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VISVODAYA INSTITUTE OF TECHNOLOGY & SCIENCE

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GEOTHERMAL ENERGY

UNIT-I V

CLASS-IV-I SEM

Subject: RENEWABLE ENERGY SYSTEMS

SYLLABUS

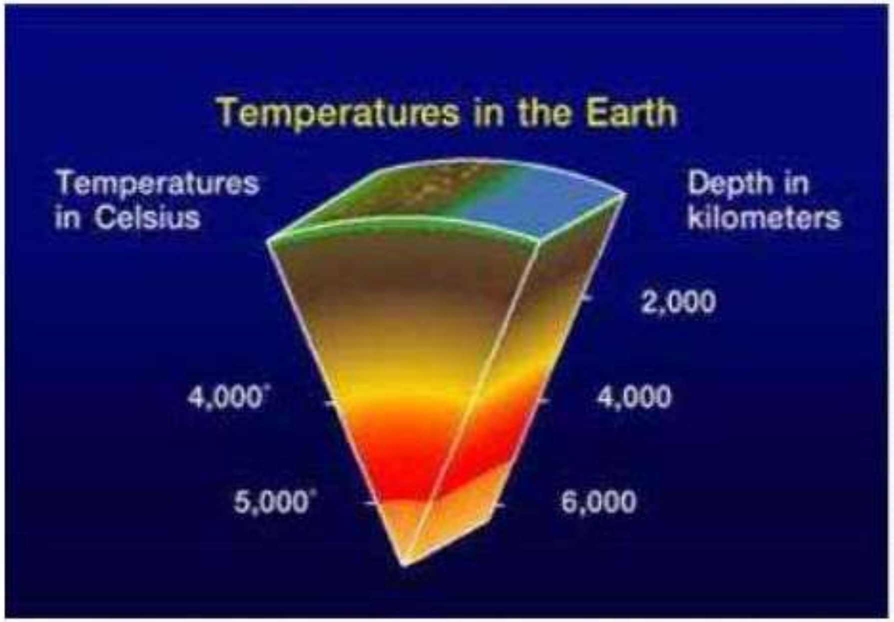
UNIT IV-------> GEOTHERMAL ENERGY

Estimation and nature of geothermal energy, geothermal sources and resources like hydrothermal, geo-pressured hot dry rock, magma. Advantages, disadvantages and application of geothermal energy, prospects of geothermal energy in India.

INTRODUCTION

- Geothermal energy is heat energy from the earth—Geo (earth) + thermal (heat).
- **Geothermal energy**, a natural resource and form of energy conversion in which heat energy from within Earth is captured and harnessed for cooking, bathing, space heating, electrical power generation, and other uses

- What is Geothermal Energy ?



It's simply the heat energy of the earth, generated by various natural processes, such as:

1. heat from when the planet formed and accreted, which has not yet been lost
2. decay of radioactive elements
3. friction

etc……

The deeper you go, the hotter it is !!!

ORIGIN AND DISTRIBUTION OF GEOTHERMAL ENERGY

- Geothermal energy is the heat that originates from the core of the earth, where temperatures are about 4000 °C.
- The heat occurs from a combination of two sources:
  - (i) the original heat produced from the formation of the earth by gravitational collapse and
  - (ii) the heat produced by the radioactive decay of various isotopes. As the thermal conductivity of the rock is very low, it is taking many billions of years for the earth to cool.

RADIOACTIVE DECAY

- **RADIOACTIVE :** When an object gives off a certain kind of energy, like the sun or an x-ray machine, it can be described as *radioactive*.
- **RADIOACTIVE DECAY**
  - **Radioactive decay** (also known as **nuclear decay**, **radioactivity**, **radioactive disintegration**, or **nuclear disintegration**) is the process by which an unstable atomic nucleus loses energy by radiation.
  - A material containing unstable nuclei is considered *radioactive*.
  - Three of the most common types of decay are alpha, beta, and gamma decay.

ALPHA RADIATION

- Alpha radiation is a type of energy released when certain radioactive elements decay or break down.
- For example, uranium and thorium are two radioactive elements found naturally in the Earth's crust.
- Over billions of years, these two elements slowly change form and produce decay products such as radium and radon.
- During this process, energy is released. One form of this energy is alpha radiation.

Uranium

- Uranium is a radioactive element that can be found in soil, air, water, rocks, plants and food. Uranium decays or breaks down very slowly into other elements including radium and radon.

Radium

- Radium is a radioactive metal that can be found at varying levels throughout Vermont and the entire Earth—in soil, water, rocks, plants and food.

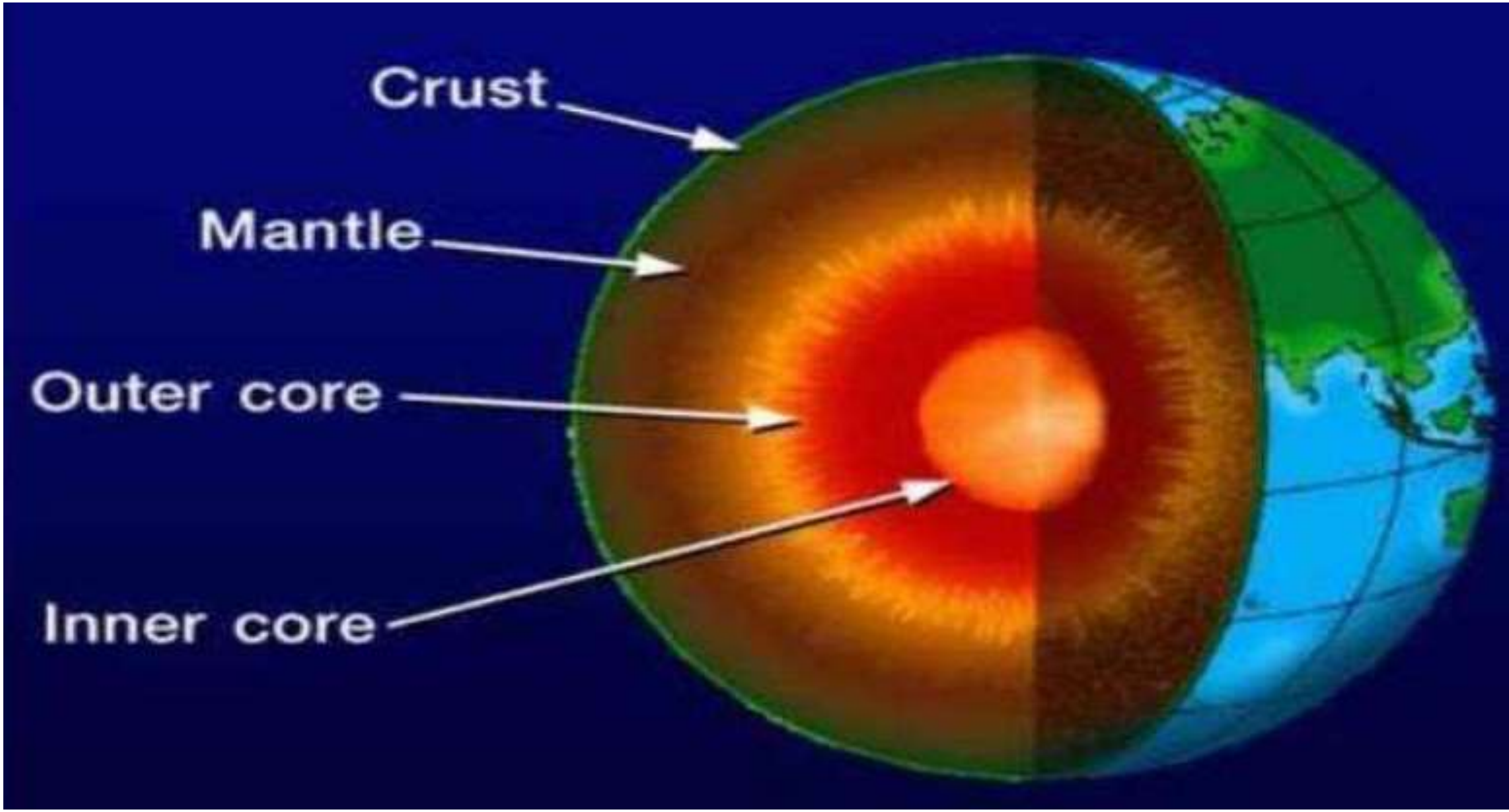
Radon

- Radon is a radioactive gas that has no color, smell or taste.
- Radon comes from the decay of uranium, which is a radioactive element found naturally in the Earth’s crust.
- Over billions of years, uranium decays into radium, and eventually into radon.

ORIGIN AND DISTRIBUTION OF GEOTHERMAL ENERGY

- Average geothermal heat dissipation from land and ocean surface is about 0.06 W/m2 , which is negligible as compared to power dissipation due to other sources e.g. solar energy (~ 1 kW/m2).
- The core is surrounded by a region, known as mantle, which consists of semi-fluid material called the magma.
- The mantle is finally covered by the outermost layer known as crust, which has average thickness of about 30 km.
- The temperature in the crust increases with depth at a rate of 30 °C/km.

INTERNAL STRUCTURE OF THE EARTH



CROSS SECTION OF THE EARTH

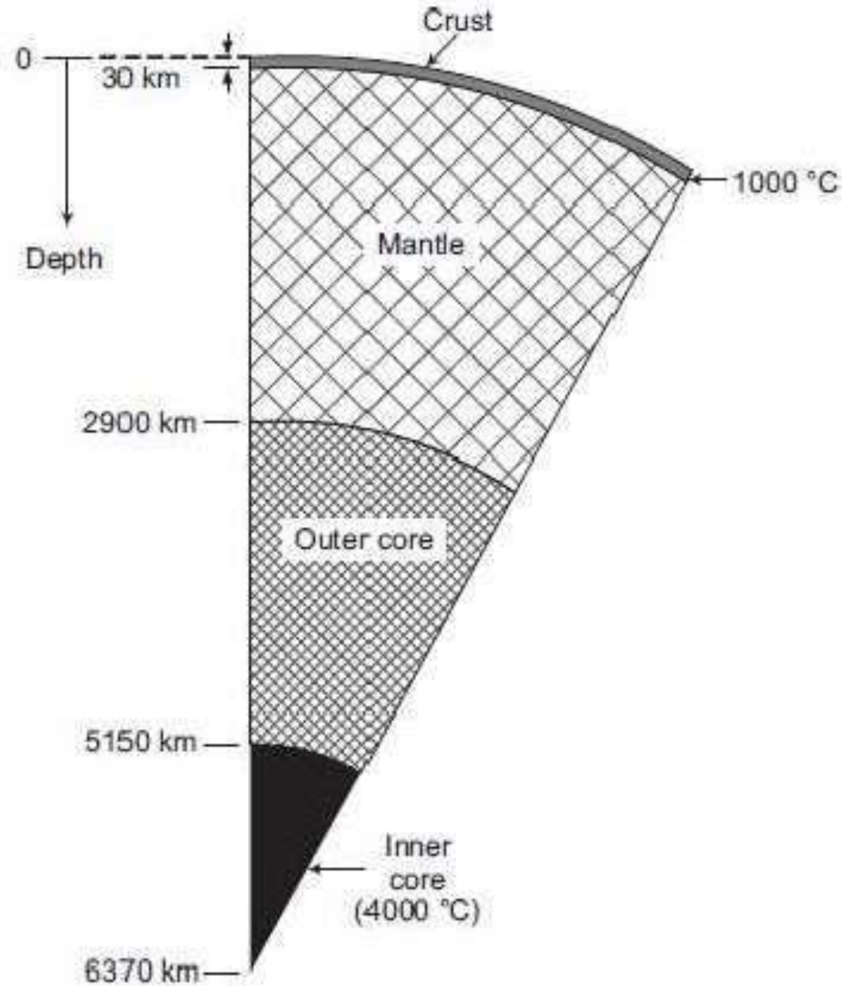


Figure 9.1 Cross section of the earth

ORIGIN AND DISTRIBUTION OF GEOTHERMAL ENERGY

- The temperature at the base of crust is about 1000 °C and then increases slowly into the core of the earth.
- ➢ A section through the earth is shown in Fig.
- Though the general distribution of layers is as shown in the Fig. ,
- There are regions in which hot molten rock (magma) of the mantle has pushed up through faults and cracks towards the surface.

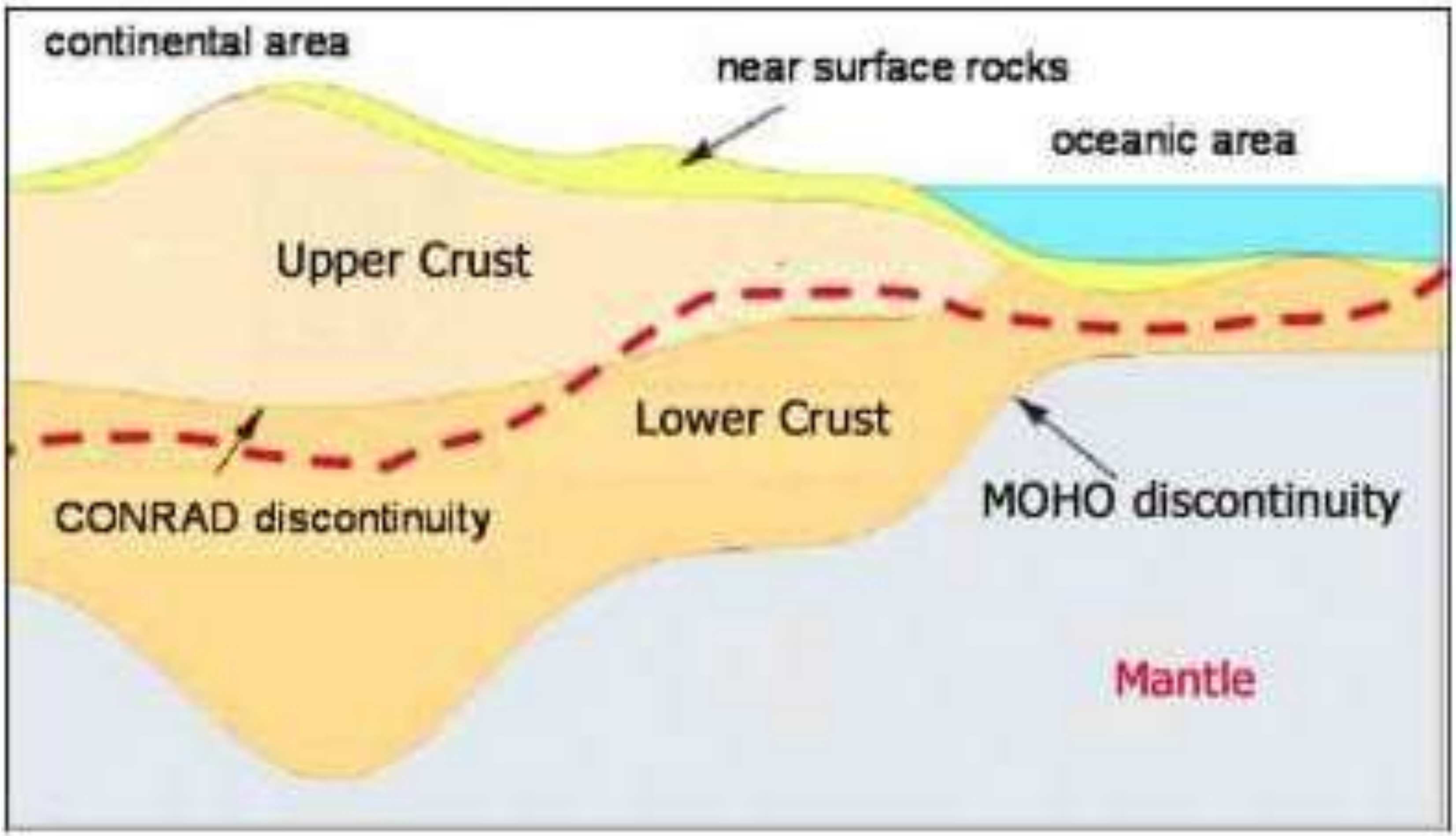
ORIGIN AND DISTRIBUTION OF GEOTHERMAL ENERGY

- In an active volcano, the magma actually reaches the surface, but more often “hot spots” occur at moderate depths (within 2 to 3 km), where the heat of the magma is being conducted upward through an overlaying rock layer.

CRUST

- It is the outermost solid part of the earth, normally about 8-40 kms thick. It is brittle in nature.
- Nearly 1% of the earth's volume and 0.5% of earth's mass are made of the crust.
- The thickness of the crust under the oceanic and continental areas are different. Oceanic crust is thinner (about 5kms) as compared to the continental crust (about 30kms).
- Major constituent elements of crust are Silica (Si) and Aluminium (Al) and thus, it is often termed as **SIAL** (Sometimes SIAL is used to refer Lithosphere, which is the region comprising the crust and uppermost solid mantle, also).

CRUST



continental area
near surface rocks
oceanic area
Upper Crust
Lower Crust
CONRAD discontinuity
MOHO discontinuity
Mantle

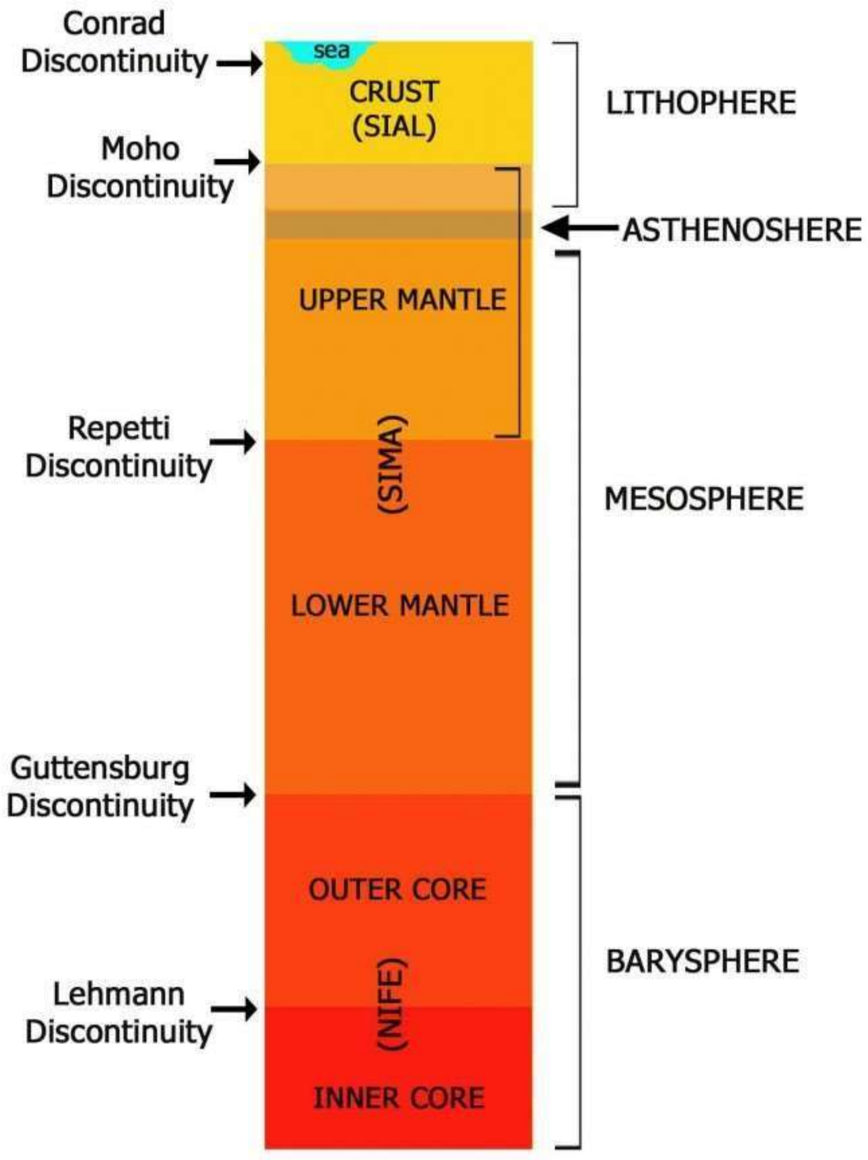
MANTLE

- The portion of the interior beyond the crust is called as the mantle.
- The discontinuity between the **crust and mantle** is called as the **Moho discontinuity.**
- The mantle is about 2900kms in thickness.
- Nearly 84% of the earth's volume and 67% of the earth's mass is occupied by the mantle.
- The major constituent elements of the mantle are Silicon and Magnesium and hence it is also termed as **SIMA**.
- The uppermost solid part of the mantle and the entire crust constitute the **Lithosphere**.
- The **asthenosphere** (in between 80-200km) is a highly viscous, mechanically weak and ductile, deforming region of the upper mantle which lies just below the lithosphere.
- The asthenosphere is the main source of magma and it is the layer over which the lithospheric plates/ continental plates move).
- The discontinuity between the **upper mantle and the lower mantle** is known as **Repetti Discontinuity**.
- The portion of the mantle which is just below the lithosphere and asthenosphere, but above the core is called as **Mesosphere**.

core

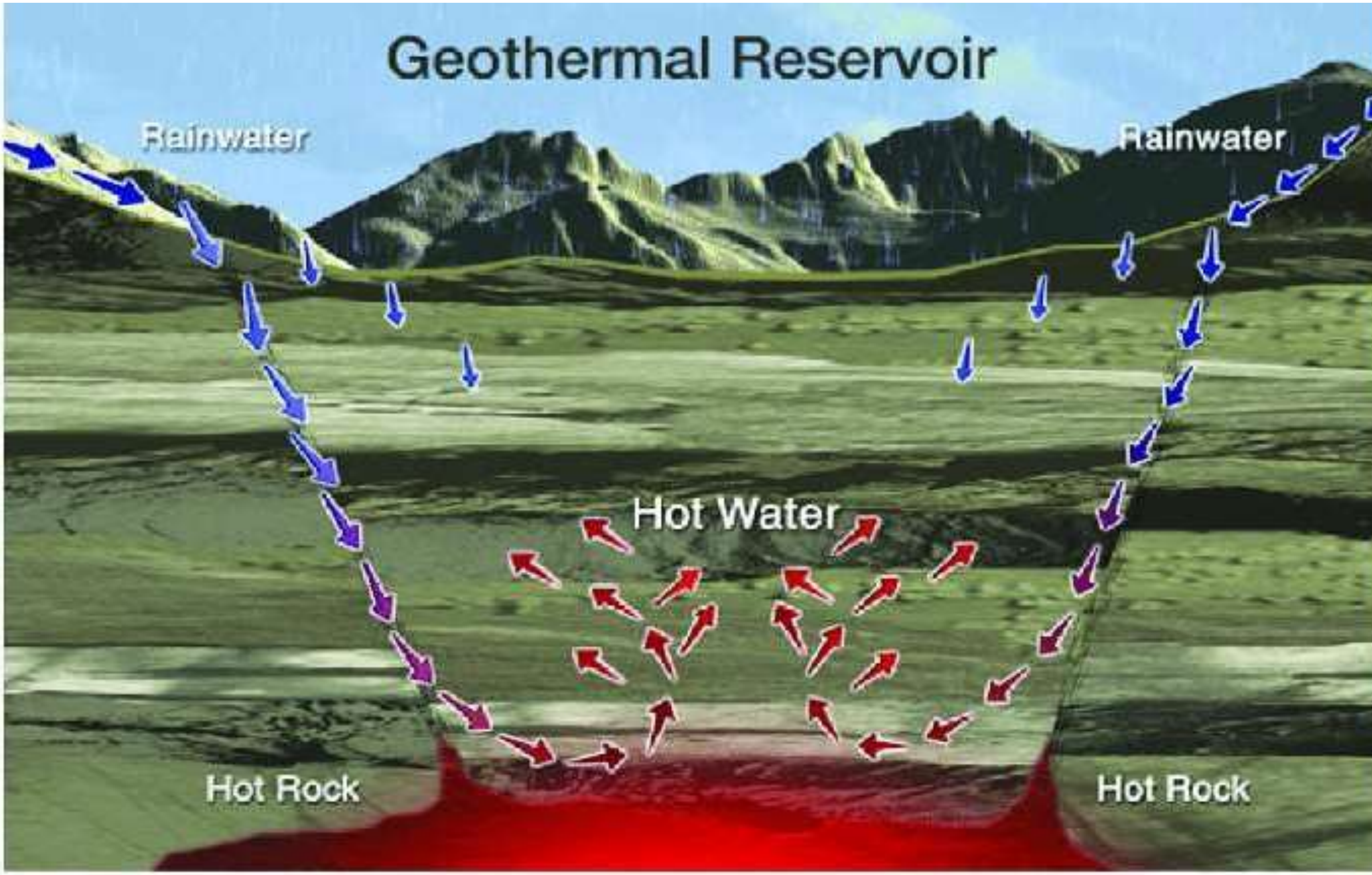
- It is the innermost layer surrounding the earth's centre.
- The **core is separated from the mantle by Guttenberg's Discontinuity**.
- It is composed mainly of iron (Fe) and nickel (Ni) and hence it is also called as **NIFE**.
- The core constitutes nearly 15% of earth's volume and 32.5% of earth's mass.
- The core is the densest layer of the earth with its density ranges between 9.5-14.5g/cm3.
- The Core consists of two sub-layers: the inner core and the outer core.
- The inner core is in solid state and the outer core is in the liquid state (or semi-liquid).
- The discontinuity between the upper core and the lower core is called as **Lehmann Discontinuity.**
- **Barysphere** is sometimes used to refer the core of the earth or sometimes the whole interior.

Structure of the earth’s interior

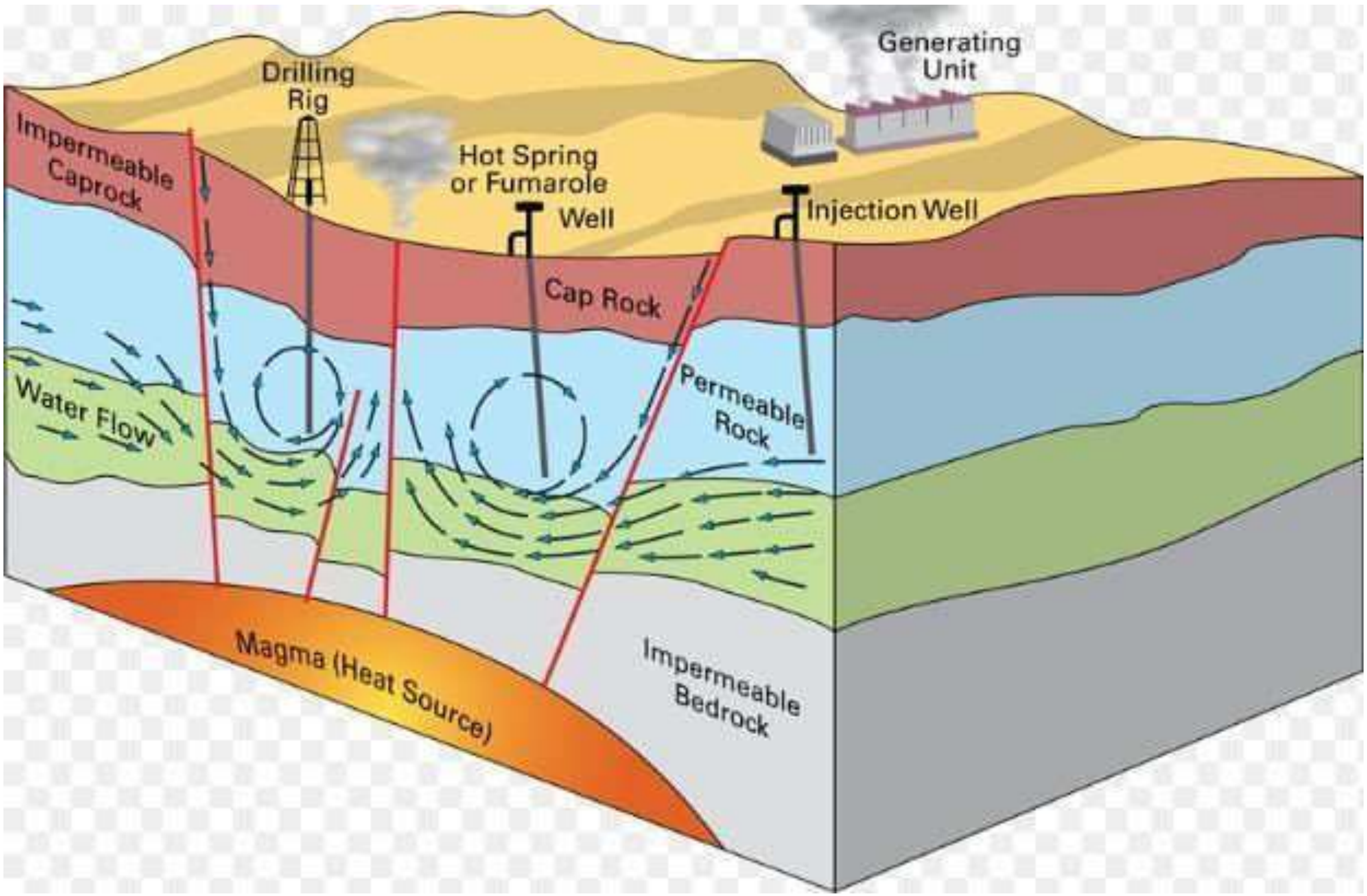


GEOTHERMAL ENERGY

- Geothermal energy is energy coming out of the molten interior (in the form of heat) of the earth towards the surface.
- Heat from Earth's interior generates surface phenomena such
  as lava flows, geysers, fumaroles, hot springs, and mud pots.


Geothermal Reservoir
Rainwater
Rainwater
Hot Water
Hot Rock
Hot Rock

Geothermal energy



Geothermal sources

1. Hydrothermal sources:

- Vapour dominated Reservoirs:

  In these systems, water is vaporized into steam which reaches earth surface at 8bar and 205^{0}C in dry condition. The steam can be used to produce power by steam turbine power plant with minimum cost. However, the steam is associated with corrosive and erosive materials.

Geothermal sources

- Liquid-dominated reservoirs:

  Liquid-dominated reservoirs (LDRs) are more common with temperatures greater than 200 °C and are found near young volcanoes surrounding the Pacific Ocean and hot spots. Generation of electricity is possible from these source. Most wells generate 2-10MW. Steam is separated from liquid via cyclone separators, while the liquid is returned to the reservoir for reheating or reuse. Lower temperature LDRs (120–200 °C) require pumping. The water which comes from low temperature is heated to required temperature by external heat exchanger and used for power generation

Geothermal sources

2. Geopressurized reservoirs:

In this type of reservoir, the hot water or brine at about 160^{0}C is trapped underground at about 2400m to 9100m depth. The pressure is more than 1000bar. Although it has great thermal and mechanical potential for power generation, it may not economical to drill for this brine/water due to great depth. This brine has recoverable methane and there may be economic feasibility to generate electricity involving combustion of methane as well as heat from the thermal energy of water.

Geothermal sources

3. Hot dry rocks sources or Enhanced geothermal systems:

- When there is no underground water, there are hot dry rocks(HDR) at 150-300^{0}C near the earth's surface.
- This heat energy from rocks can be utilized and this energy is called as petrothermal energy.
- For utilizing the heat energy from rocks, The water will have to be pumped into HDR and back out to the earth surface.
- Drillers can employ directional drilling to expand the size of the reservoir

4. Normal Geothermal Gradient:

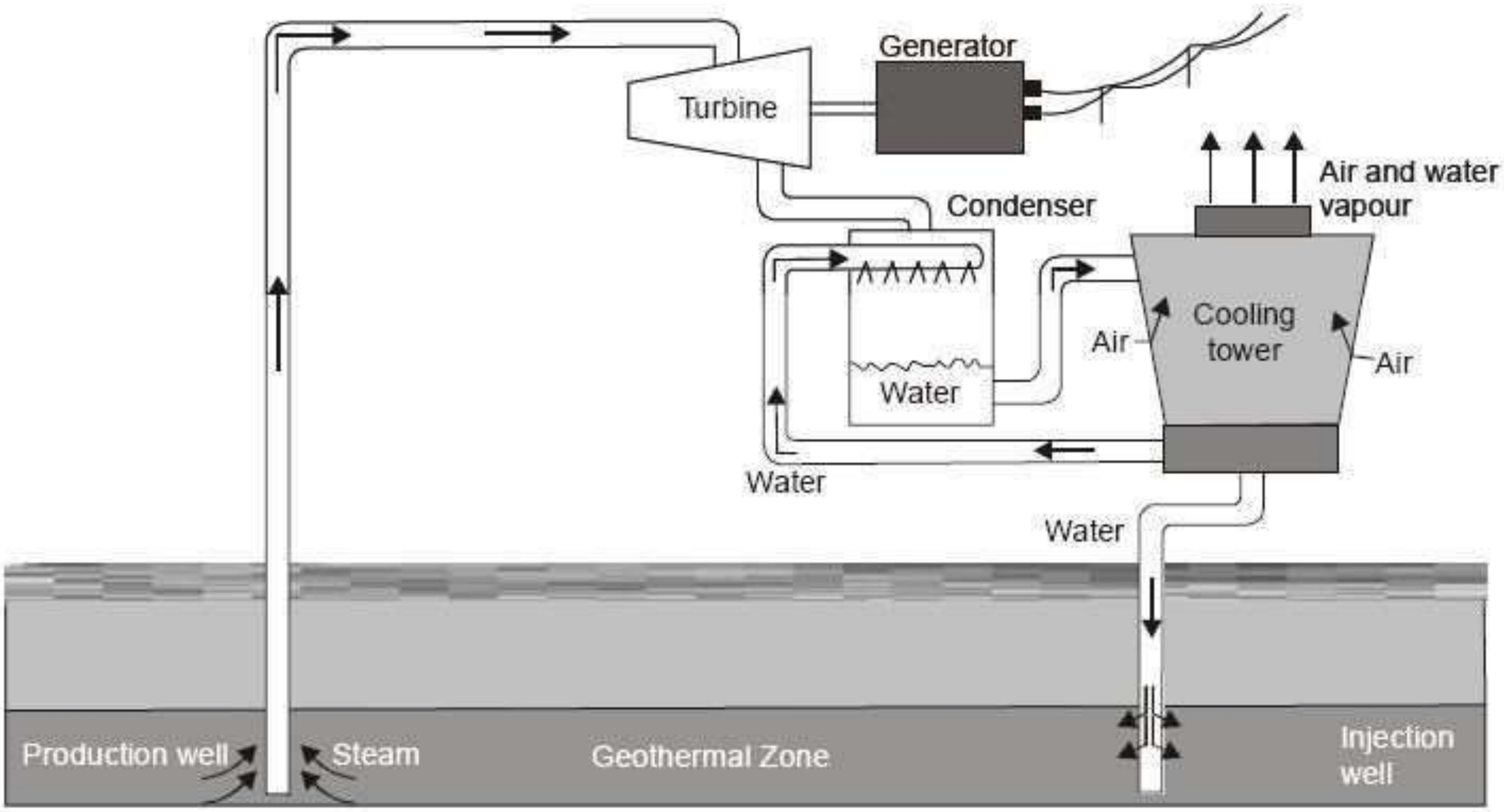
- At any place on the planet, there is a normal temperature gradient of +30^{0}C per km dug into the earth.
- Therefore, if one digs 20,000 feet the temperature will be about 190^{0}C above the surface temperature.
- This difference will be sufficient to produce electricity. However, no useful and economical technology has been developed to extracted this large source of energy.

Surface Geothermal Systems

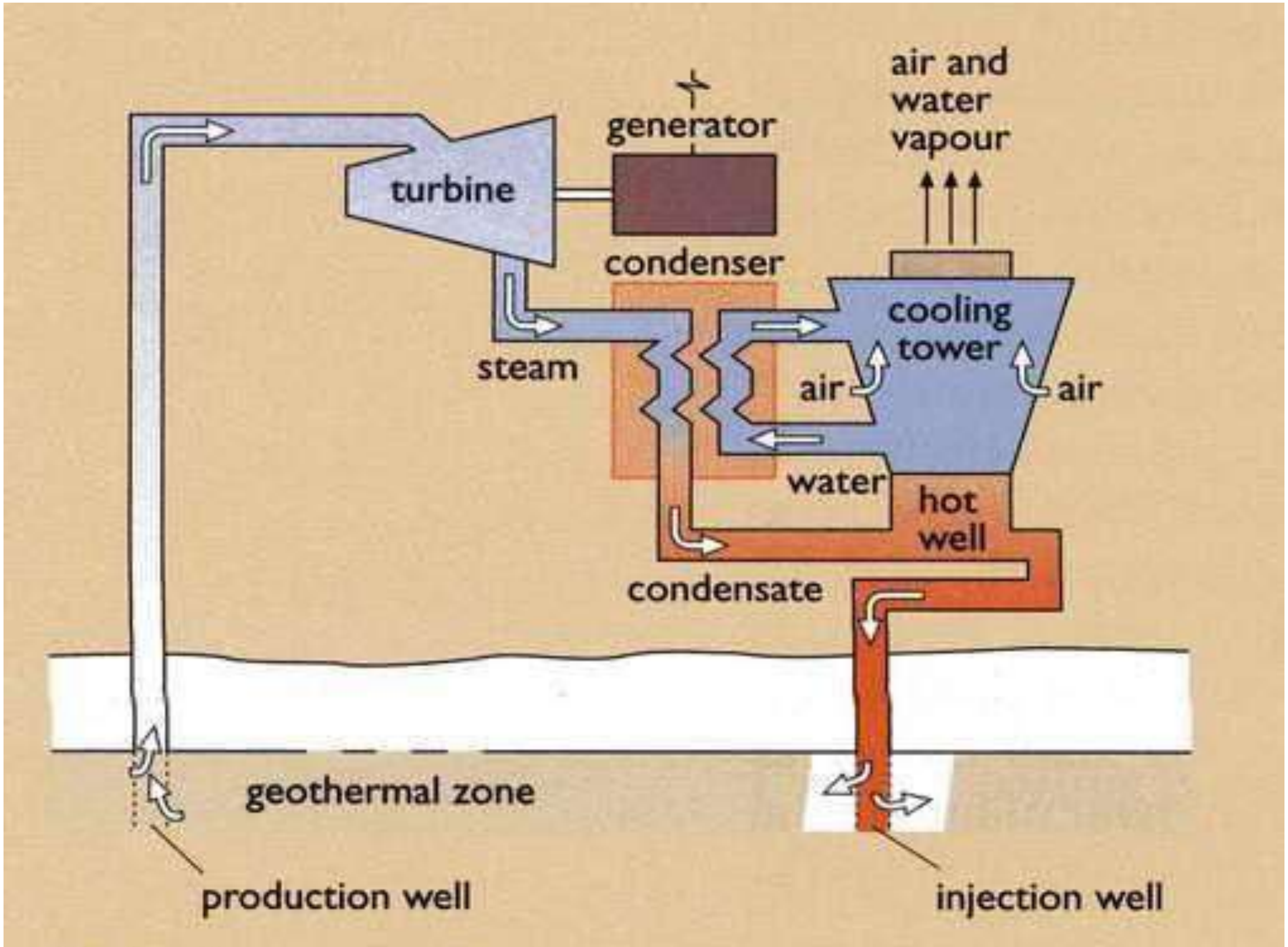
There are three different types surface of Geothermal system designs :

- Dry Steam Power Plants
- Flash / Steam Plants
- Binary cycle power plant

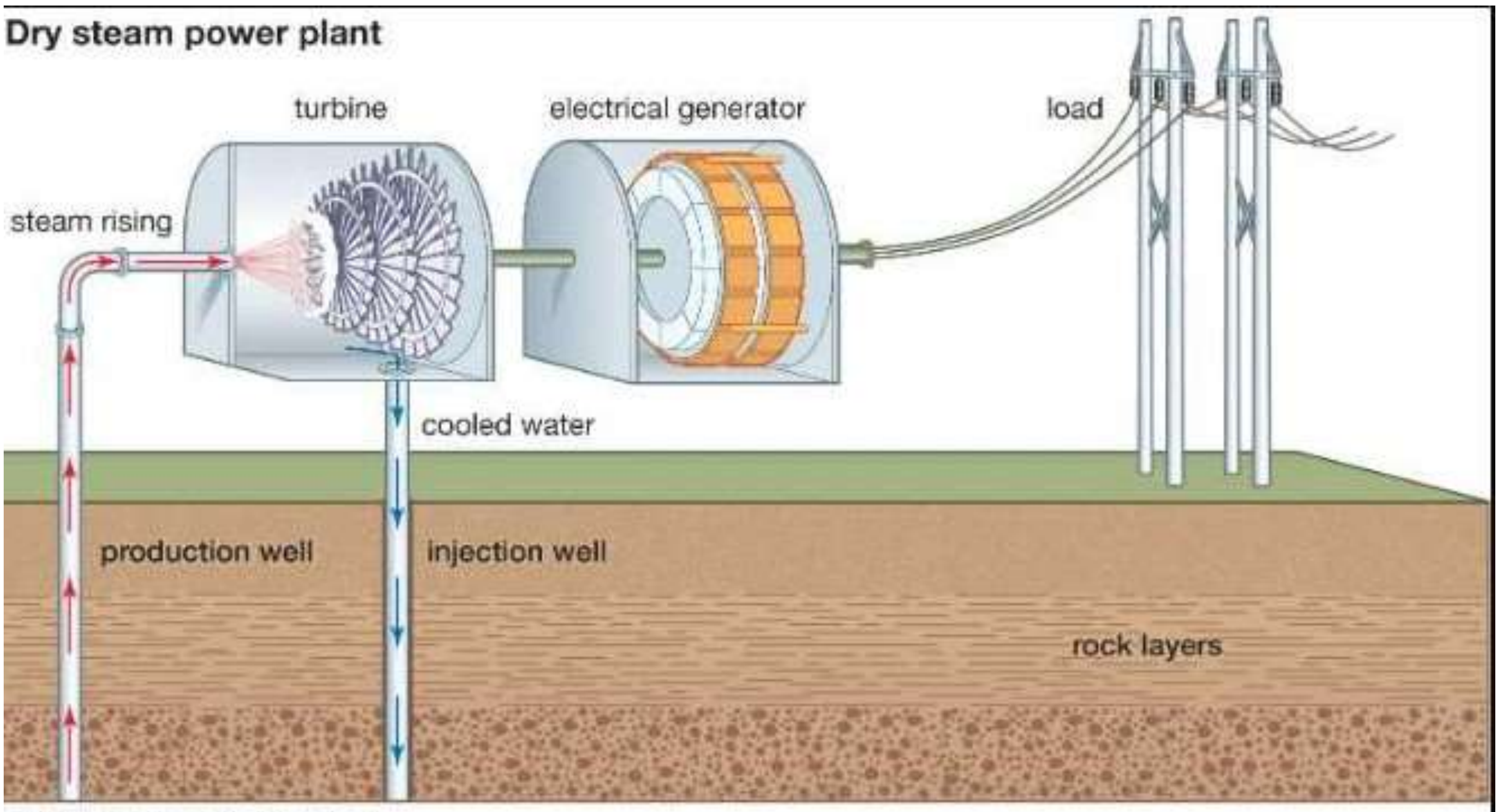
Dry Steam Power Plant (Vapour Dominated System)



Dry Steam power plant

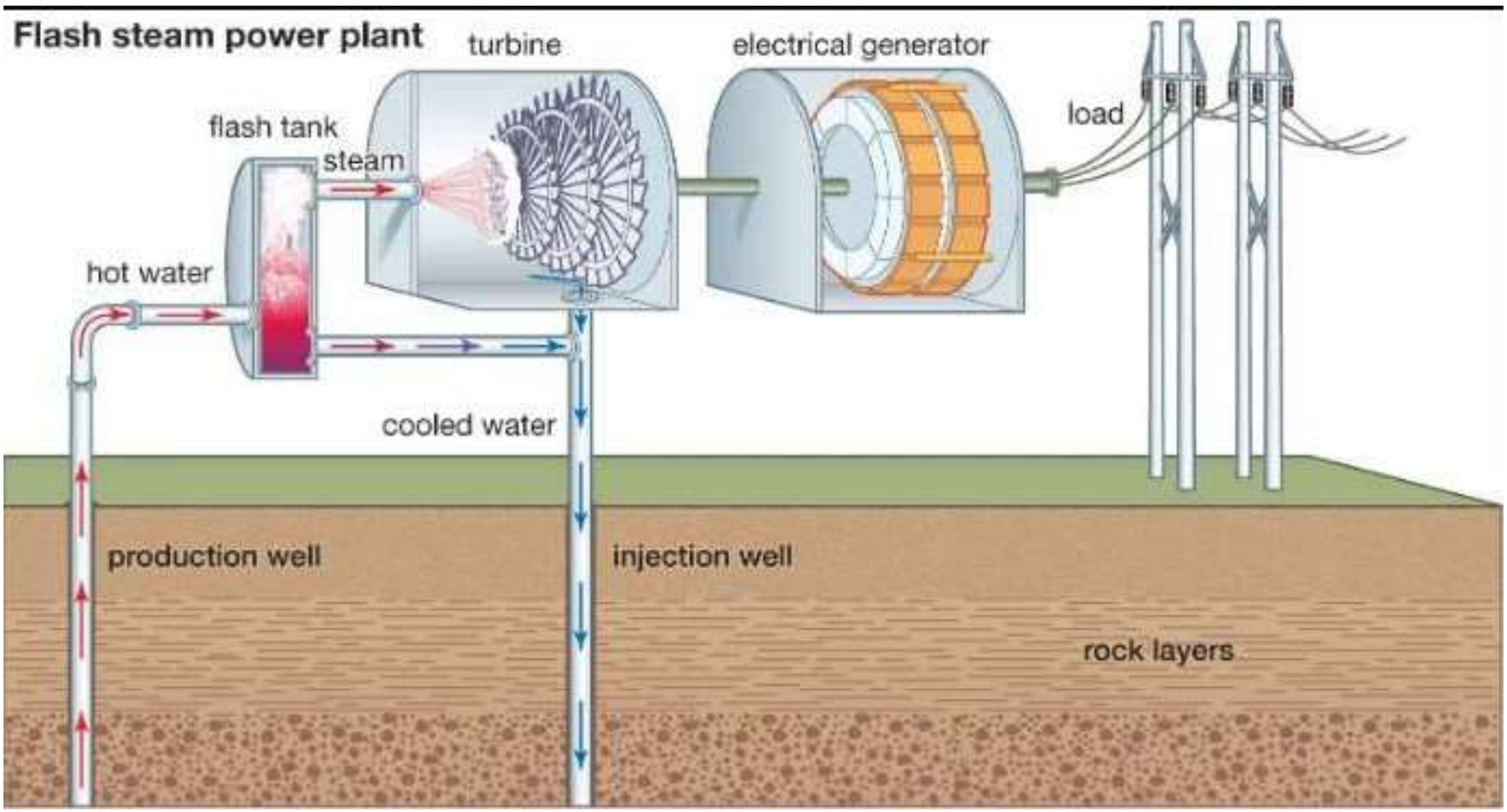


(a) dry steam power plant

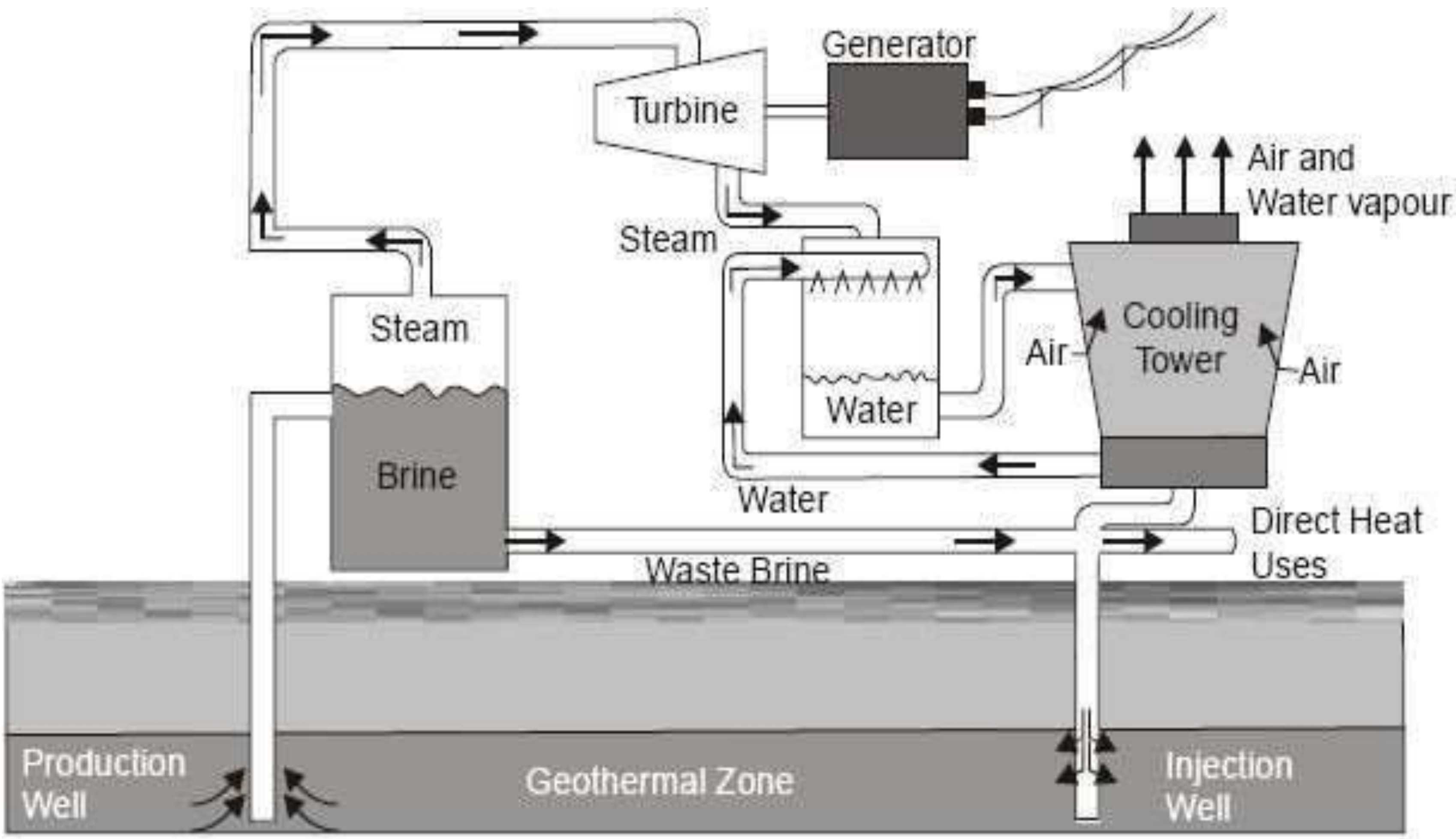

Dry steam power plant
turbine
electrical generator
load
steam rising
cooled water
production well
injection well
rock layers

Dry Steam Power Plant

- Dry steam is extracted from natural reservoir.
- These plants are operated with dry steam with temperature range 180-225 ^{o}C , pressure range 4-8 MPa .
- Steam is used to drive a turbo-generator
- Exhaust Steam from turbine is condensed and pumped back into the ground


Flash steam power plant
turbine
electrical generator
flash tank
steam
load
hot water
cooled water
production well
injection well
rock layers

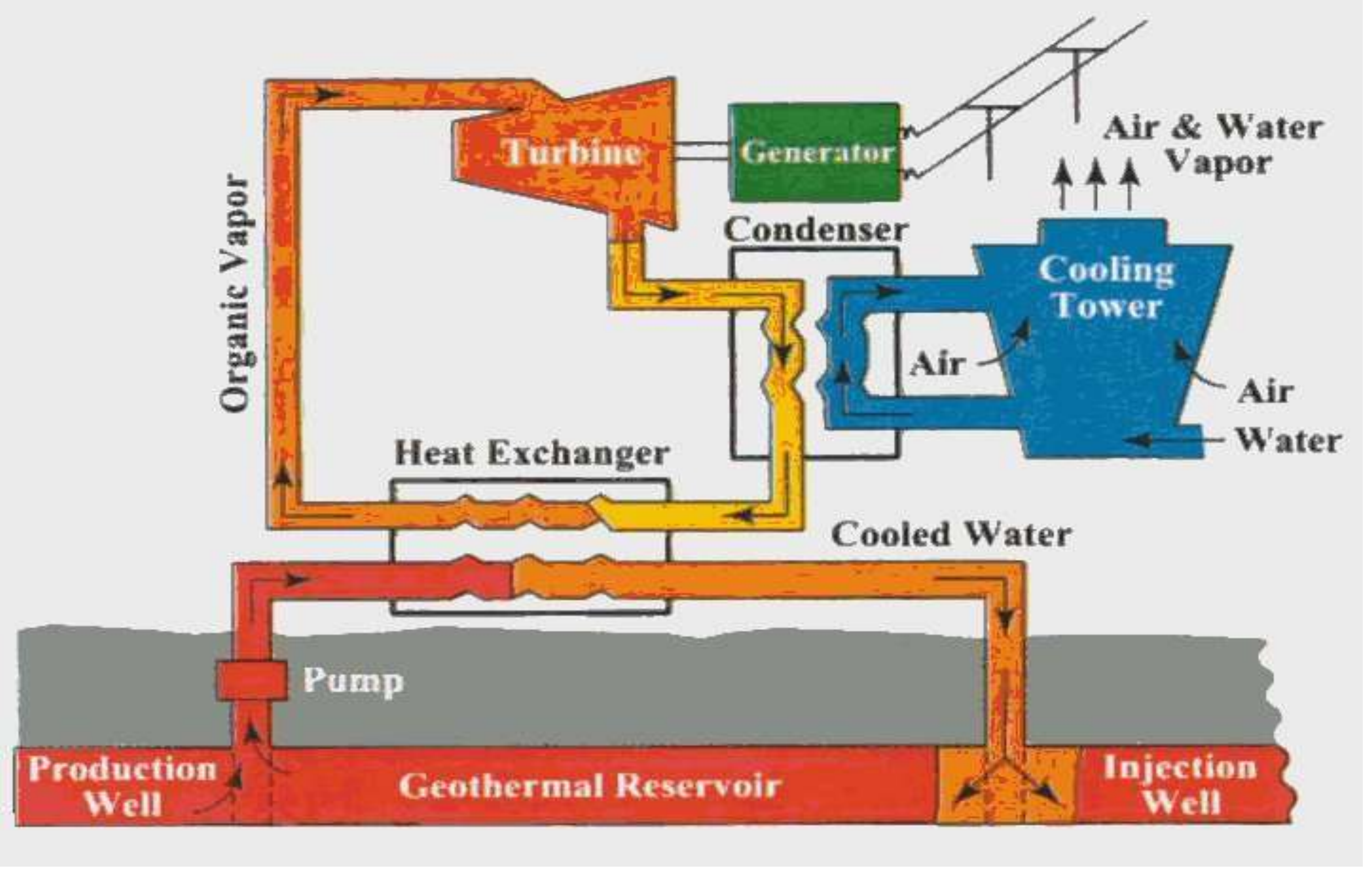
Flash Steam Power Plant (Liquid Domain System)



Flash Steam Power Plant (Liquid Domain System)

- The steam has been separated from the water and supplied to the powerhouse where it is used to drive the steam turbine. The steam is condensed after leaving the turbine, creating a partial vacuum and thereby maximizing the power generated by the turbine-generator.
- The steam is usually condensed either in a direct contact condenser, or a heat exchanger type condenser
- Typically, flash condensing geothermal power plants vary in size from 5 MW to over 100 MW.
- Depending on the steam characteristics, gas content, pressures, and power plant design, between 6 and 9 tonne of steam each hour is required to produce each MW of electrical power.
- Small power plants (less than 10 MW) are often called well head units as they only require the steam of one well and are located adjacent to the well on the drilling pad in order to reduce pipeline costs. The well head units do not have a condenser and they are also called as backpressure units. They are very cheap and simple to install, but are inefficient (typically 10-20 tonne per hour of steam for every MW of electricity).

Binary Cycle Power Plant



Binary Cycle Power Plant

- Binary cycle plants are often utilized for reservoirs where temperatures are typically ranges between 220^{o}C and 100^{o}C .
- The reservoir fluid (either steam or water or both) is passed through a heat exchanger which heats a secondary working fluid which has a boiling point lower than 100^{o}C . This is typically an organic fluid such as Isopentane, which is vaporized and is used to drive the turbine. The organic fluid is then condensed and recycled back to the heat exchanger and formed a closed loop. The cooled reservoir fluid is again re-injected back into the reservoir. Binary cycle type plants are usually between 7 and 12 % efficient depending on the temperature of the primary (geothermal) fluid.
- If the geothermal resource has a temperature between 100^{o}C and 150^{o}C , electricity can still be generated using binary plant technology.
- The size of binary units range from 0.1 to 40 MW.

Advantages of Geothermal energy

- **Environmentally Friendly:** Unlike fossil fuels, geothermal energy doesn’t produce harmful emissions. Expanding its use could significantly reduce the carbon footprint of India’s energy sector.
- **Baseload Power:** Unlike solar or wind energy, geothermal energy is available 24/7, making it a reliable baseload power source.
- **Reduced Dependency on Imports:** India imports a significant amount of its energy resources. Harnessing geothermal energy can reduce this dependency, ensuring energy security.

ADVANTAGES OF GEOTHERMAL ENERGY

- **Job Creation:** Investments in geothermal energy can lead to job creation in the exploration, installation, and maintenance sectors.
- **Potential for Direct Heating:** In addition to electricity generation, geothermal energy can also be used for direct heating purposes, which can be particularly beneficial in colder regions.

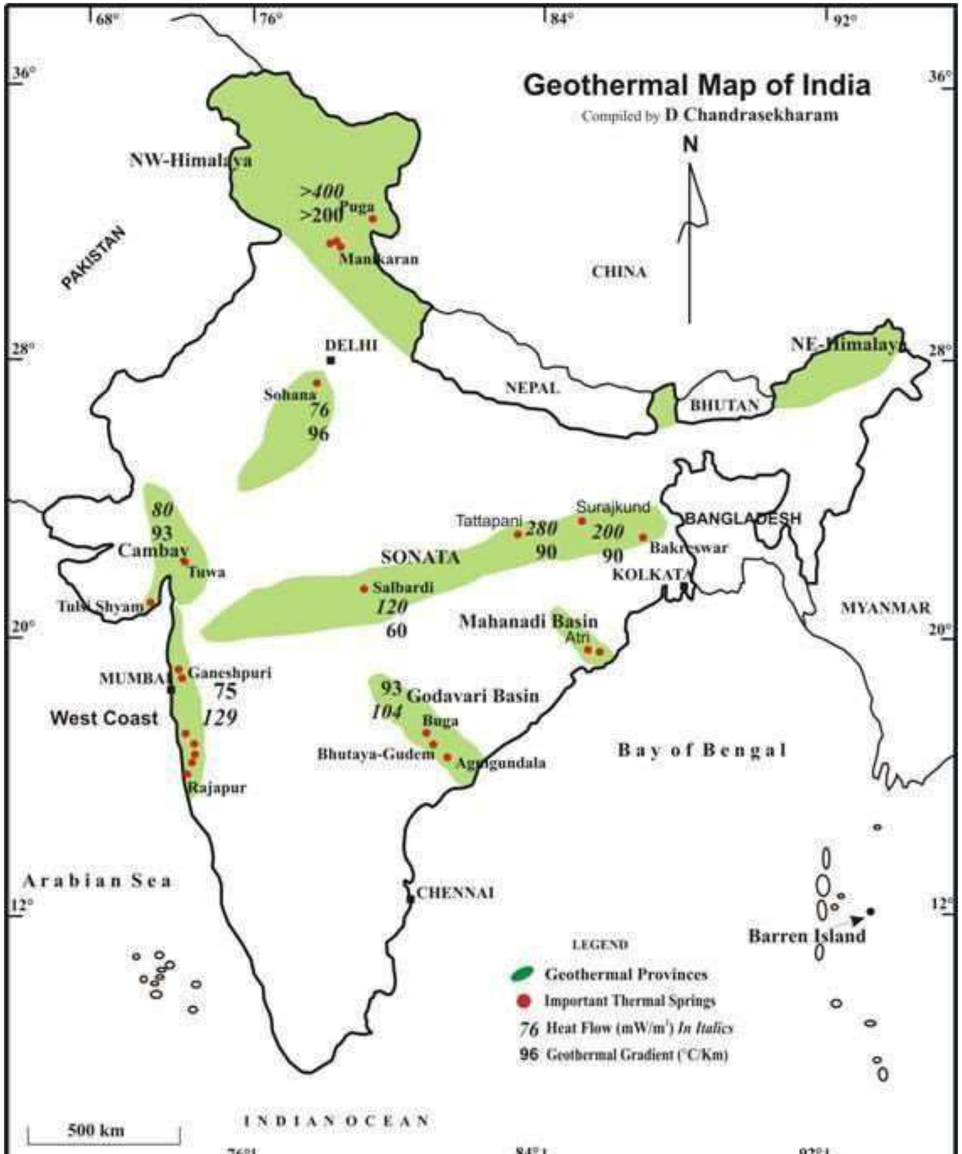
DISADVANTAGES

- There is a noise pollution during the drilling of wells.
- Installation cost is high.
- Geothermal energy can not be easily transported. Once the tapped energy is extracted, it can be only used in the surrounding areas.

Applications of Geothermal energy

1. Space Heating
2. Air Conditioning
3. Industrial Processes
4. Drying
5. Agriculture
6. Hot Water
7. Resorts And Pools
8. Melting Snow

Prospects of Geothermal



Geothermal provinces in India

- Puga Valley (J&K)
- Tatapani (Chhattisgarh)
- Godavari Basin Manikaran (Himachal Pradesh)
- Bakreshwar (West Bengal)
- Tuwa (Gujarat)
- Unai (Maharashtra)
- Jalgaon (Maharashtra)

Geothermal provinces in India

Province	Surface Temp C	Reservoir Temp C	Heat Flow	Thermal gradient
Himalaya	>90	260	468	100
Cambay	40-90	150-175	80-93	70
West coast	46-72	102-137	75-129	47-59
Sonata	60 – 95	105-217	120-290	60-90
Godavari	50-60	175-215	93-104	60

Geothermal energy potential in India

- India has reasonably good potential for geothermal; the potential geothermal provinces can produce 10,600 MW of power.
- Thermax is planning to set up a 3 MW pilot project in Puga Valley, Ladakh (Jammu & Kashmir)