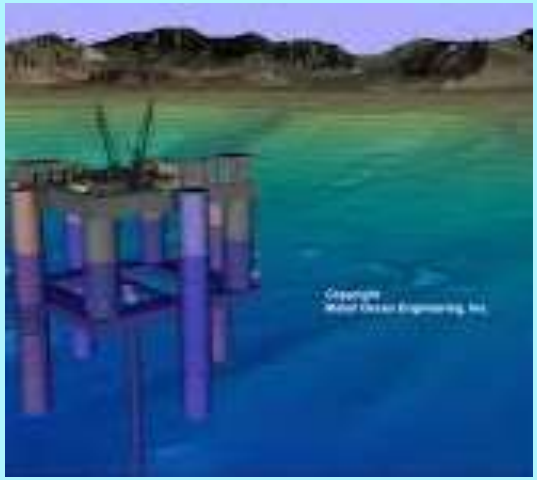
Unit 5:- Other Alternate Sources



Ocean Thermal Energy Conversion

Syllabus…Unit 5

- **Other Alternate Sources:** Ocean Thermal Energy Conversion, Geothermal, Tidal, Wave Energy, MHD, Fuel Cells, environmental issues of energy services.

Books …

- Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley - IEEE

Press, August 2004.

- Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
- Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

Supplementary Reading:

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

Lecture 1 Ocean Thermal Energy Conversion (OTEC)

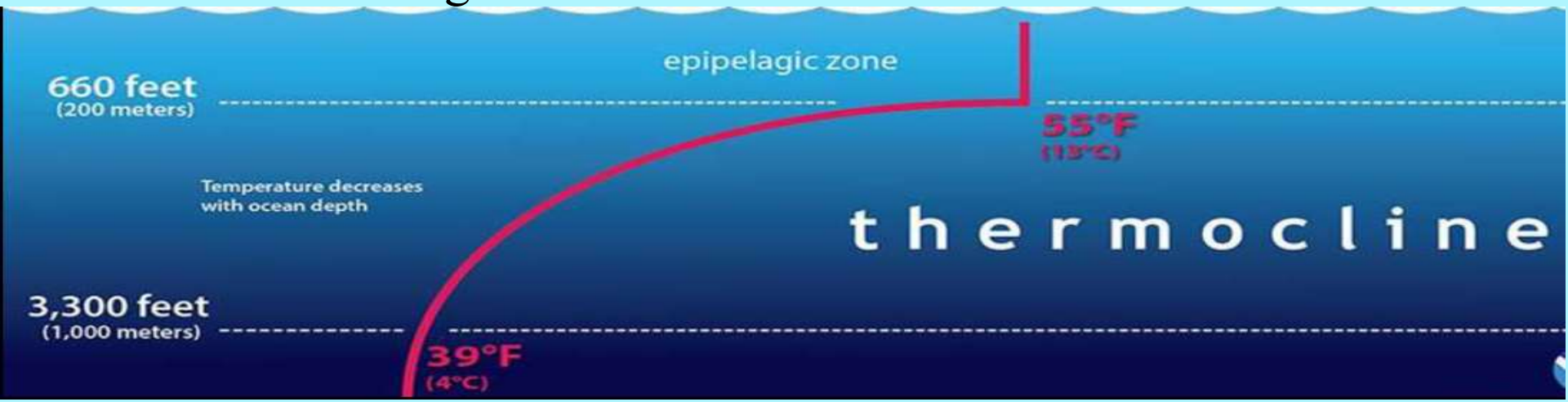
- Ocean Thermal Energy Conversion
- O T E C Characteristics
- Ocean Thermal Temperature
- OTEC History
- OTEC Plants
- OTEC Advantages
- OTEC Disadvantages
- OTEC Plant Theory
- OTEC Plant Classification
- Closed Cycle
- Open Cycle
- Land based OTEC Plant
- Off shore OTEC Plant
- Other Uses, Benefits
- Limitations

Ocean Thermal Energy Conversion

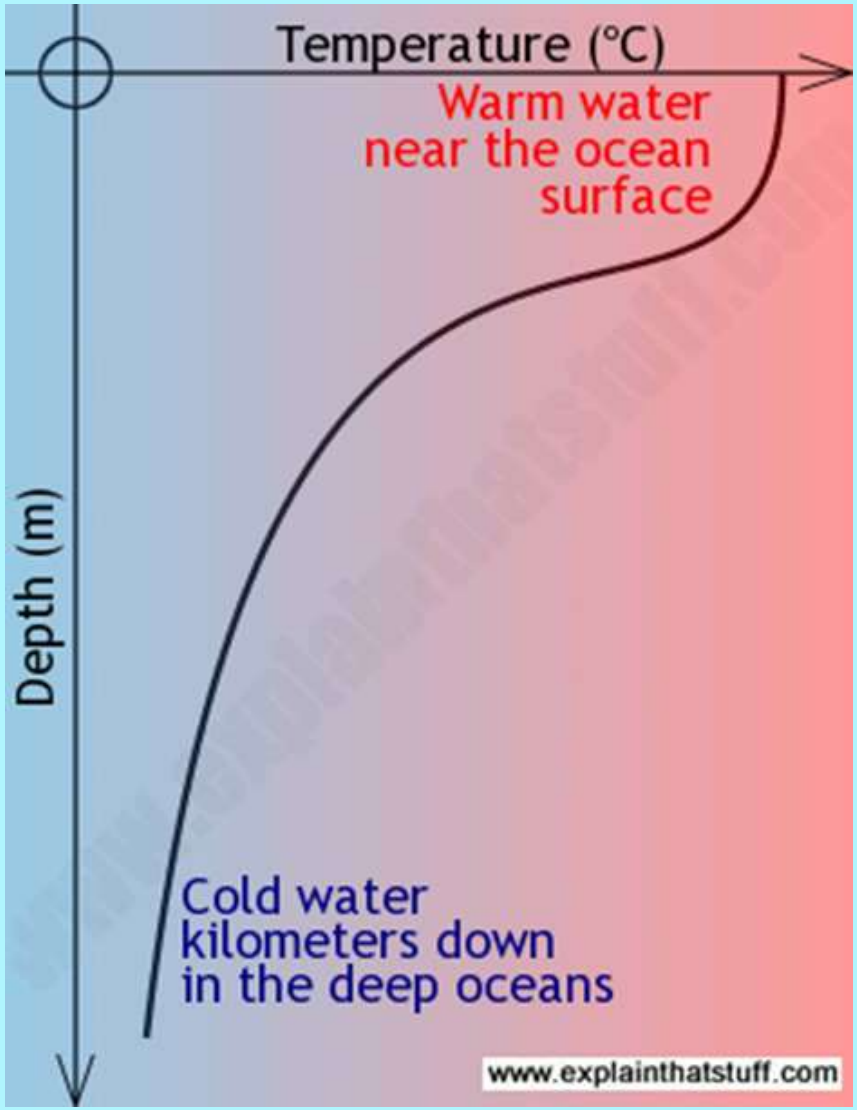
- The oceans cover a around 71 percent of the Earth's surface. Hence, world's largest solar energy collector and energy storage system.
- Ocean thermal energy conversion (OTEC) is a way to generate electricity using the temperature difference of sea water at different depth to run heat engines and produce useful work.
- Since OTEC exploits renewable solar energy, recurring costs to generate electrical power are minimal.
- OTEC utilizes the world’s largest solar radiation collector - The ocean. The ocean contains enough energy power all of the world’s electrical needs.

O T E C Characteristics

- It uses the ocean's naturally available temperature gradient (thermocline), or thermal energy.
- It is completely Green Renewable Energy
- Unlike Solar or wind, available continuously as a base load. Thus eliminating the need to store energy.
- Up to 88,000 TWh/yr of power could be generated from OTEC without affecting the ocean's thermal structure.

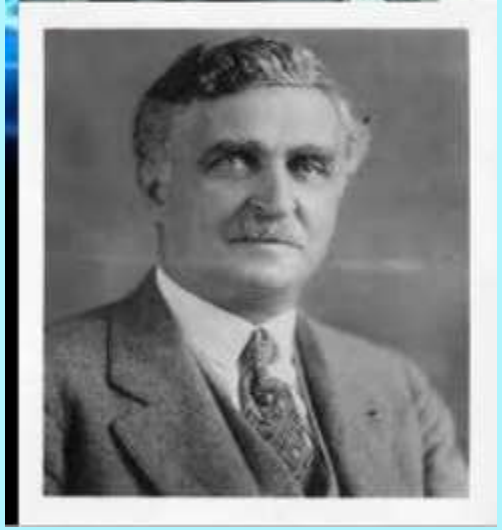


Ocean Thermal Temperature



- A heat engine efficiency is greater for large temperature difference.
- In the oceans the temperature difference is greatest in the tropics, although still a modest 20 to 25 °C.
- OTEC has the potential to offer global amounts of energy that are 10 to 100 times greater than other ocean energy options such as wave power

OTEC History



- In 1881, Jacques Arsene d'Arsonval, a French physicist, proposed tapping the thermal energy of the ocean
- . D'Arsonval's student, Georges Claude, built the first OTEC plant, in Matanzas, Cuba in 1930, The plant was later destroyed in a storm
- In 1935, Claude constructed a plant aboard a 10,000-ton cargo vessel moored off the coast of Brazil.Weather and waves destroyed it before it could generate net power
- In 1962, J. Hilbert Anderson and James H. Anderson, Jr. focused on increasing component efficiency. They patented their new "closed cycle" design in 1967.

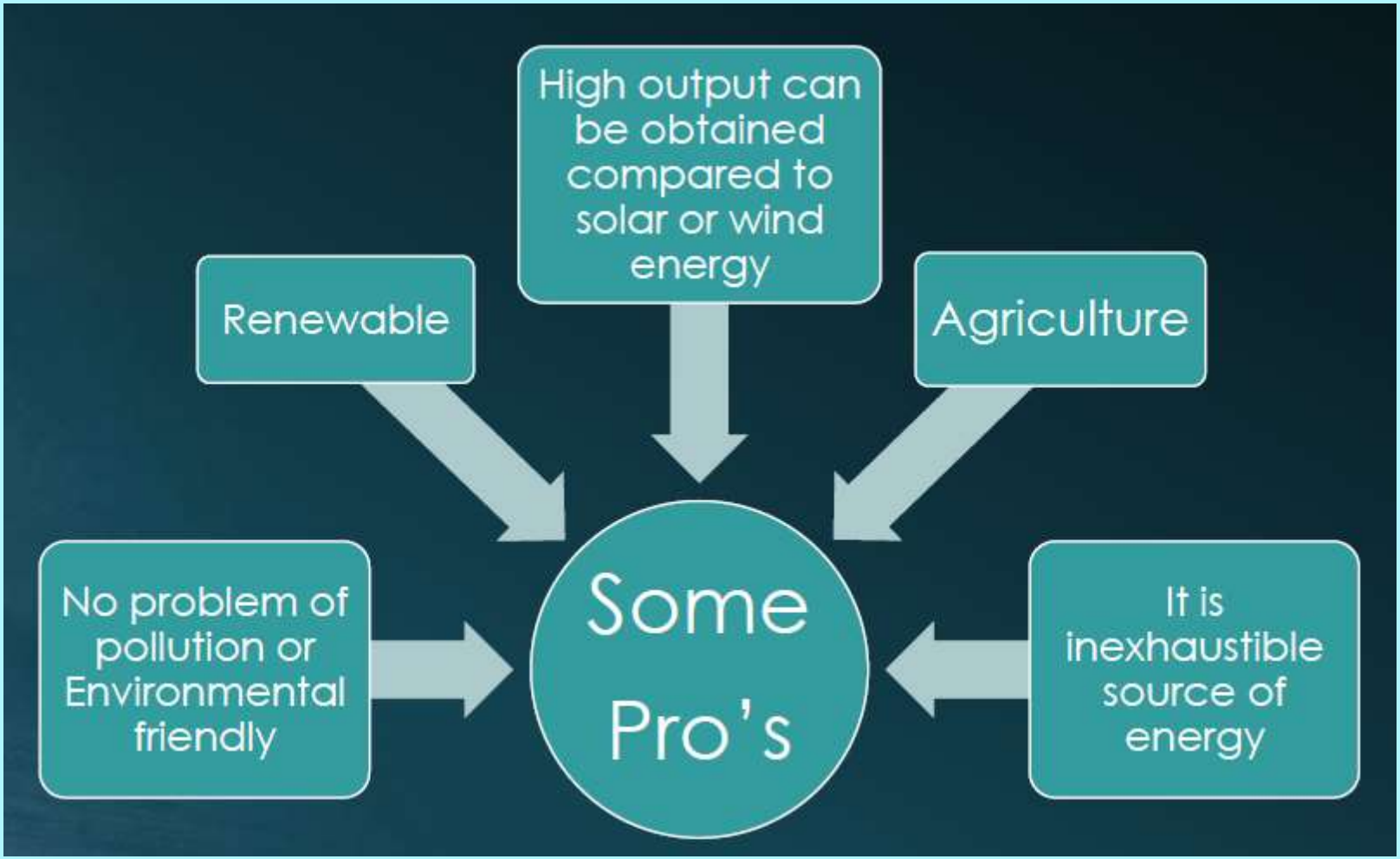
OTEC History

- Japan is a major contributor to the development of OTEC technology. Beginning in 1970 the Tokyo Electric Power Company successfully built and deployed a 100 kW closed-cycle OTEC plant on the island of Nauru
- OTEC test facility at Keahole Point, Kona, Hawaii (estd. 1974)
- In 2002, India tested a 1 MW floating OTEC pilot plant near Tamil Nadu.

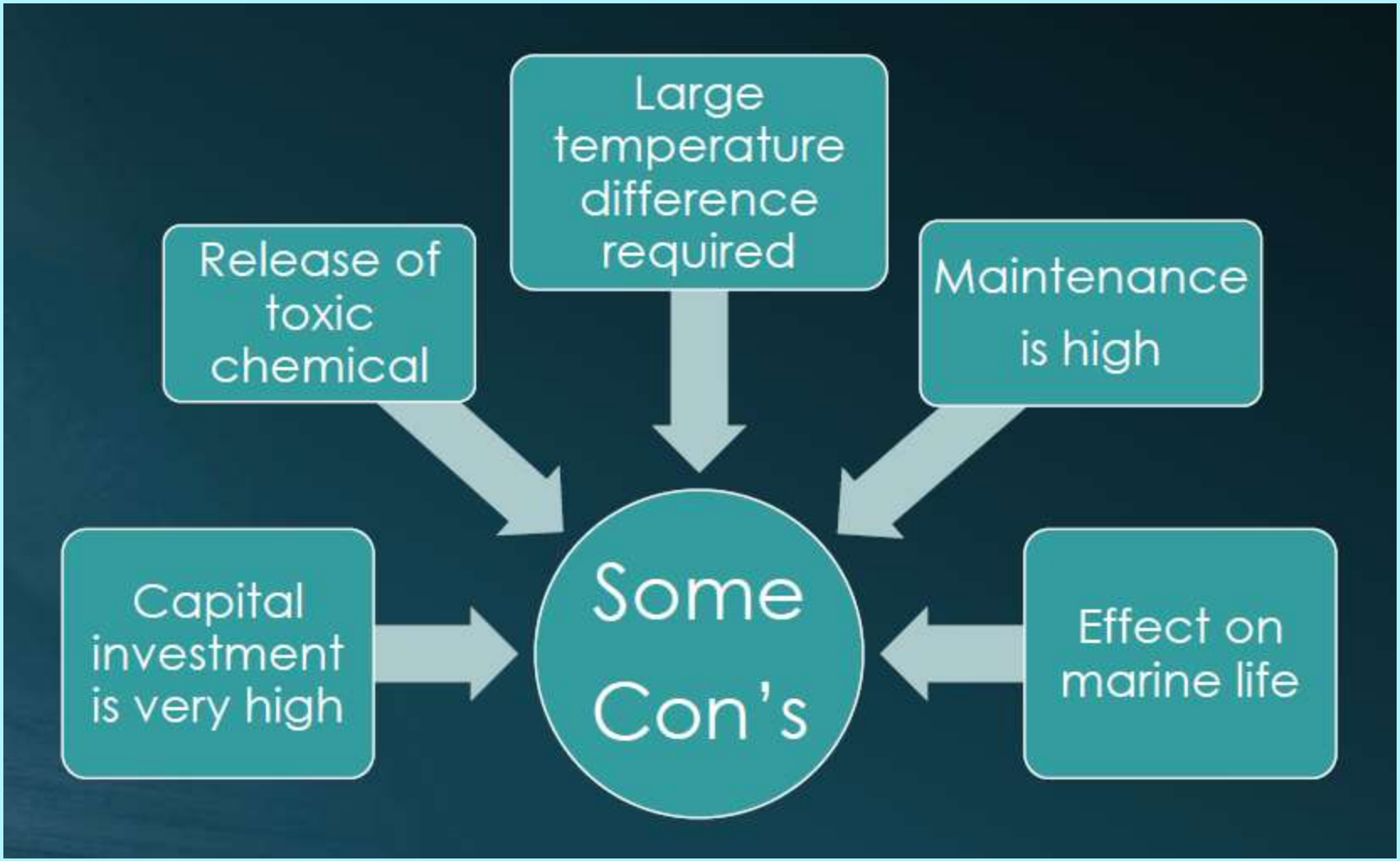
OTEC Plants

Country	Power output	Purpose	Year
Saga, Japan	30 kW	Research and development	1980
Gosung, Korea	20 kW	Research and development	2012
Reunion Island, France	15 kW	Research and development	2012
Kumejima, Japan	100 kW	Research and development, electricity production	2013
Hawaii, USA	105 kW	Electricity production	2015

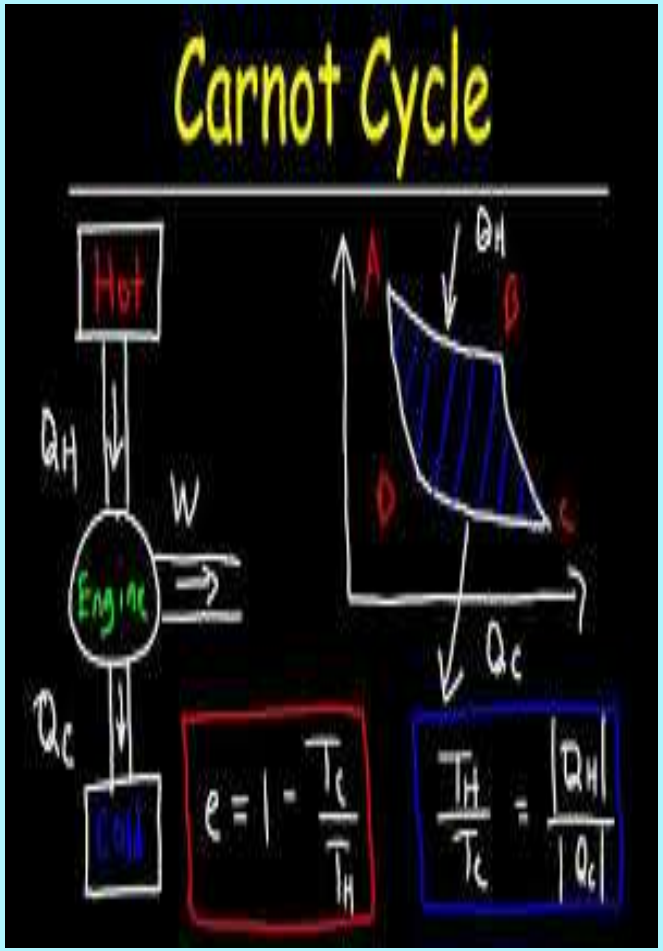
OTEC Advantages



OTEC Disadvantages

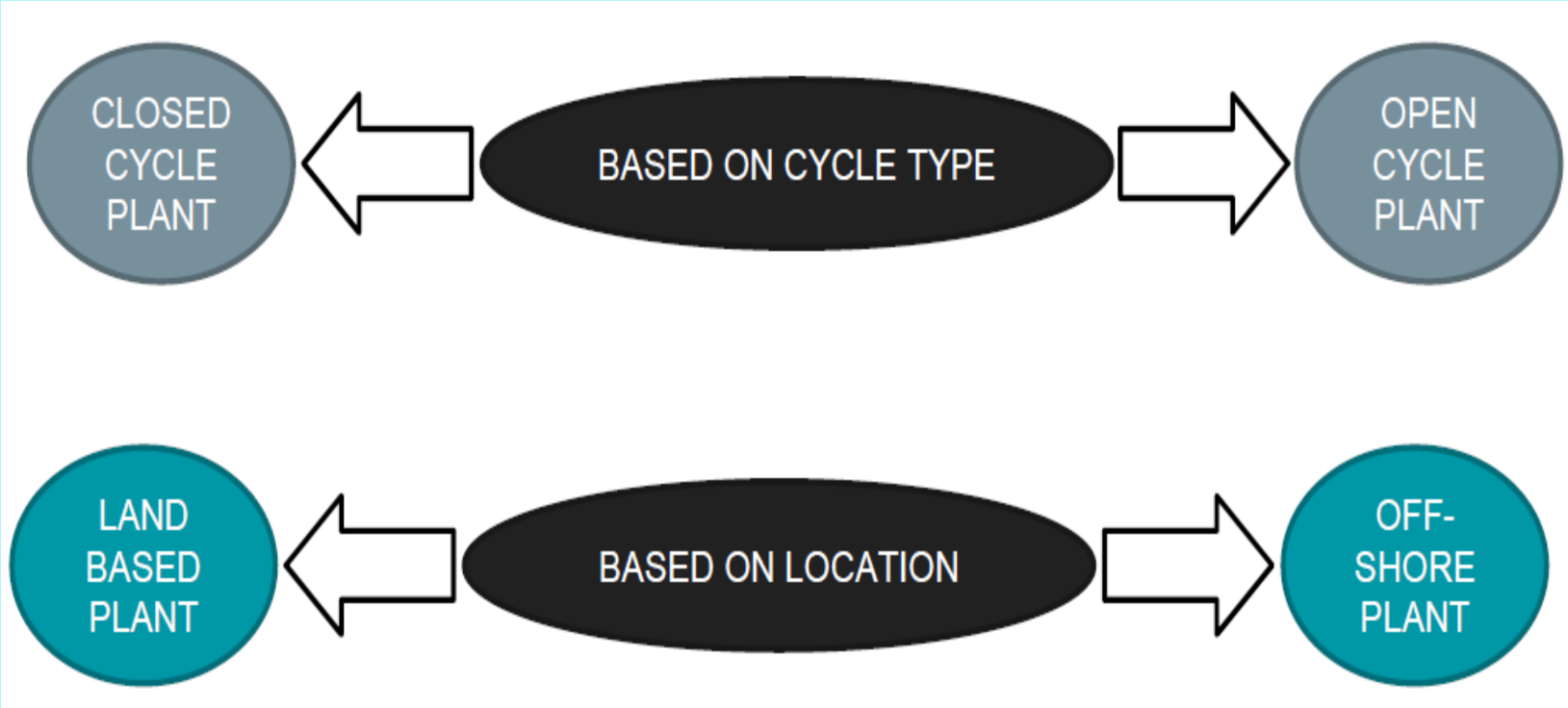


OTEC Plant Theory

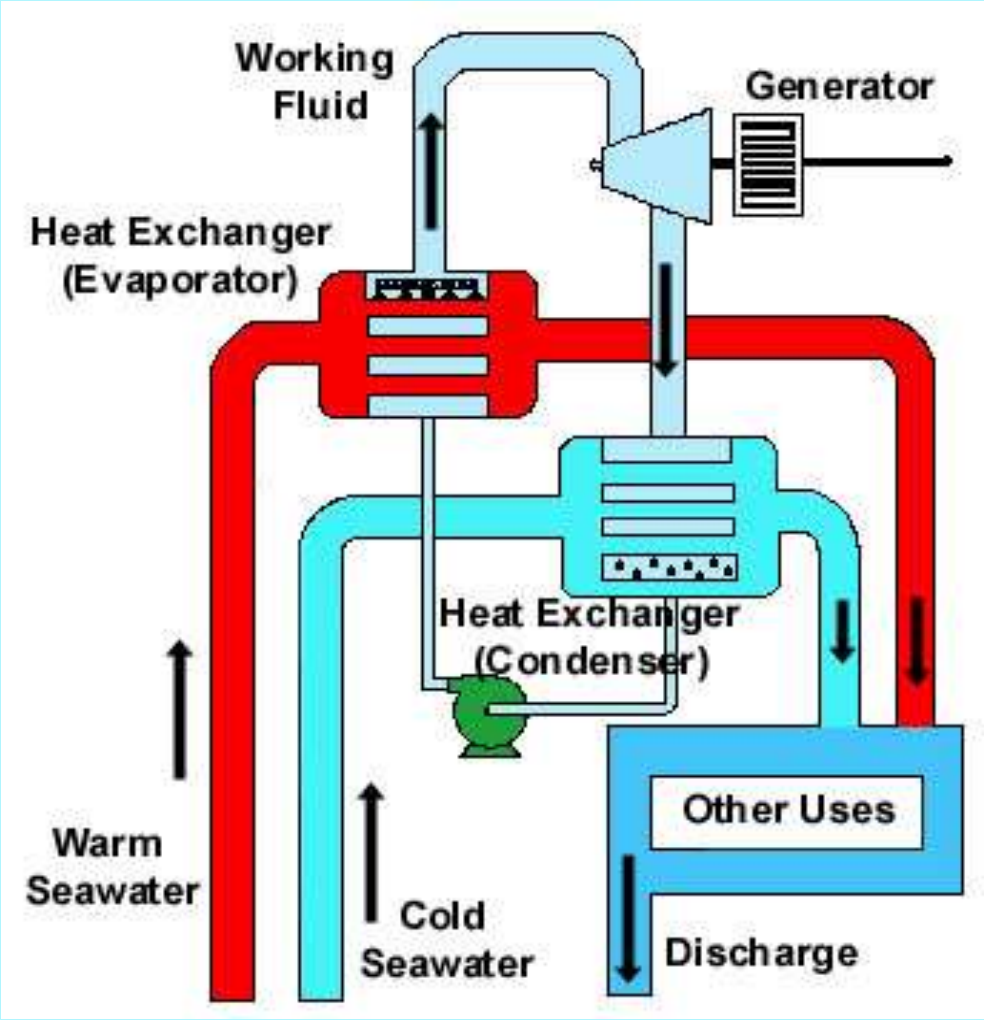


Thermodynamic efficiency:
The main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature differences. It is still considered an emerging technology. Early OTEC systems were 1 to 3 percent thermally efficient, well below the theoretical maximum 6 and 7 percent for this temperature difference. Modern designs allow performance approaching the theoretical maximum Carnot efficiency.

OTEC Plant Classification

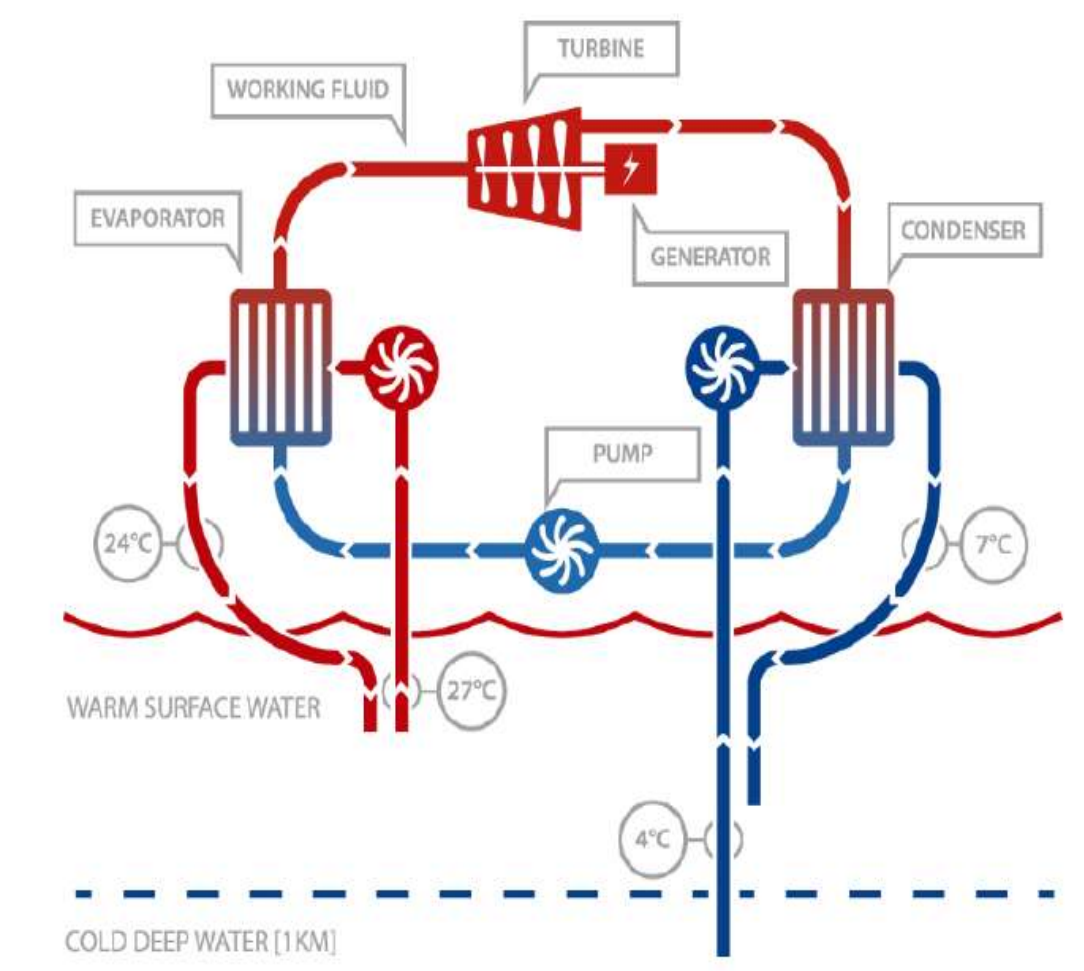


OTEC Closed Cycle

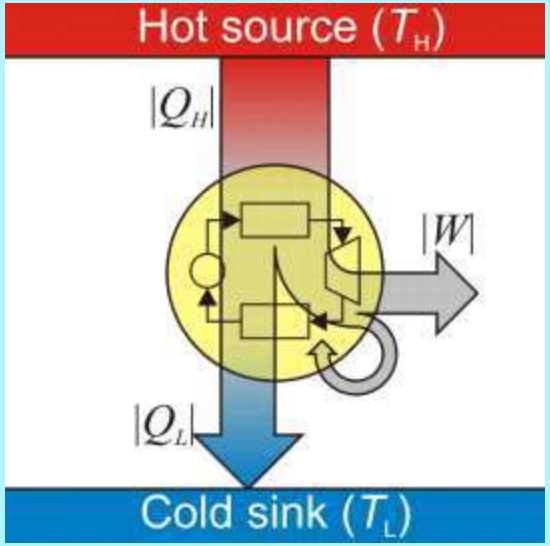


Closed-cycle systems use fluid with a low boiling point, such as ammonia (having a boiling point around -33 °C at atmospheric pressure), to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor turns the turbo-generator.

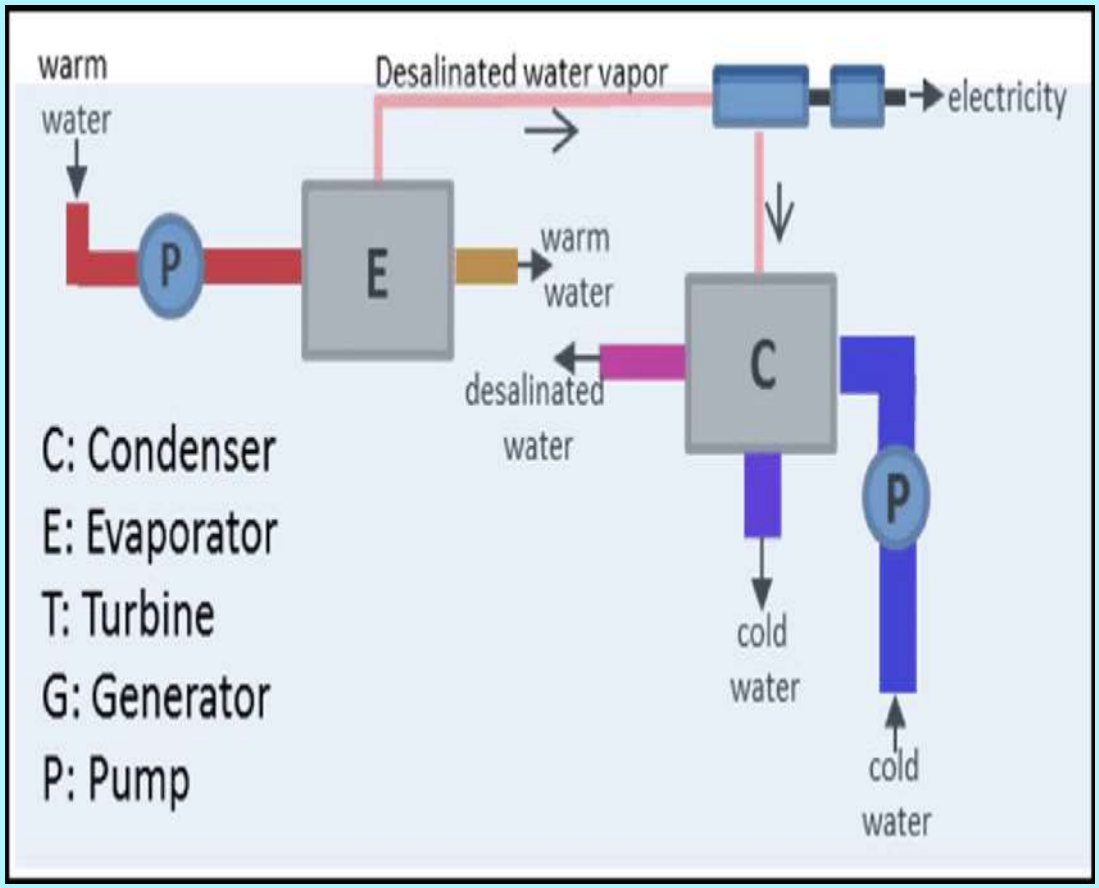
OTEC Closed Cycle



Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.

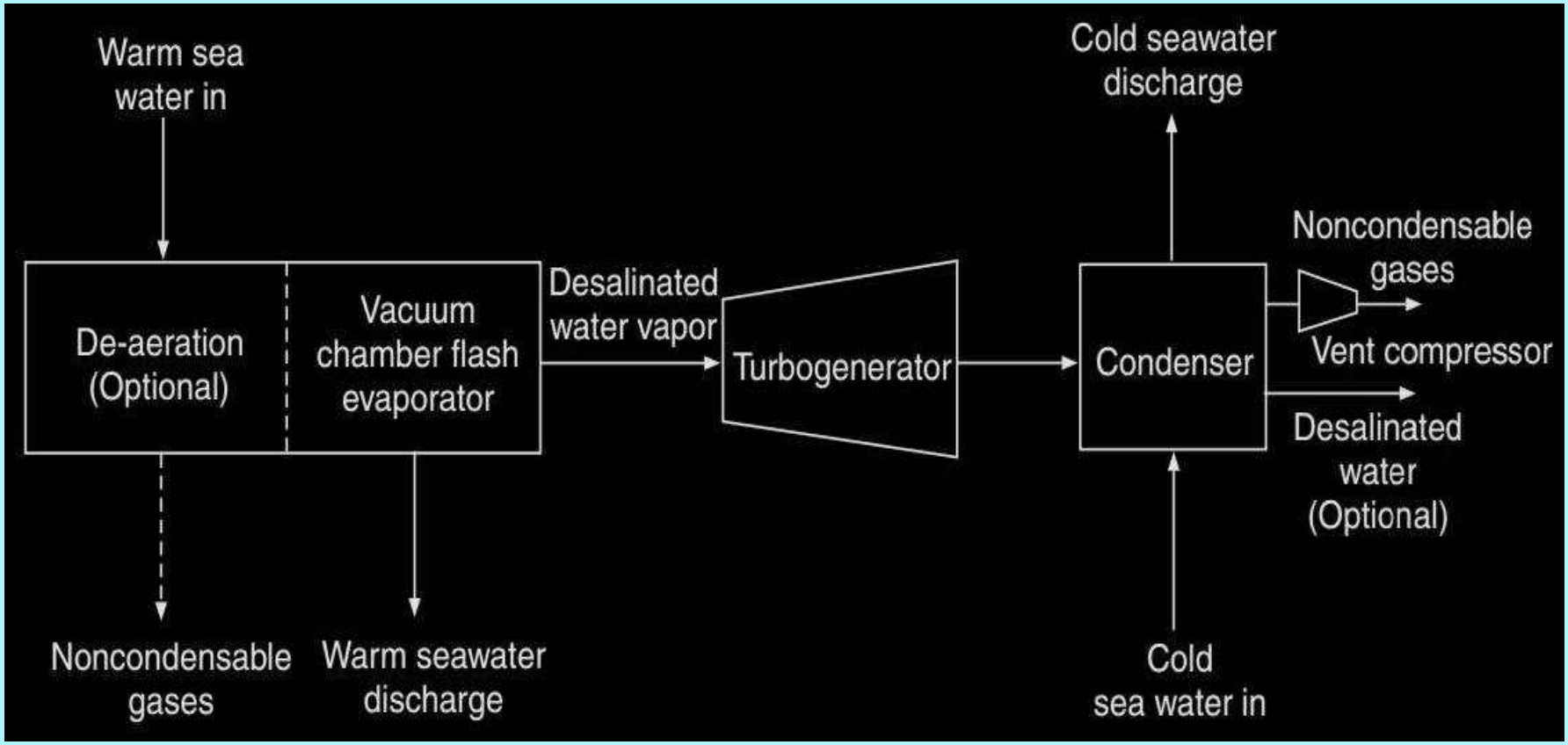


OTEC Open Cycle



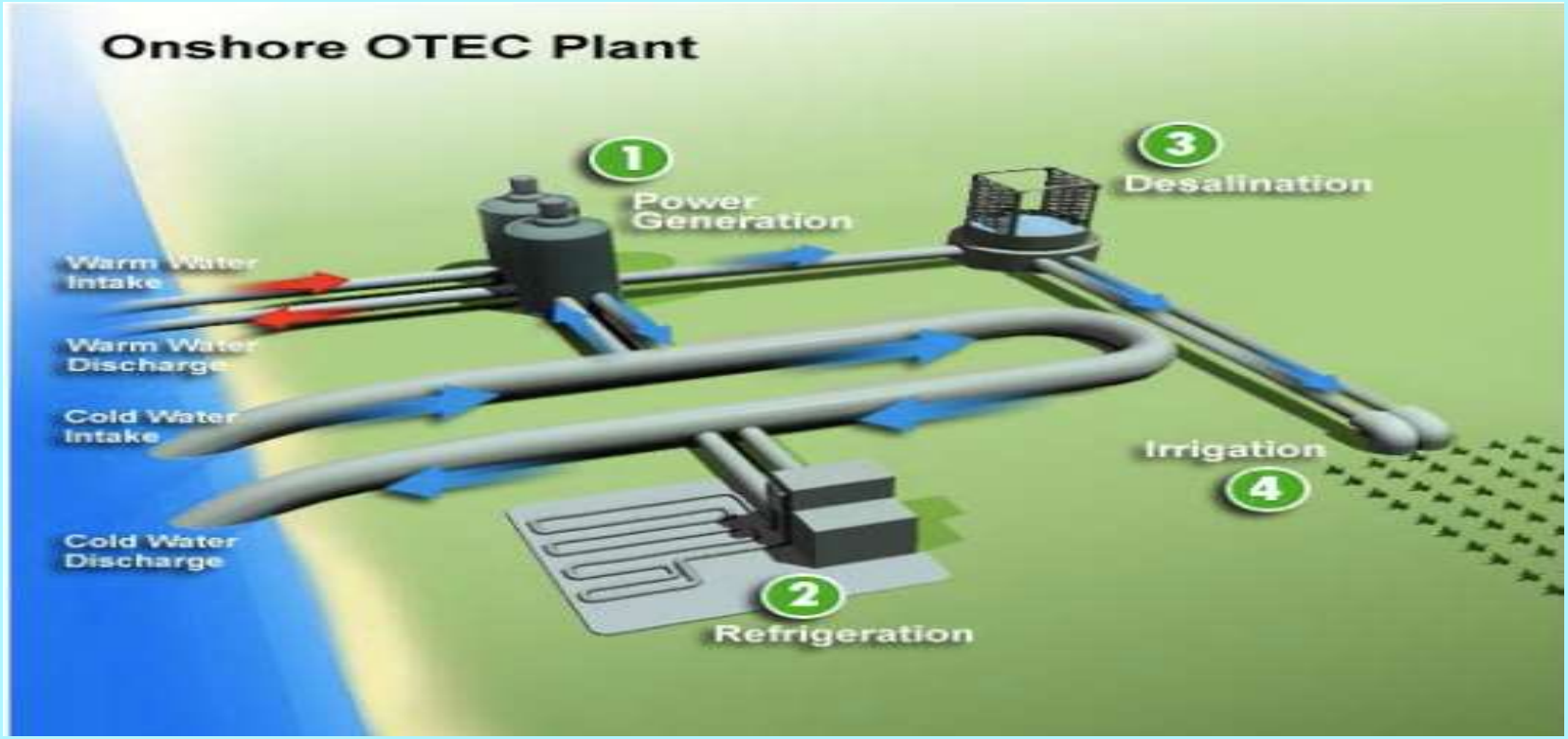
Open-cycle OTEC uses warm surface water directly to make electricity. The warm seawater is first pumped into a low-pressure container, which causes it to boil. In some schemes, the expanding vapor drives a low-pressure turbine attached to an electrical generator.

OTEC Open Cycle



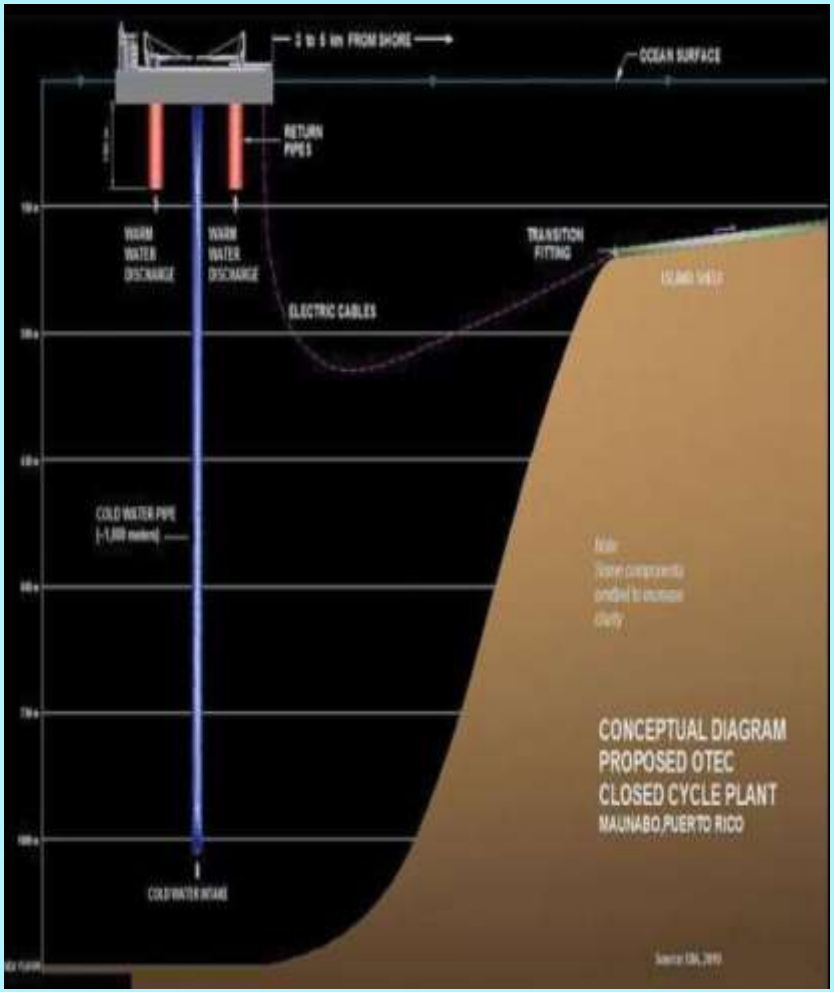
The vapor, which has left its salt and other contaminants in the low-pressure container, is pure fresh water.

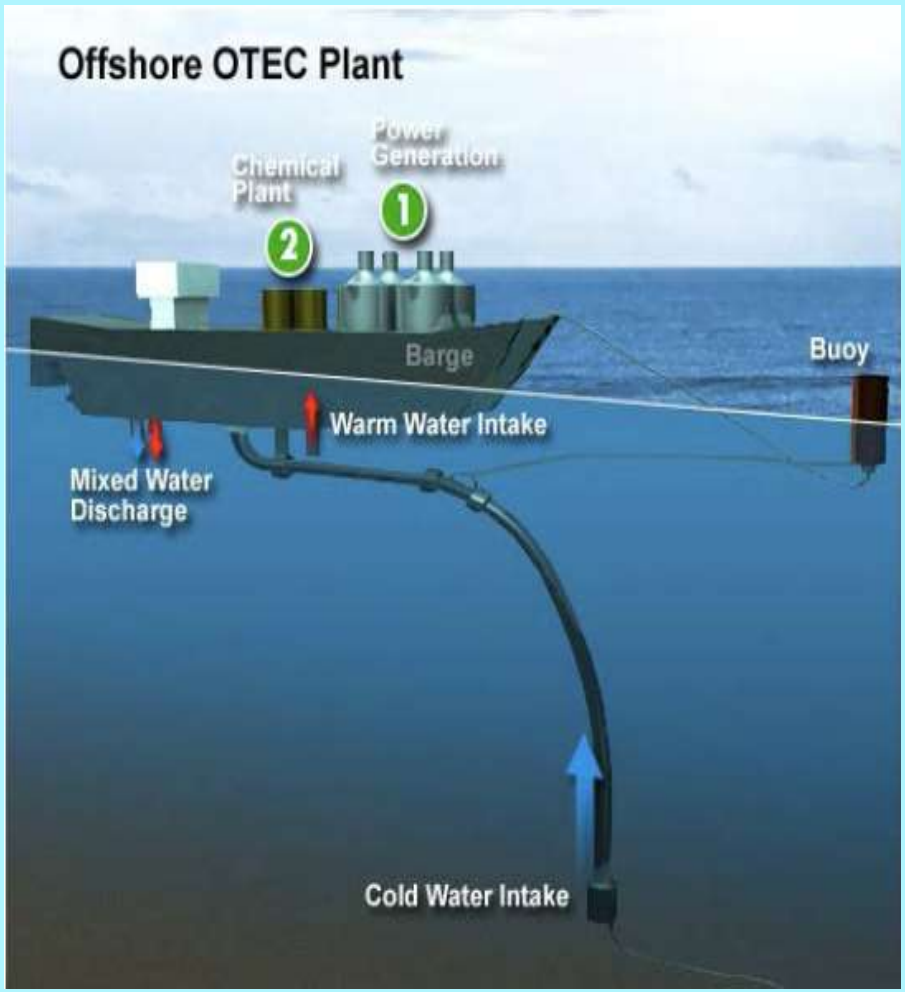
Land based OTEC Plant



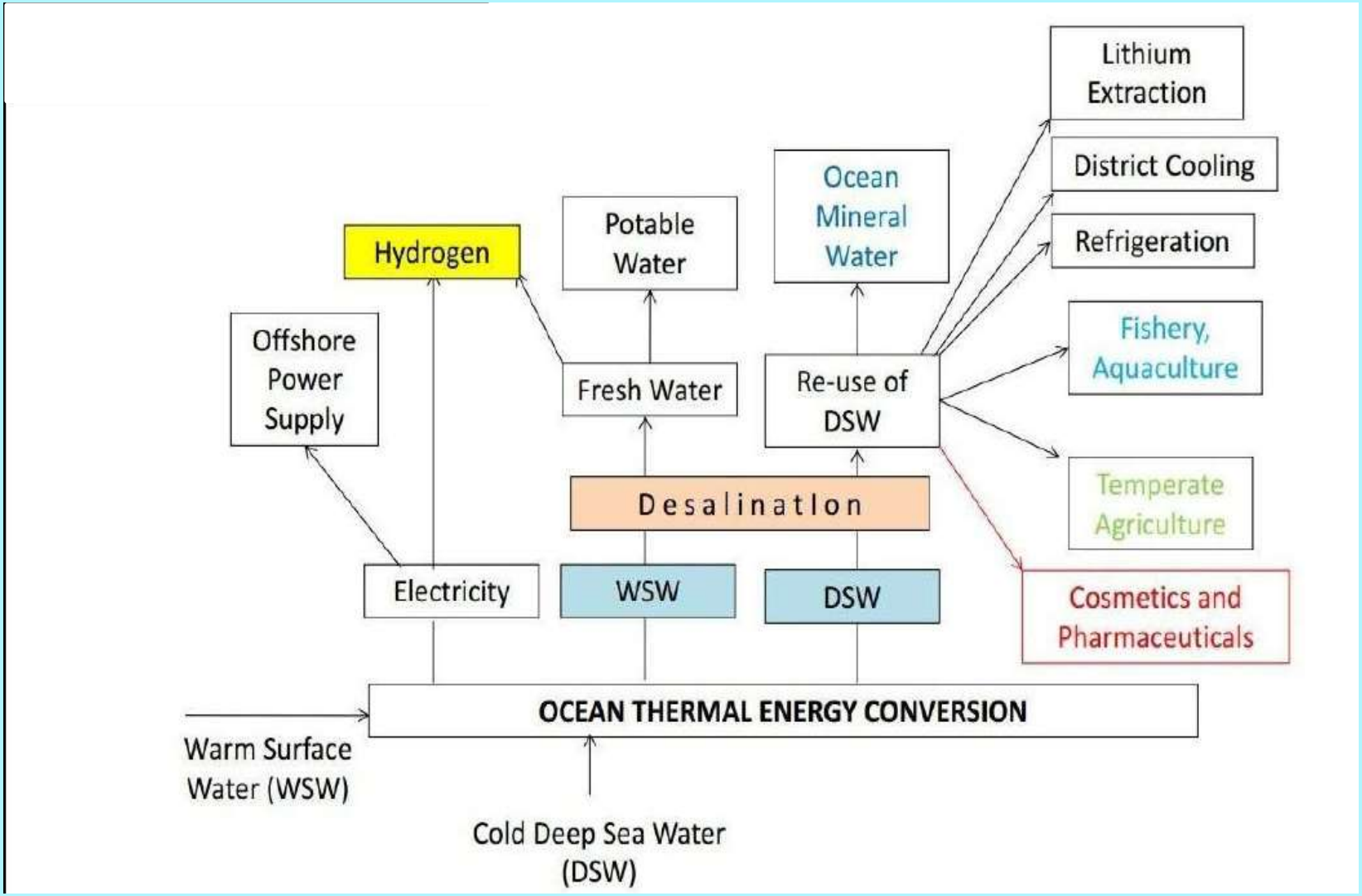
Notice how it can be used for irrigation and refrigeration besides power generation.

OFFSHORE OTEC Plant

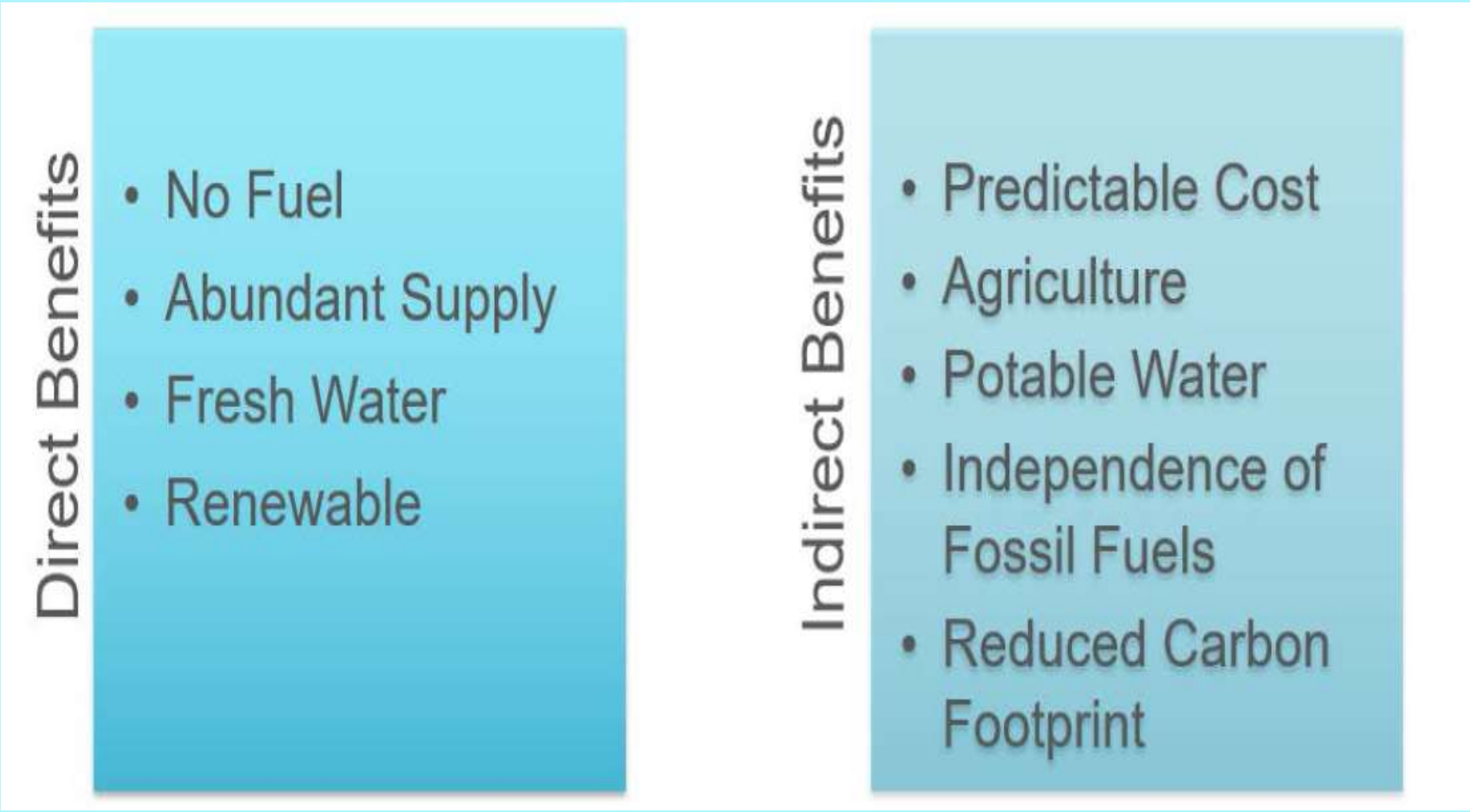




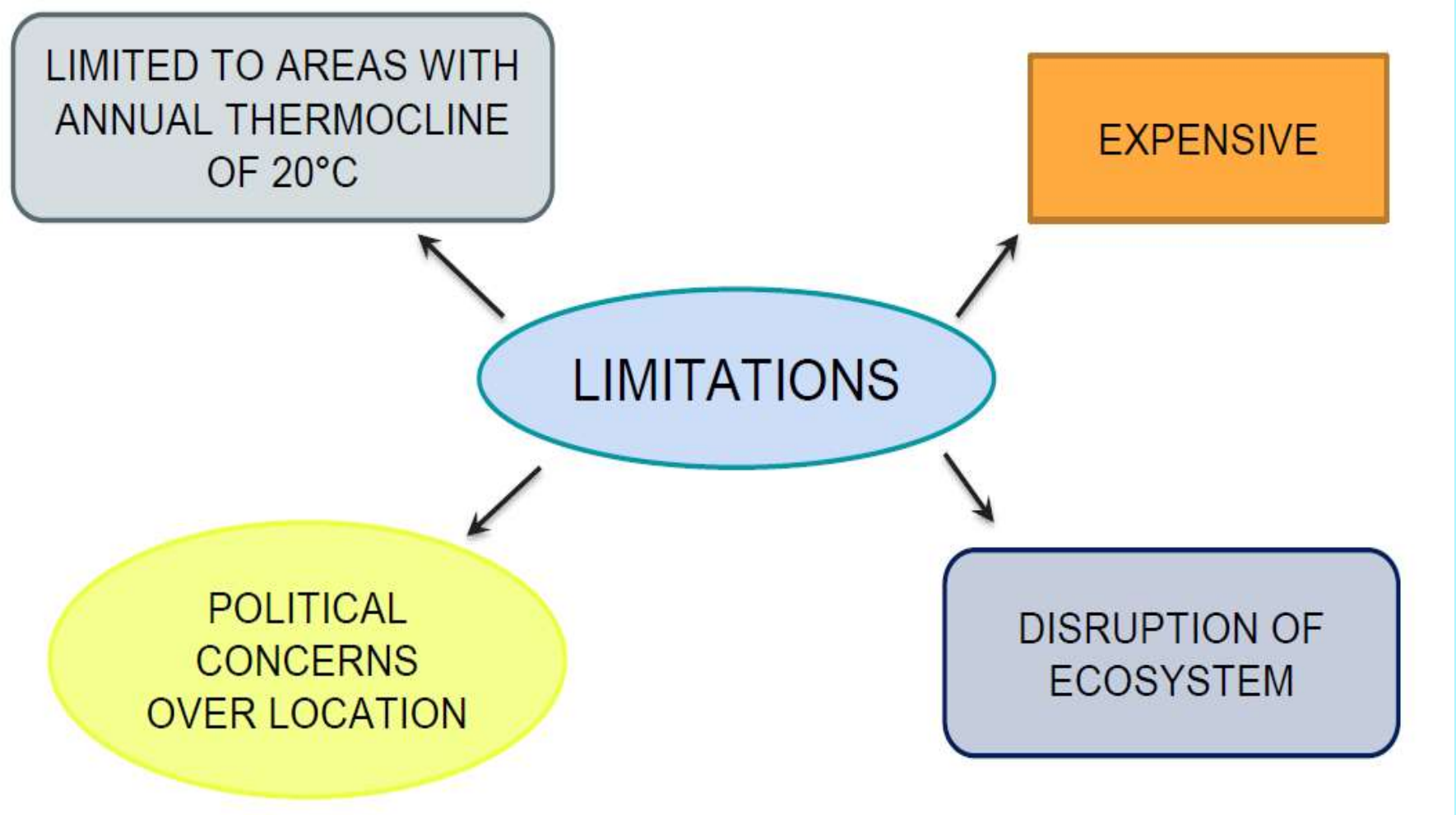
OTEC Other Uses



OTEC Benifits



OTEC Limitations



Thank You

Unit 5:- Other Alternate Sources

Geothermal Energy

Syllabus…Unit 5

- **Other Alternate Sources:** Ocean Thermal Energy Conversion, Geothermal, Tidal, Wave Energy, MHD, Fuel Cells, environmental issues of energy services.

Books …

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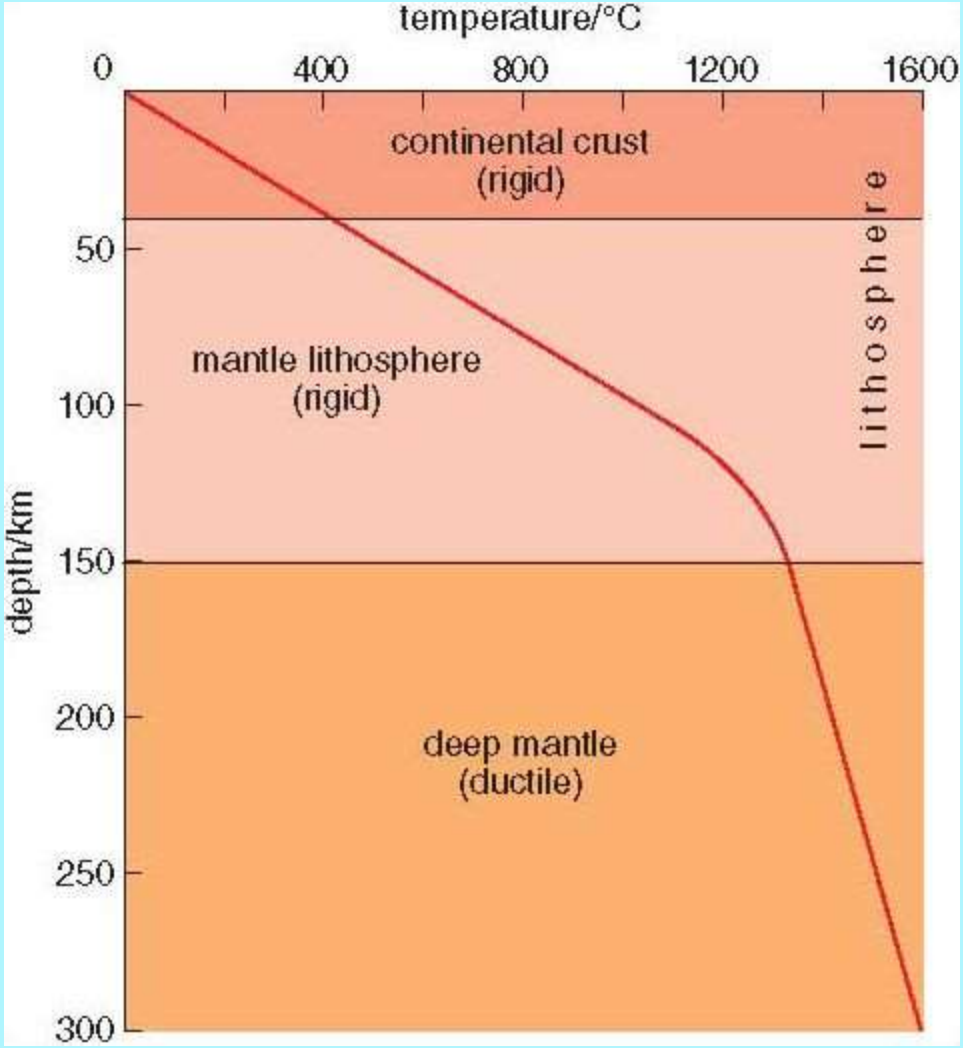
Lecture 2 Geothermal Energy

- Introduction
- Understanding Geothermal Temperature
- Geothermal Reservoirs
- Geothermal History & Installed Capacity Worldwide
- Geothermal Energy Forms: Liquid Dominated Plants
- Thermal Energy Forms
- Enhanced geothermal Energy Forms
- Generation Power Plant Types
- Dry steam power plant
- Flash steam power plant
- Binary cycle power plant
- Difference in Power Plant
- Advantages & Disadvantages
- Conclusions

Introduction

- “Geothermal" comes from the Greek words geo (earth) and thermal (heat). So, geothermal means earth’s heat
- Geothermal heat originates from earth's fiery consolidation of dust and gas over four billion years ago.
- The geothermal energy of the Earth's crust originates from the original formation of the planet and from radioactive decay of materials
- For every 100m down the earth temperature increases by $3^{o}C$

Understanding Geothermal Temperature



Deeper we go, the hotter it is !!!

- The heat from the earth's core continuously flows outward. It transfers (conducts) to the surrounding layer of rock, the mantle.
- When temperatures and pressures become high enough, some mantle rock melts, becoming magma
- Temperatures at the core–mantle boundary may reach over 4000 °C (7,200 °F).

Geothermal Reservoirs

←Geyser & Hot spring

←Boiling mud pot

↓Volcano Springs

Hot springs→

Geothermal History

- The oldest known spa is a stone pool on China's Lisan mountain built in the Qin Dynasty in the 3rd century BC, at the same site where the Huaqing Chi palace was later built.

- The world's oldest geothermal district heating system, Chaudes-Aigues, in France, has been operating since the 15th century.
- The earliest industrial exploitation began in 1827 with the use of geyser steam to extract boric acid from volcanic mud in Larderello, Italy

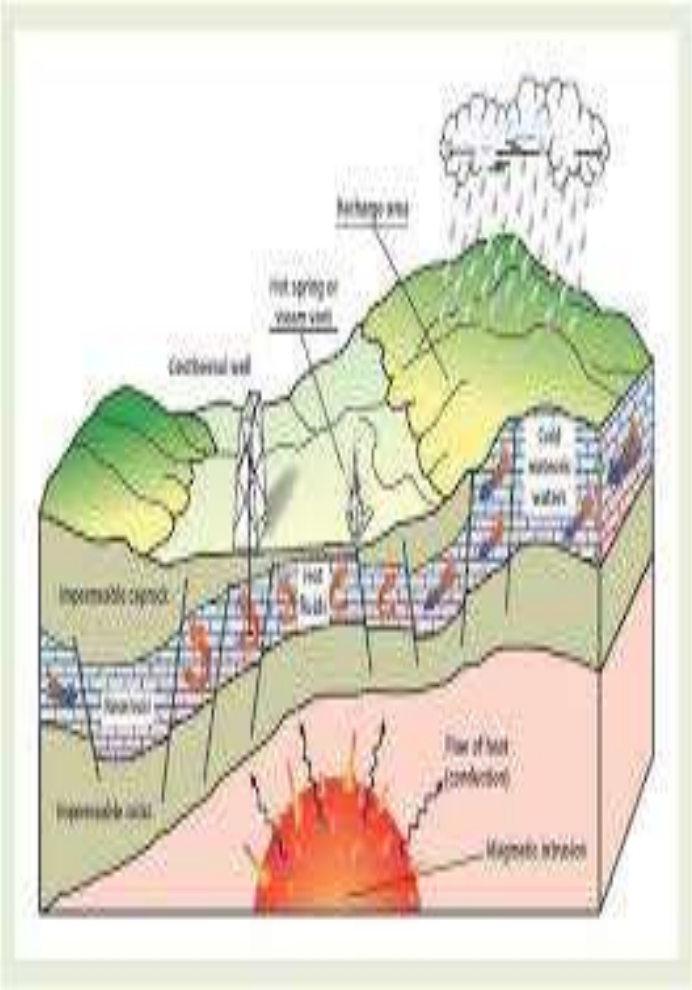
Geothermal History

- The first known building in the world to utilize geothermal energy as its primary heat source was the Hot Lake Hotel in Union County, Oregon, whose construction was completed in 1907
- In the 20th century, demand for electricity led to the consideration of geothermal power as a generating source. Prince Piero Ginori Conti tested the first geothermal power generator on 4 July 1904, at the same Larderello dry steam field where geothermal acid extraction began. It successfully lit four light bulbs.

Geothermal Installed Capacity Worldwide

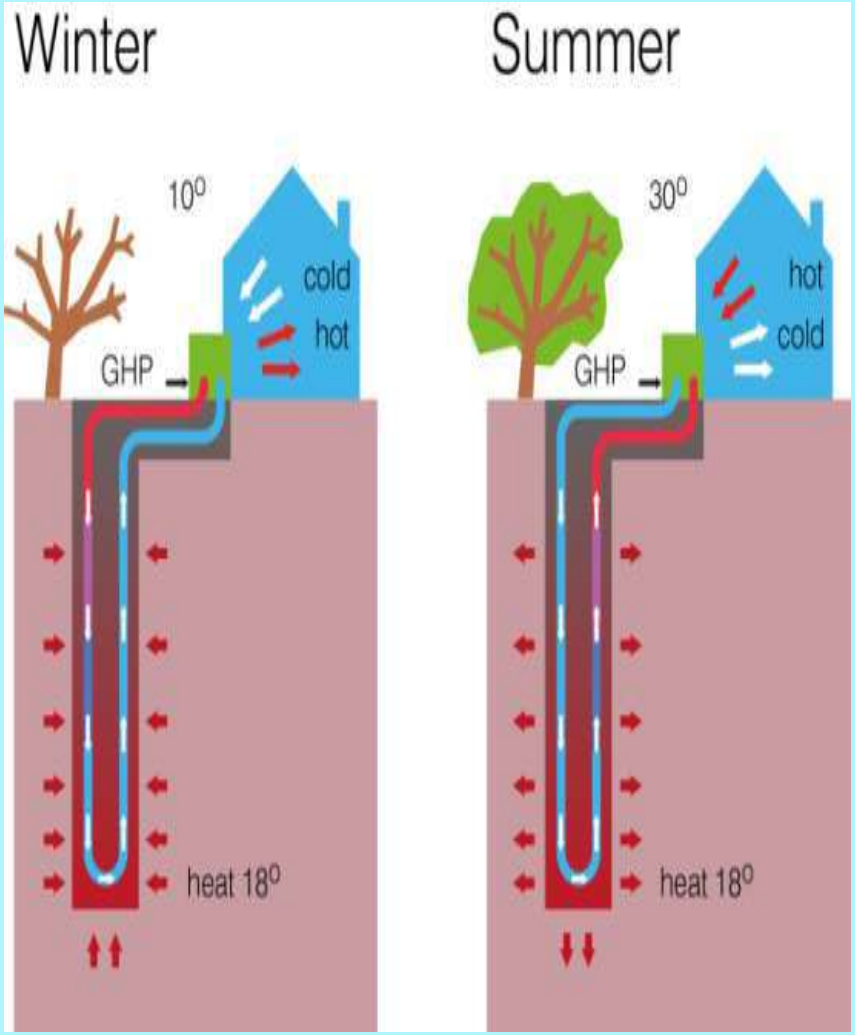
Installed geothermal electric capacity				
Country	Capacity (MW) 2007	Capacity (MW) 2010[31]	Percentage of national electricity production	Percentage of global geothermal production
United States	2687	3086	0.3	29
Philippines	1969.7	1904	27	18
Indonesia	992	1197	3.7	11
Mexico	953	958	3	9
Italy	810.5	843	1.5	8
New Zealand	471.6	628	10	6
Iceland	421.2	575	30	5
Japan	535.2	536	0.1	5
Iran	250	250		

Types of Geothermal Energy Forms: Liquid Dominated Plants



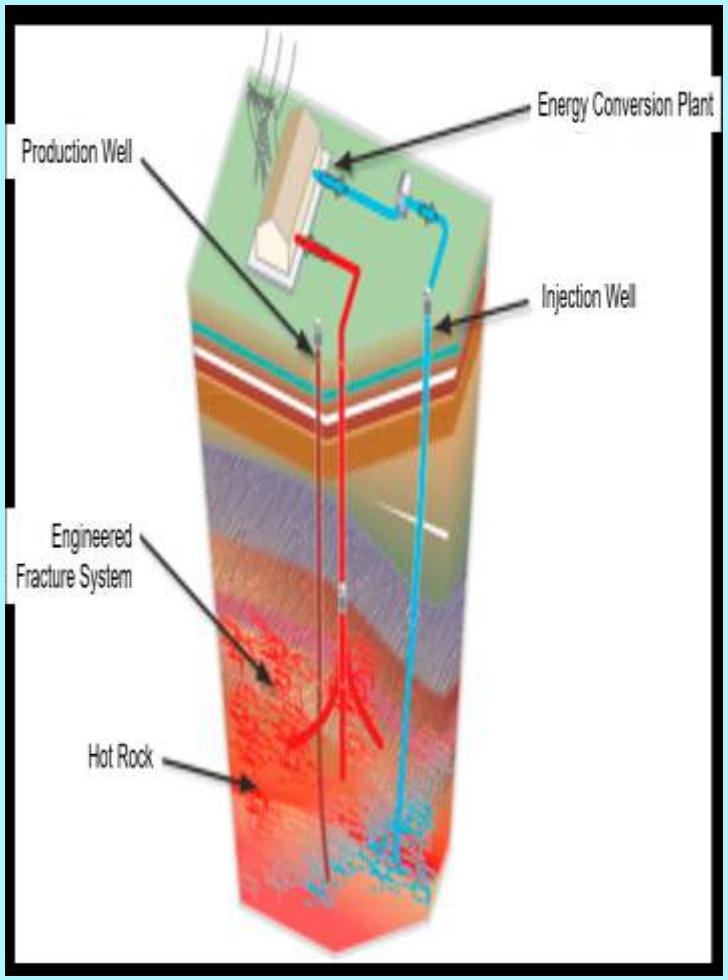
- Geothermal energy comes in either *vapor-dominated* or *liquid- dominated* forms. Vapor-dominated sites offer temperatures from 240 to 300 °C that produce superheated steam.
- **Liquid-dominated plants:** Liquid-dominated reservoirs (LDRs) are more common with temperatures greater than 200 °C (392 °F). Water passes through a heat exchanger in a Rankine cycle binary plant. The water vaporizes an organic working fluid that drives a turbine

Thermal Energy Forms



- **Thermal Energy plants:** Sources with temperatures of 30–150 °C are used without conversion to electricity as district heating, greenhouses, fisheries, mineral recovery, industrial process heating and bathing.
- Heat pumps extract energy from shallow sources at 10–20 °C used in various countries for in space heating and cooling.

Enhanced geothermal Energy Forms

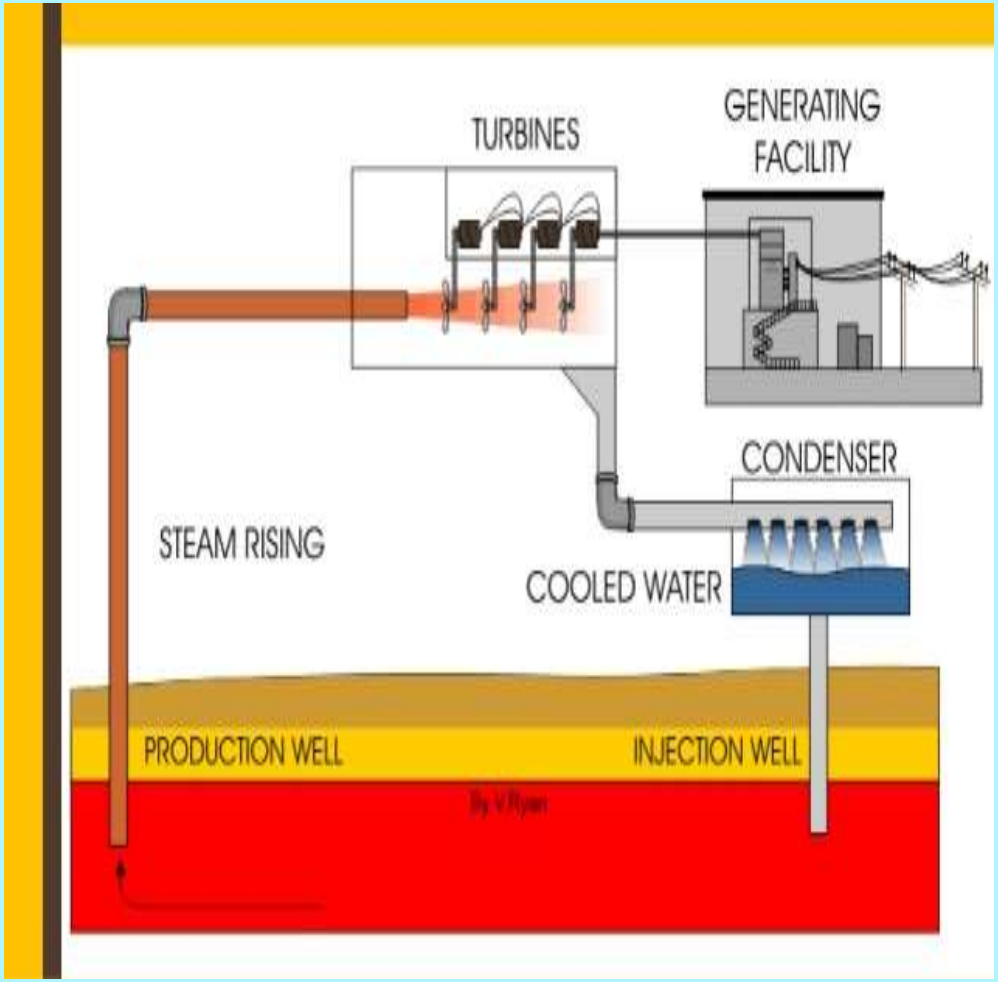


- **Enhanced geothermal:** Enhanced geothermal systems (EGS) actively inject water into wells to be heated and pumped back out. The water is injected under high pressure to expand existing rock fissures to enable the water to freely flow in and out.
- The technique was adapted from oil and gas extraction techniques.
- EGS technologies enhance and/or create geothermal resources in this hot dry rock (HDR) through 'hydraulic stimulation'.

Generation Power Plant Types

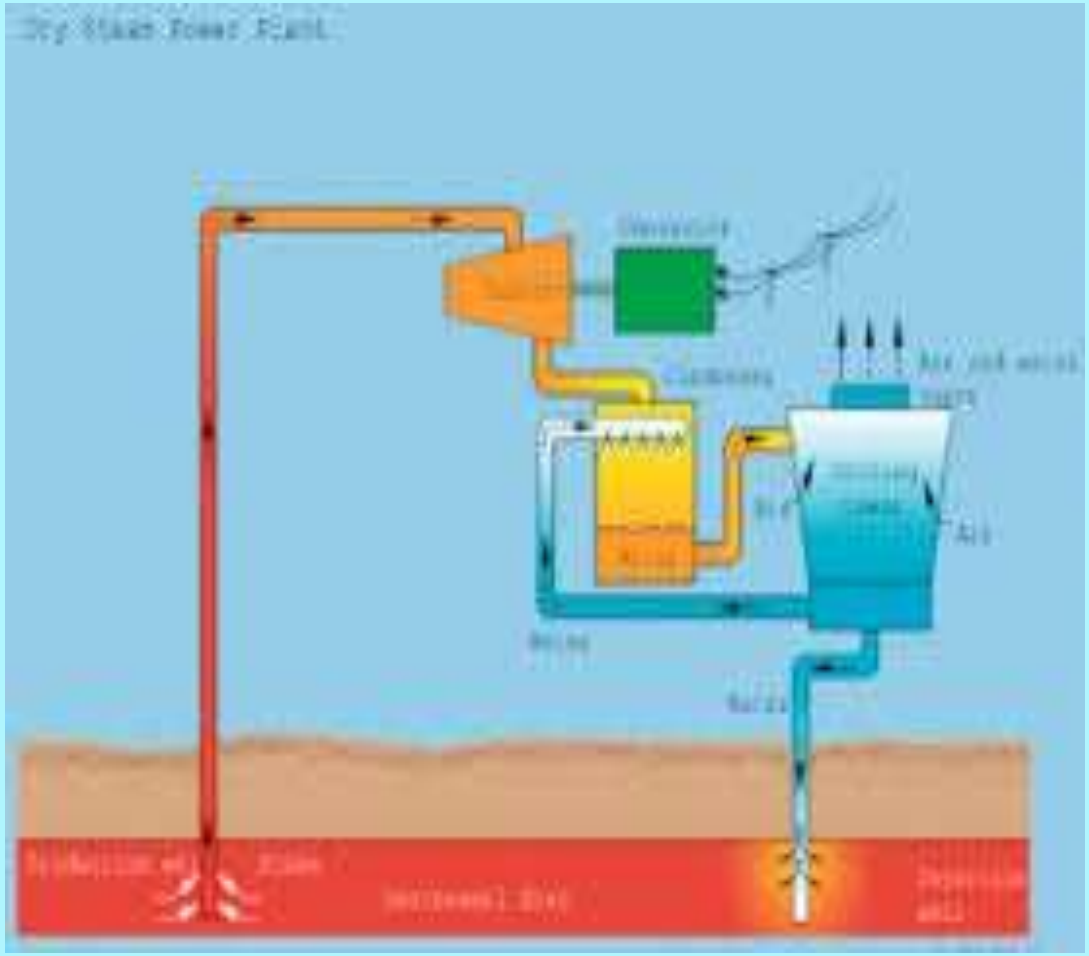
- **Dry steam power plant**
- **Flash steam power plant**
- **Binary cycle power plant**

Dry Steam Power Plant



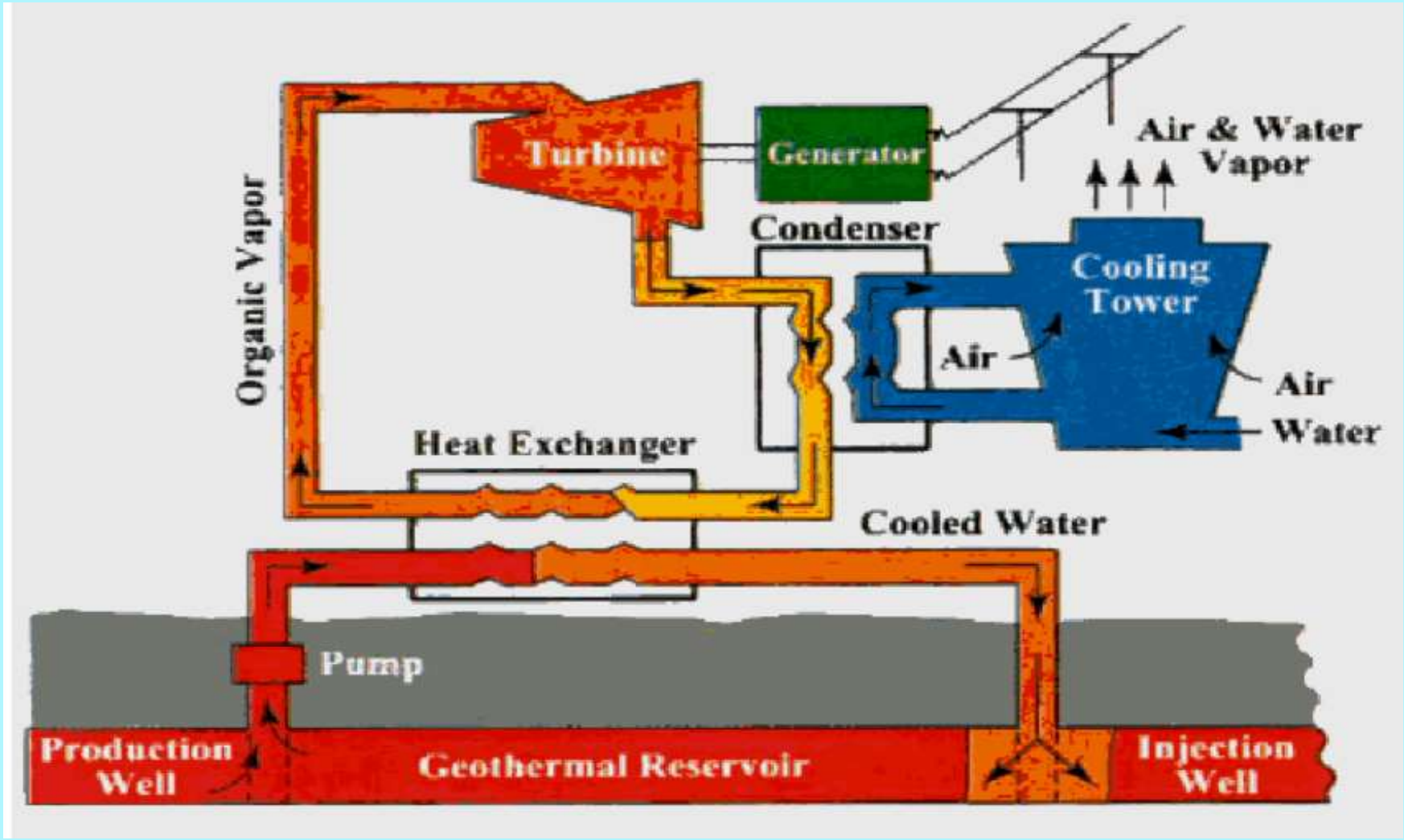
- The oldest type of Geothermal power plant used.
- Geothermal reservoir containing pure steam is required.
- Pure dry steam drives turbine.
- Very rare type of geothermal power plant.
- Operating at California, Italy, and Japan.

Flash Steam Power Plant



- Commonly used geothermal power plant.
- Geothermal reservoirs containing both hot water & steam is required. It flashes steam at 182^{o}C
- Pressure changing system is required.
- Operating at Hawaii, Nevada, Utah & some other places

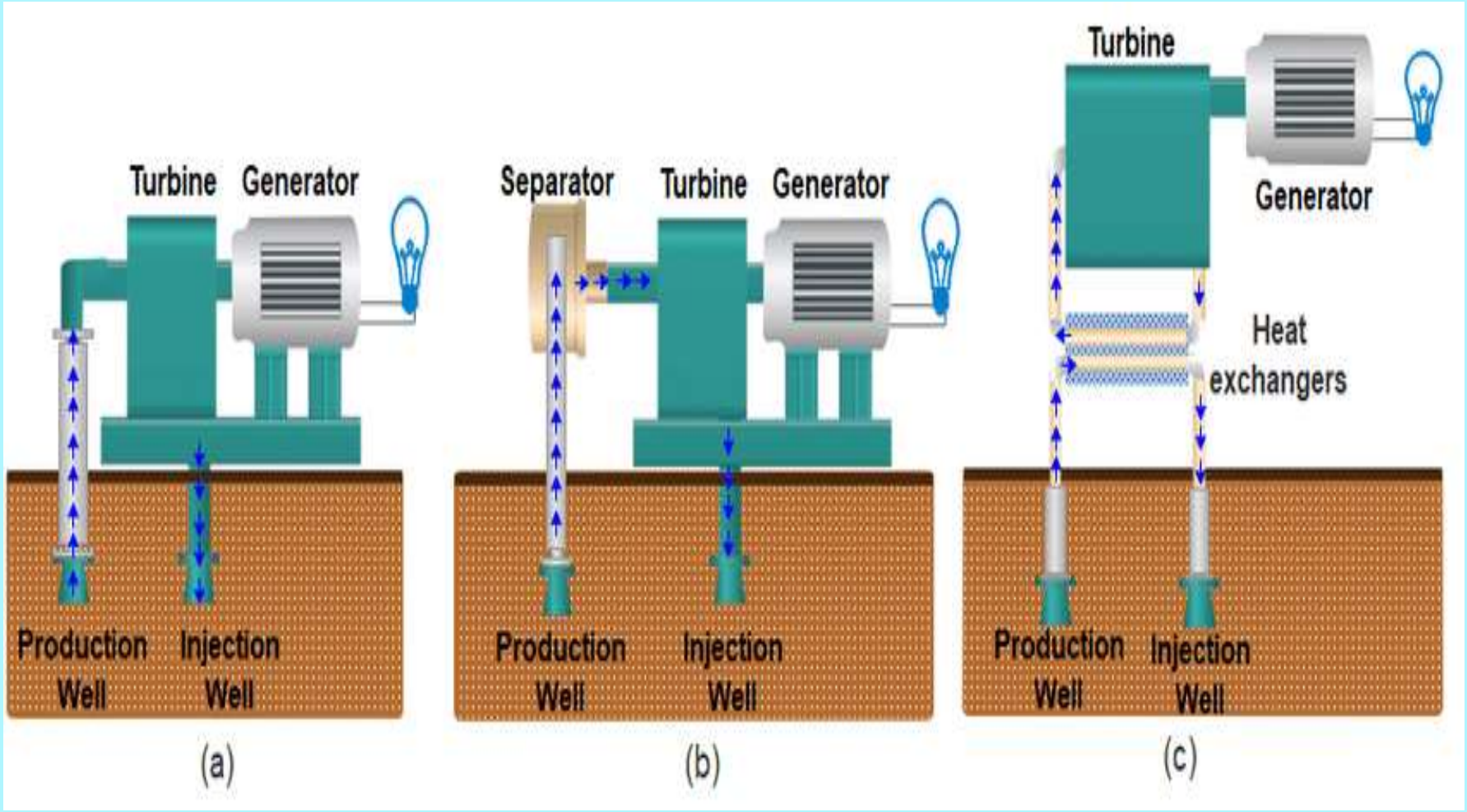
Binary Cycle Power Plant



Binary Cycle Power Plant

- Does not use steam directly to spin turbines.
- Only the heat of the underground water is used.
- Vaporized hydrocarbons are used to spin the turbine.
- Hydrocarbons having lower boiling point such as Isopentane, Isobutane and propane can be used. No harmful gas is emitted to the atmosphere because the
- underground water is never disclosed to outside.
- This’s the worldwide accepted power plant.

Difference in Power Plant



(a)Dry steam plant (b)Flash steam plant (C) Binary cycle plant

Advantages

- Available all the year around.
- Does not involve any combustion of fuel.
- Independent of weather
- Clean Resource – Very little emissions or overall environmental impact.
- Economically Sound Alternative – The fuel is free, rate / KWh likely to be competitive
- Overall, geothermal energy is a sustainable resource.

Disadvantages

- Not widespread source of energy
- High installation costs
- Can run out of steam
- May release harmful gases
- Transportation
- Earthquakes

Conclusion

- Geothermal heating system can replace fossil fuel heating system in a particular area.
- Annual costs for common heating purposes can be reduced by more than 60%.
- Continued energy shortages have created added interest in geothermal energy for power generation.
- Potential exists to provide all energy requirements in the U.S
- Geothermal energy appears to be a partial solution to our energy needs.

Thank You

Unit 5:- Other Alternate Sources

Tidal & Wave Energy

Syllabus…Unit 5

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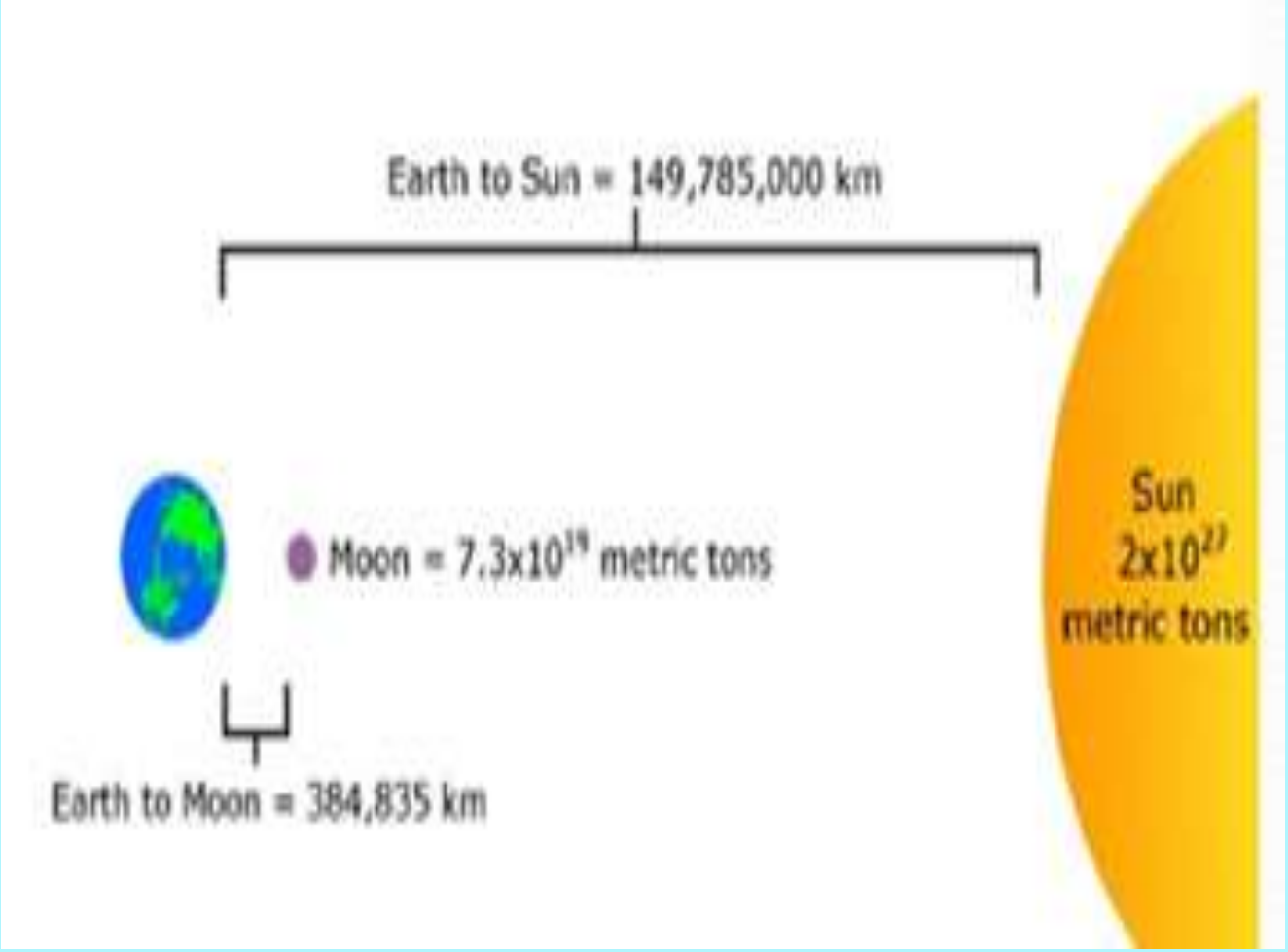
Lecture 3 Tidal & Wave Energy

- Tidal Force

Tidal Force



Tides are the rise and fall of sea levels caused by the combined effects of the gravitational f orces exerted by the Moon and the Sun, and the rotation of the Earth.

Tidal Force

$$\text{Tide-Generating Force} = \propto \frac{\text{Mass}}{(\text{Distance})^3}$$

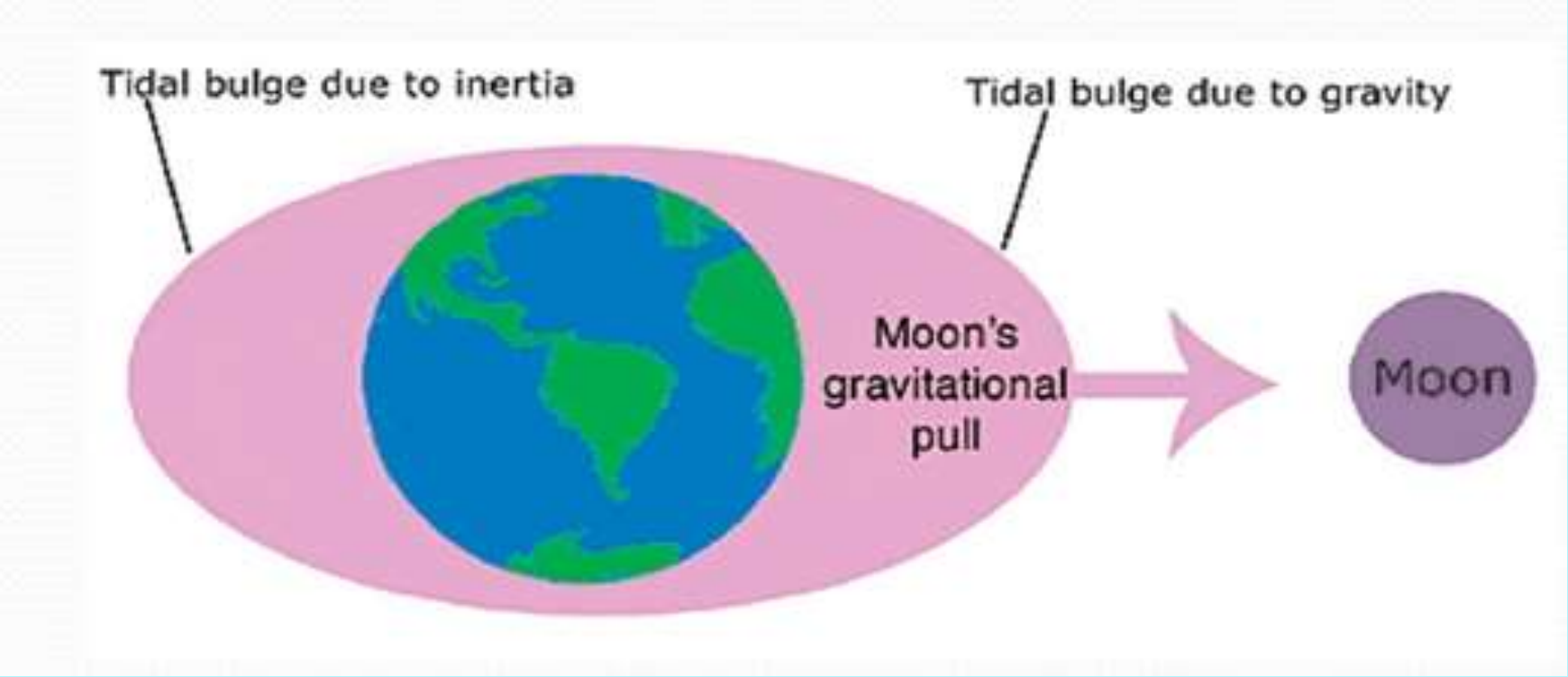
$$\text{Tide-Generating Force of the Sun} = \propto \frac{\text{Sun's Mass}}{(\text{Sun's Distance to Earth})^3}$$

*NOTE: The sun has 27 million times more mass than the moon and is 390 times farther away from the earth than the moon.

$(390)^3 = 59{,}000{,}000$ So... $\frac{27 \text{ million}}{59 \text{ million}} = 0.46$ or 46%

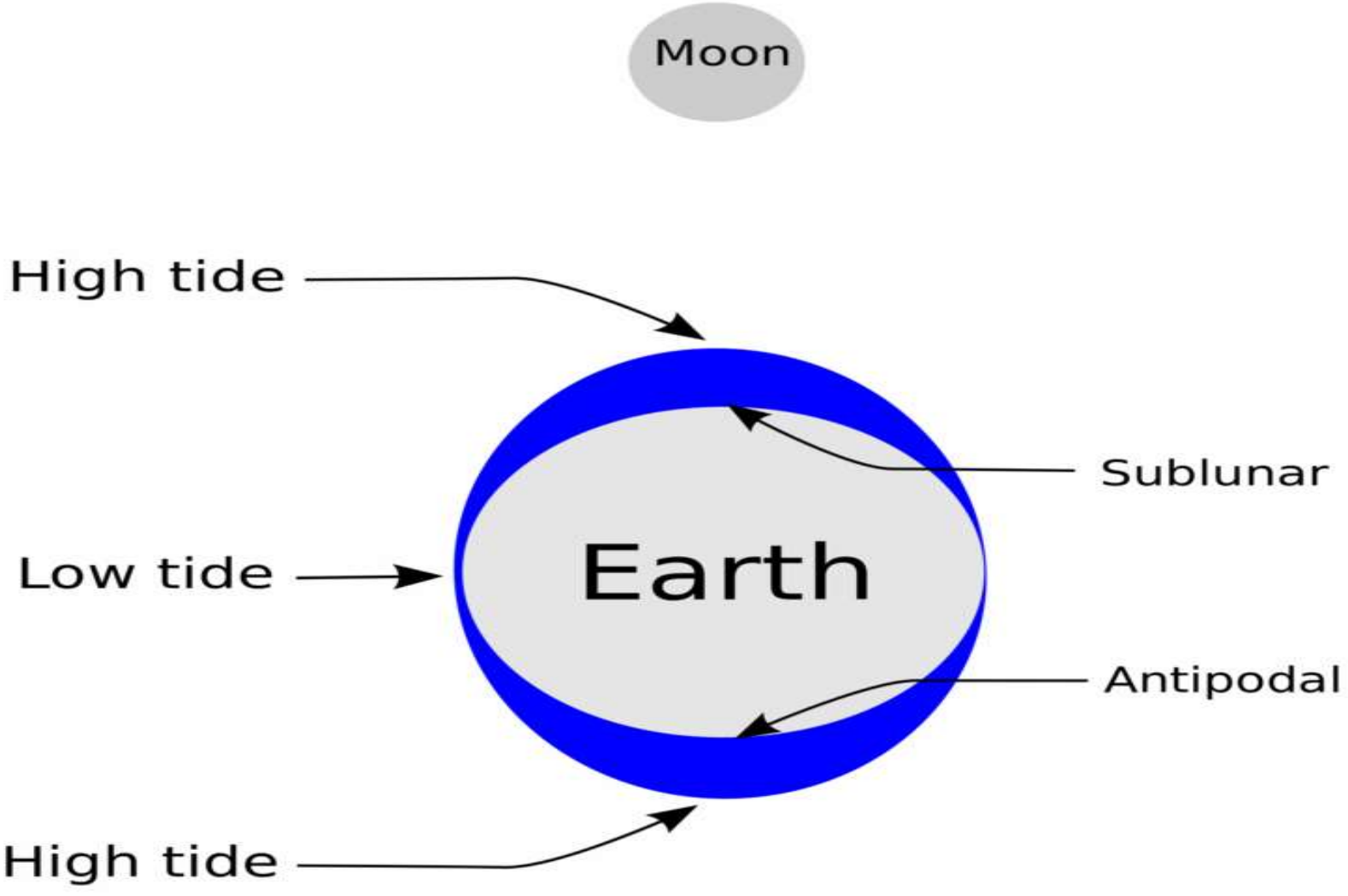
The Sun has only 46% of the tide generating force that of the Moon.

Tidal Force: Gravity Inertia & Bulges

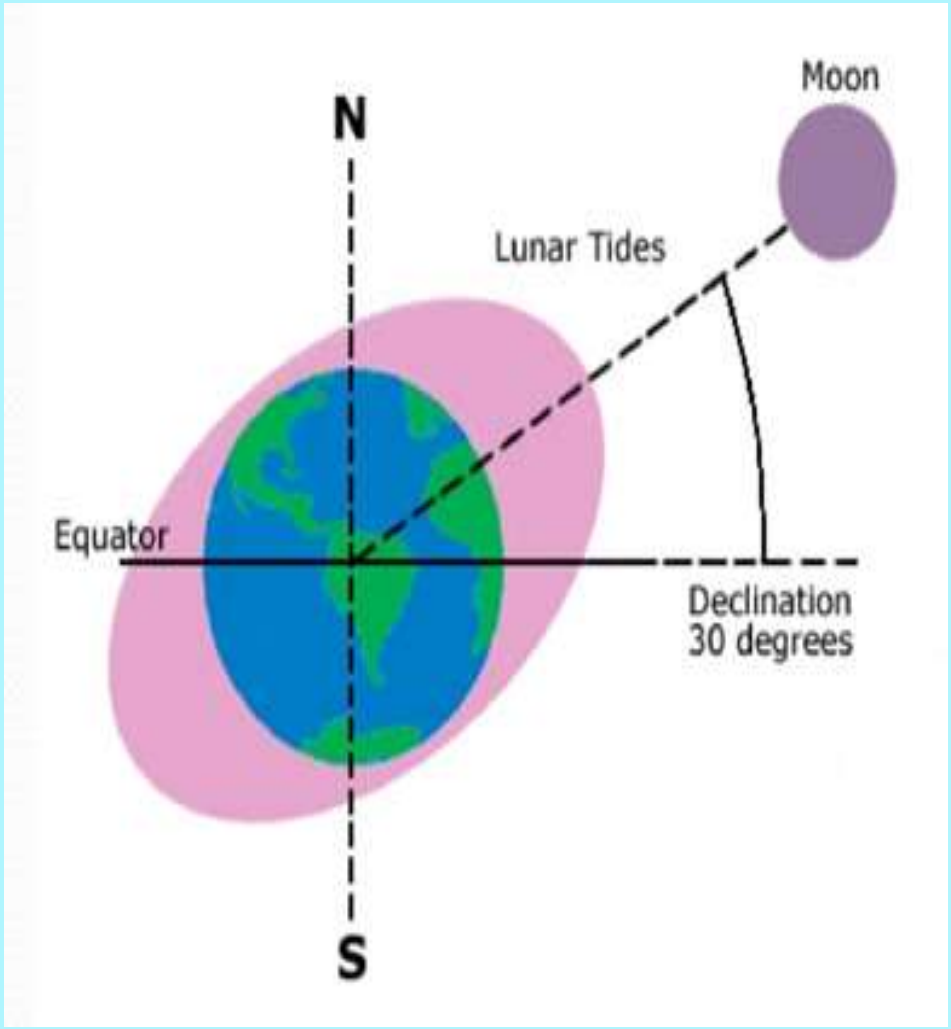


Tides are commonly *semi-diurnal* (two high waters and two low waters each day), or *diurnal* (one tidal cycle per day).

Tidal Force: Gravity Inertia & Bulges

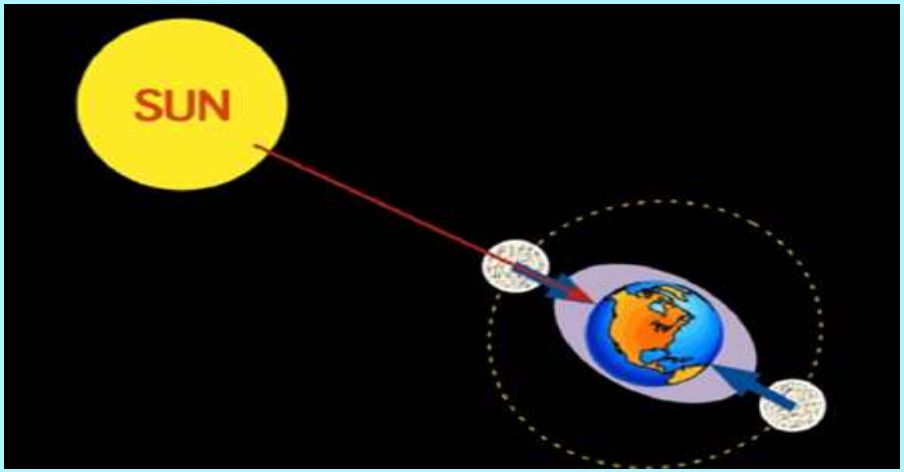


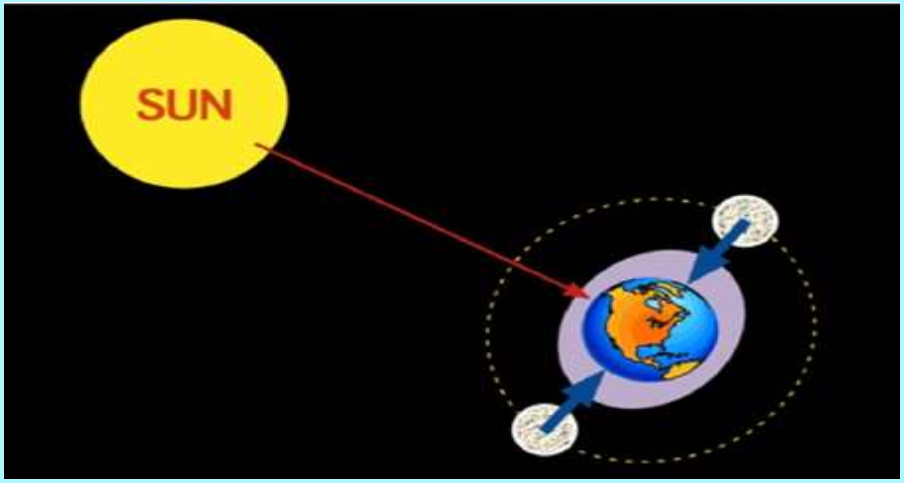
Effect of Angle on Tides



The two high waters on a given day are typically not the same height (the daily inequality); these are the *higher high water* and the *lower high water* in tide tables. Similarly, the two low waters each day are the *higher low water* and the *lower low water*. The daily inequality is not consistent and is generally small when the Moon is over the Equator.

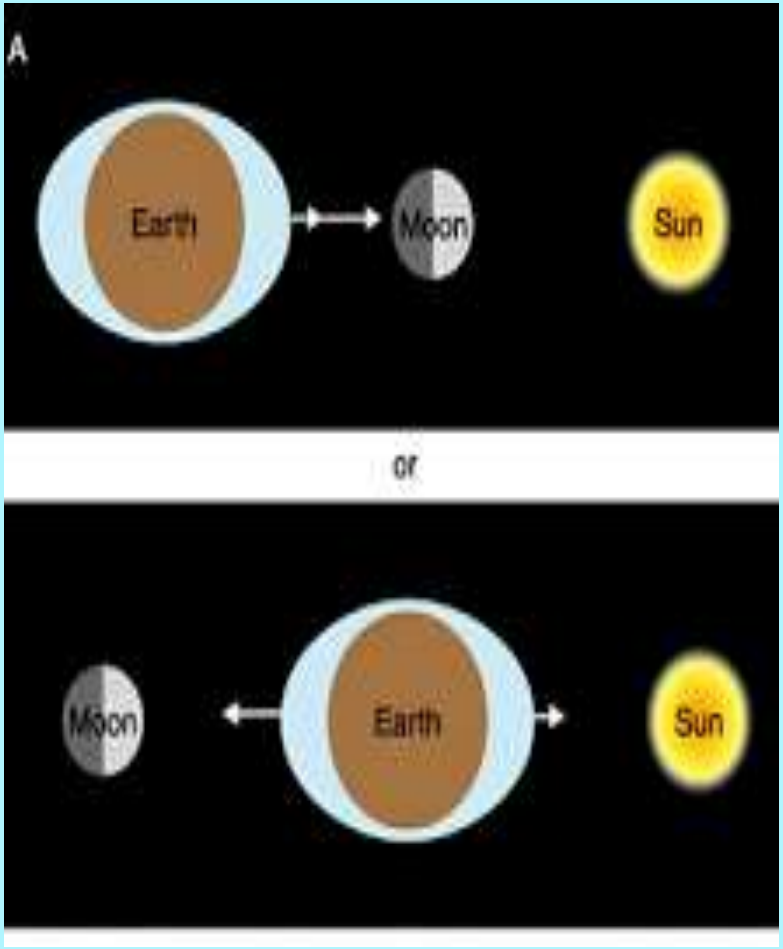
Effect of Angle on Tides

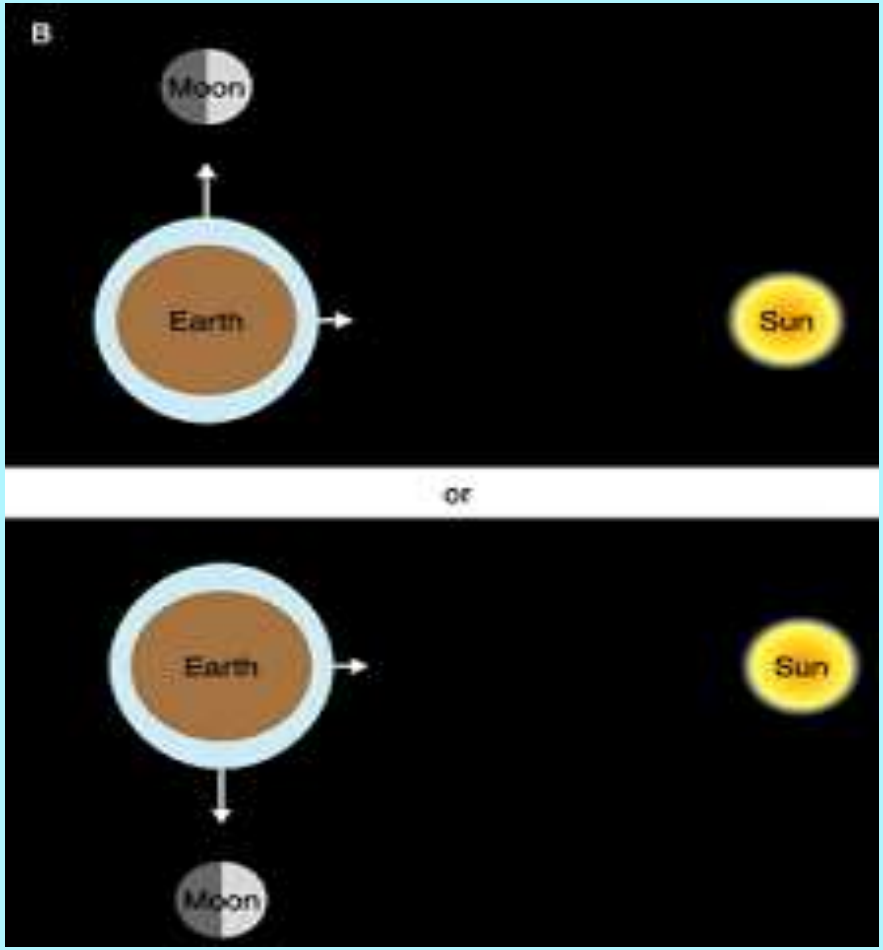




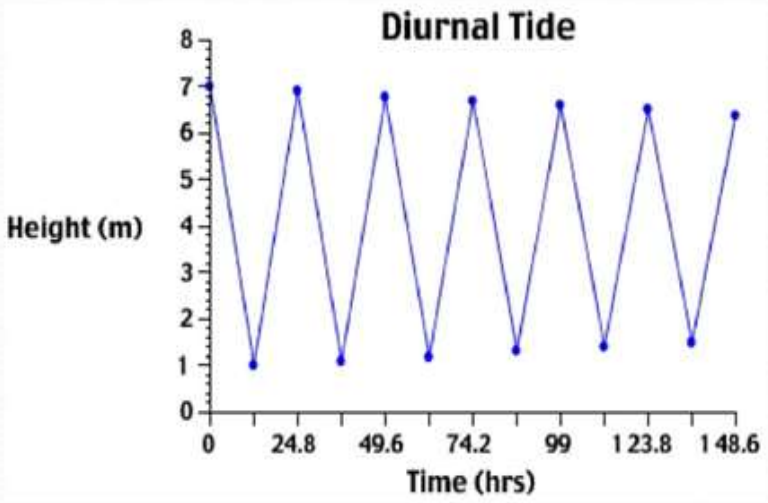
Tide tables can be used for any given locale to find the predicted times and amplitude (or "tidal range"). The predictions are influenced by many factors including the alignment of the Sun and Moon, the phase and amplitude of the tide (pattern of tides in the deep ocean), the Amphidromic systems of the oceans, and the shape of the coastline and near-shore bathymetry.

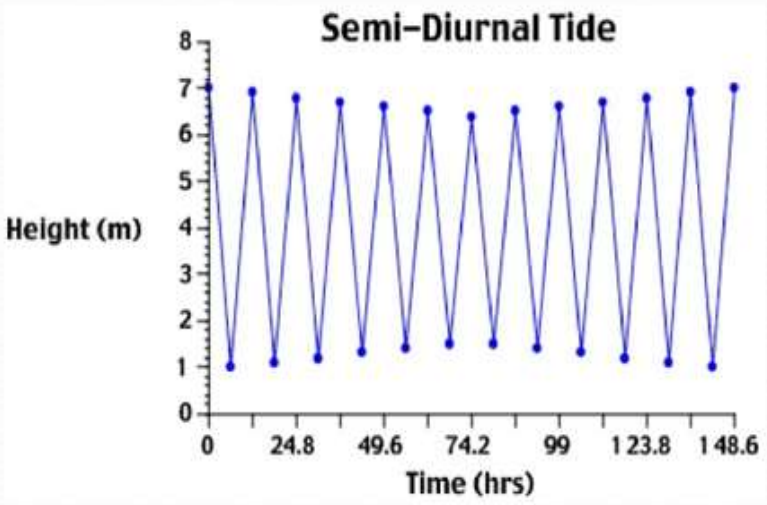
Types Of Sea Tides

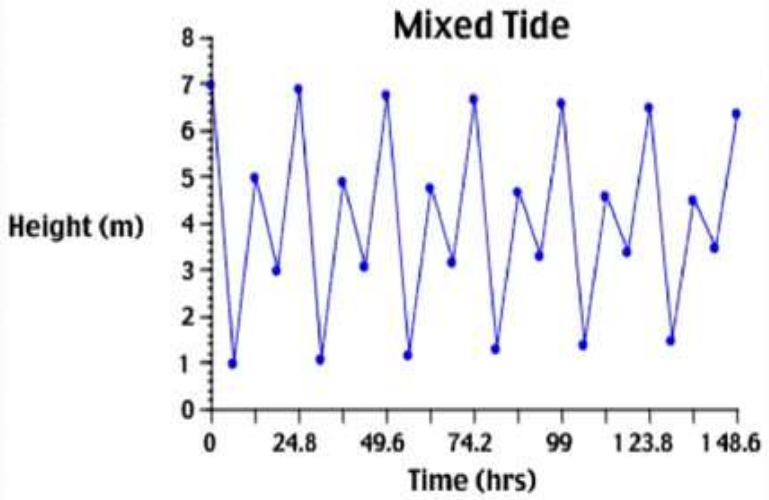




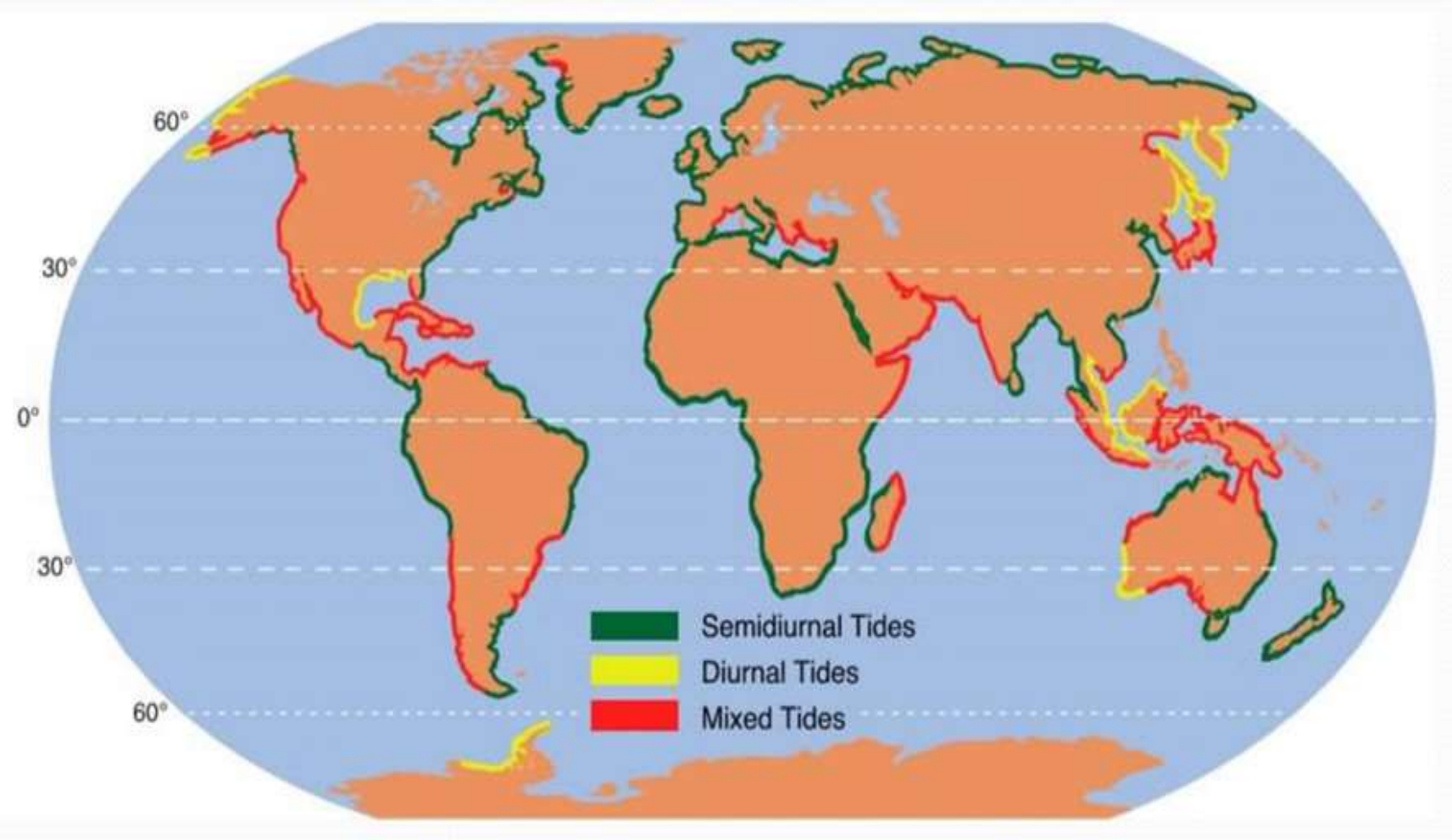
Types Of Sea Tides





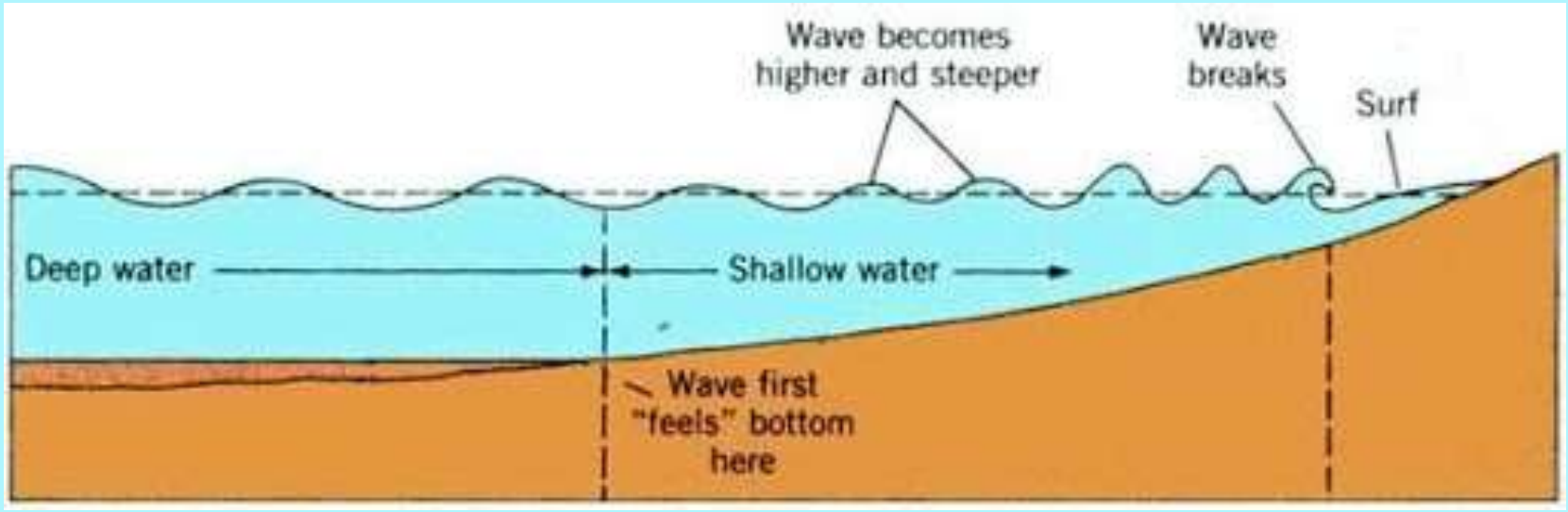


Types Of Sea Tides

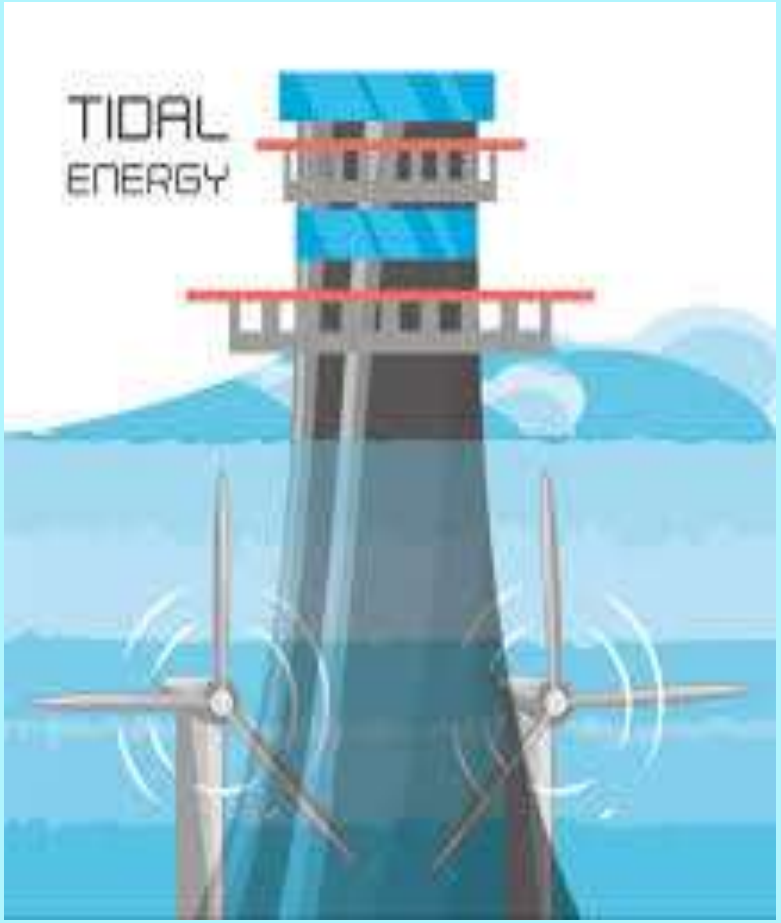


Parameters Affecting Tides

- Shape of shore line (wide continental margin)
- Shape of bays and estuaries
- Wind
- Pressure

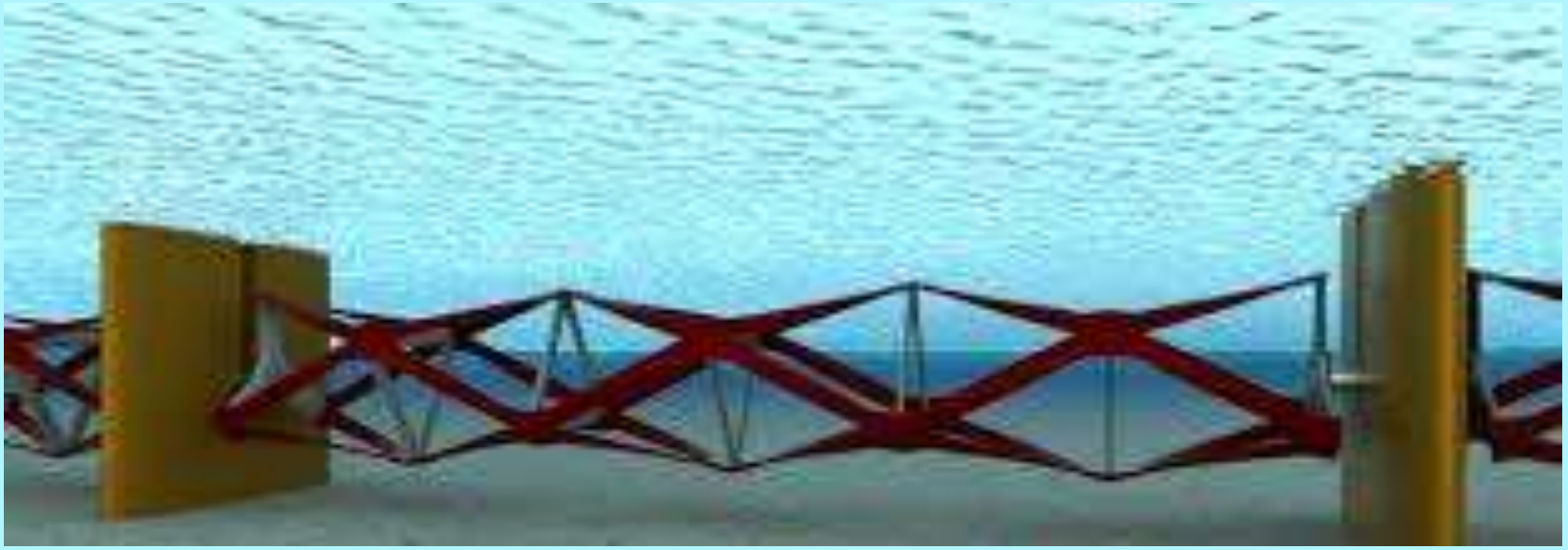


Types of Tidal Power Plants



- Kinetic Energy
  - Tidal Fence
  - Tidal Farms
- Potential Energy: Barrage Type / Basin Type
  - Flood Generation
  - Ebb Generation
  - Two way Generation

Kinetic Energy: Tidal Fence Power Plants



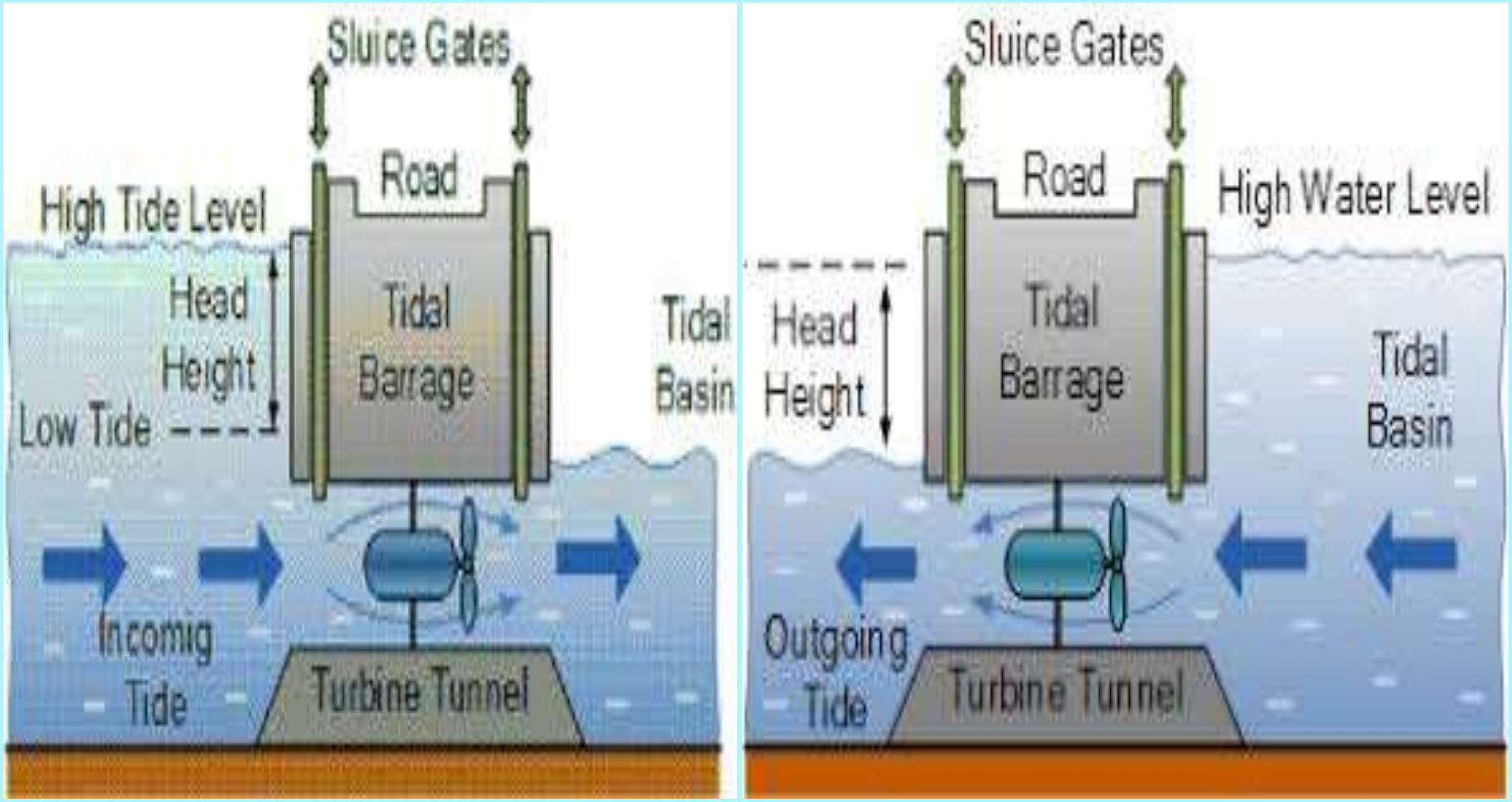
Kinetic Energy: Tidal Farms Power Plants

Potential Energy Tidal Barrage / Basin Type

2. Tidal Barrage

- Uses PE of water
- Uses a dam like structure
- 2 flow directions
- Oldest method

Potential Energy Tidal Barrage / Basin Type



Thank You