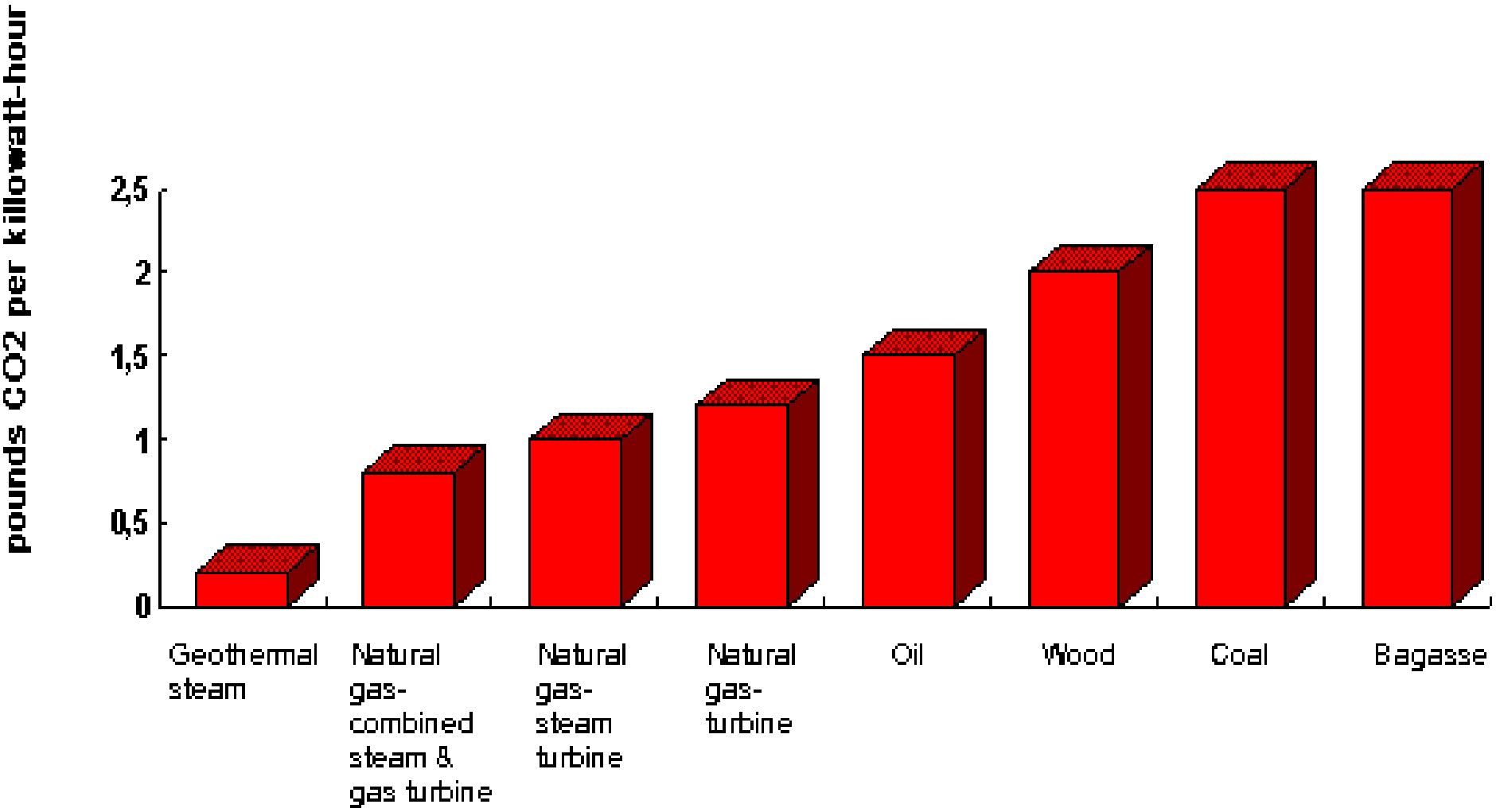
-initially costs more to install, but its maintenance cost is 1/3 of the cost for a typical conventional heating system and it decreases electric bill. This means that geothermal space heating will save the consumer money.can be installed with the help of special programs that offer lowinterest rate loans.

➤Electricity generated by geothermal plants saves 83.3 million barrels of fuel each year from being burned world wide. This prevents 40.2 million tons of CO_2 from being emitted into the atmosphere.

➤Direct use of geothermal energy prevents 103.6 million barrels of fuel each year from being burned world wide. This stops 49.6 tons of CO_2 from being emitted into the atmosphere.

CARBON DIOXIDE EMMISIONS

per unit of energy produced



Comparison of CO_2 emissions between conventional energy systems and geothermal plants to generate electricity

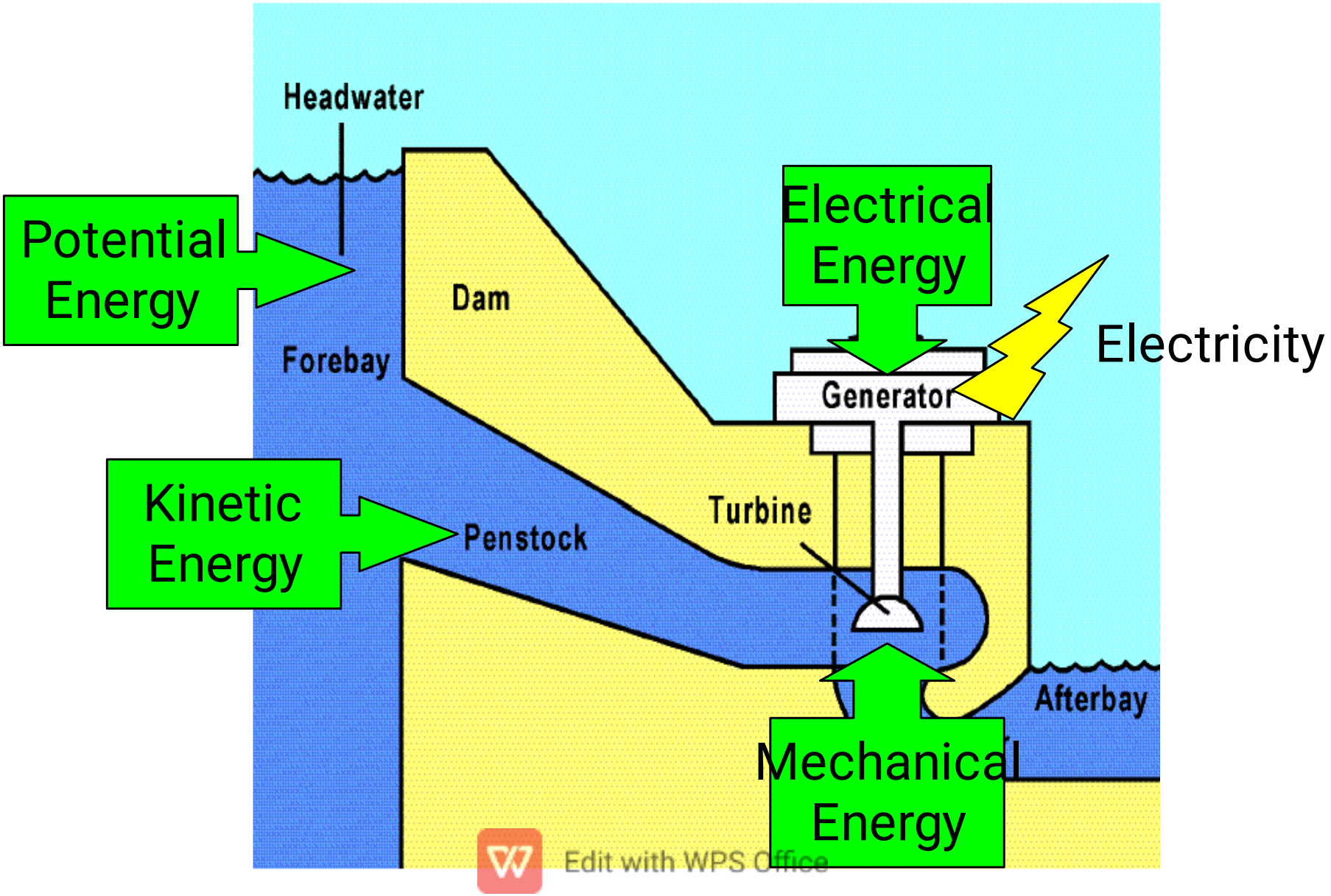
HYDEL ENERGY

Hydro energy

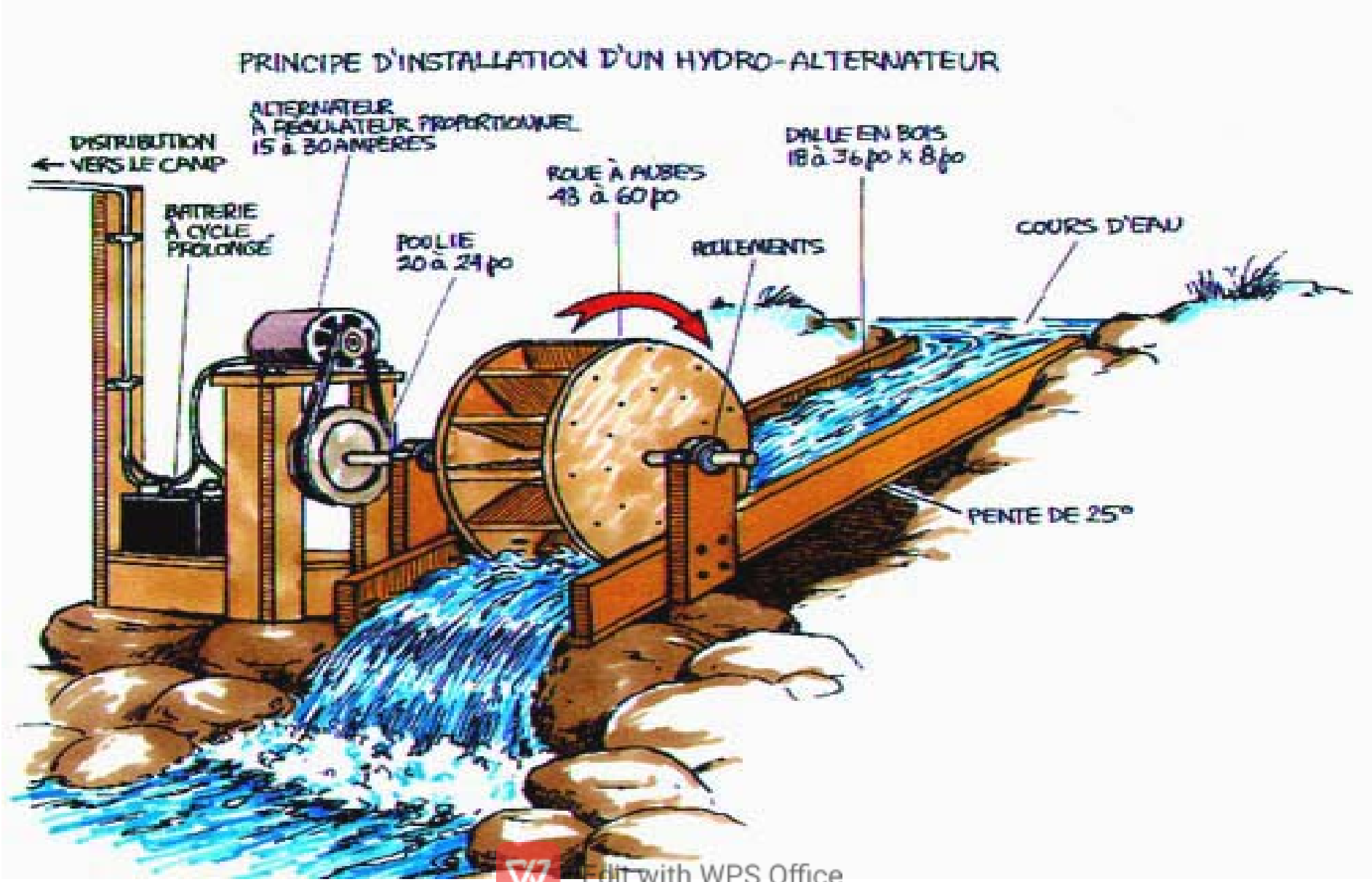
Hydro energy is derived from f bwing water in rivers, water streams in mountains or from man-made installations where water f bws from a high-level reservoir down through a tunnel and away from the dam.

- A *dam is built to trap water*, usually in a valley where there is an existing lake.
- Water is allowed to flow through *tunnels* in the dam, to turn turbines and thus drive generators and the electricity is produced

Hydropower to Electric Power

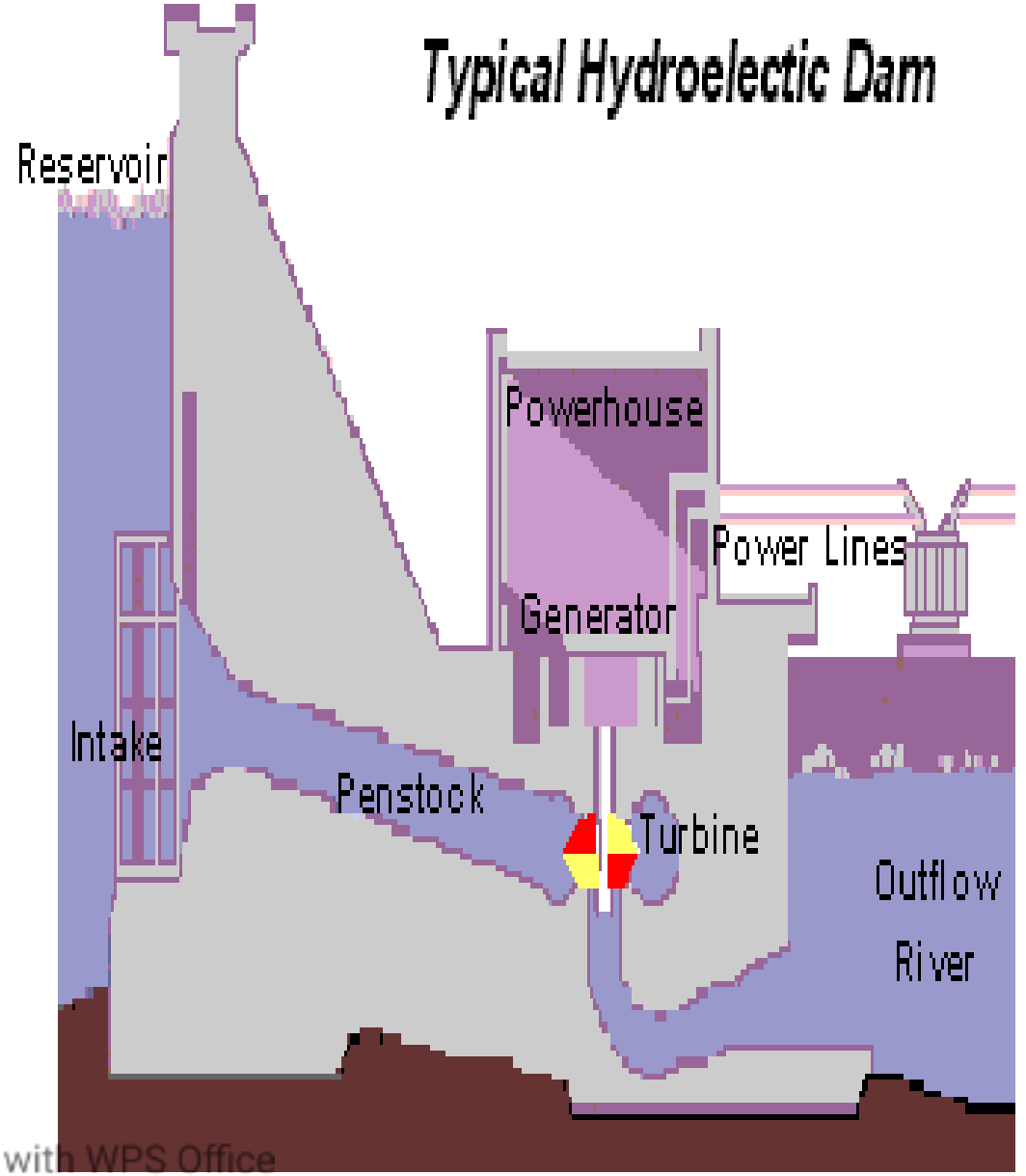


Hydropower to Electric Power



How Hydropower Works

- Water from the reservoir flows due to gravity to drive the turbine.
- Turbine is connected to a generator.
- Power generated is transmitted over power lines.



How Hydropower Works (2)

- A water turbine that cover the energy of flowing or falling water into mechanical energy that drives a generator, which generates electrical power. This is a heart of hydropower power plant.
- A control mechanism to provide stable electrical power. It is called governor.
- Electrical transmission line to deliver the power to its destination.

Sizes of Hydropower Plants

- **Pico hydroelectric plant**
  - ➤ Up to 10kW, remote areas away from the grid
- **Micro hydroelectric plant**
  - – Capacity 10kW to 300kW, usually provided power for small community or rural industry in remote areas away from the grid
- **Small hydroelectric plant**
  - ➤ Capacity 300kW to 1MW
- **Mini hydroelectric plant**
  - ➤ Capacity above 1MW
- **Medium hydroelectric plant**
  - ➤ 15 - 100 MW usually feeding a grid
- **Large hydroelectric plant**
  - ➤ More than 100 MW feeding into a large electricity grid

Micro Hydropower Systems

- Many creeks and rivers are permanent, they never dry up, and these are the most suitable for micro-hydro power production
- Micro hydro turbine could be a waterwheel
- Newer turbines : Pelton wheel (most common)
- Others : Turgo, Crossflow and various axial flow turbines

Turbine Classified