MODULE - 5

OCEAN THERMAL ENERGY CONVERSION (OTEC)

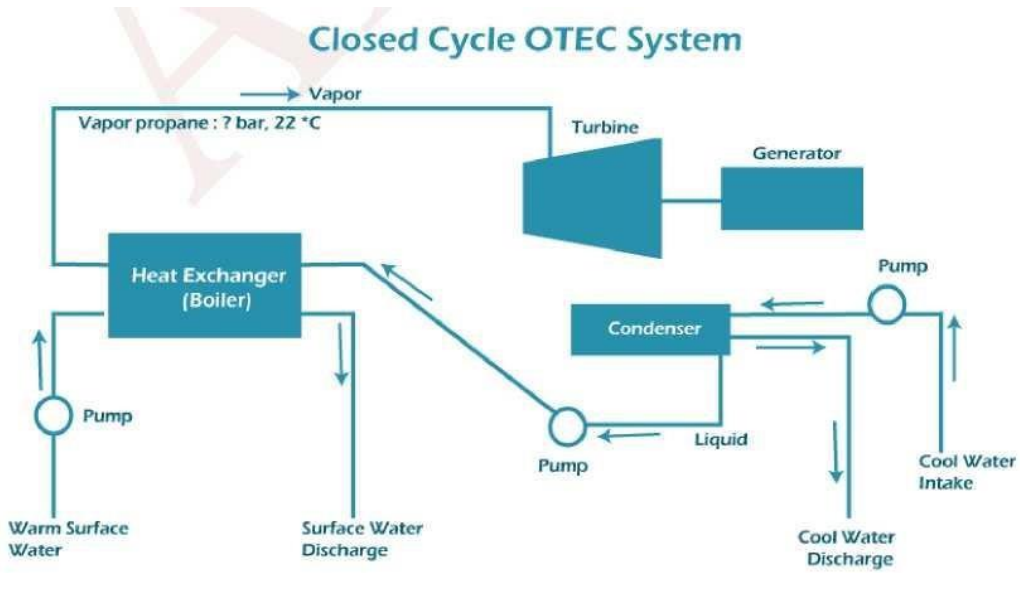
Principle of Working

Ocean Thermal Energy Conversion (OTEC) is a process that generates electricity by exploiting the temperature difference between the warm surface water of the ocean and the colder deep water. This temperature gradient is a result of solar energy heating the surface of the ocean.

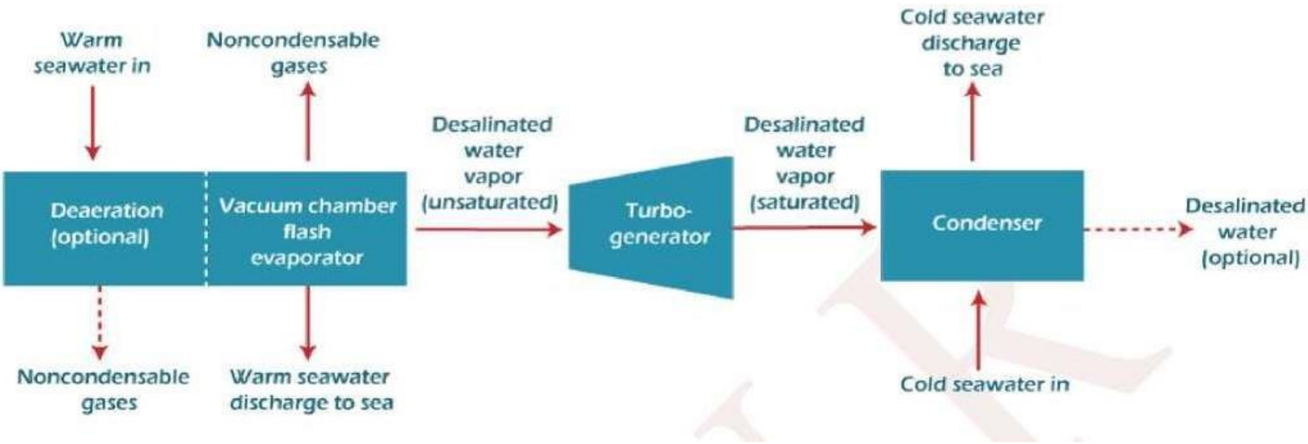
1. **Warm Surface Water:** The warm surface water, typically around 25°C to 30°C, is pumped through a heat exchanger, where it heats a working fluid with a low boiling point, such as ammonia or a refrigerant.
2. **Evaporation:** The working fluid evaporates into a gas due to the heat from the warm seawater. This gas expands and drives a turbine connected to a generator, producing electricity.
3. **Cold Deep Water:** Cold seawater, drawn from depths of around 1000 meters where the temperature is approximately 4°C to 5°C, is pumped through another heat exchanger. This cold water cools and condenses the vaporized working fluid back into a liquid.
4. **Recirculation:** The condensed working fluid is then recirculated back to the evaporator to repeat the cycle.

Types of OTEC Systems:

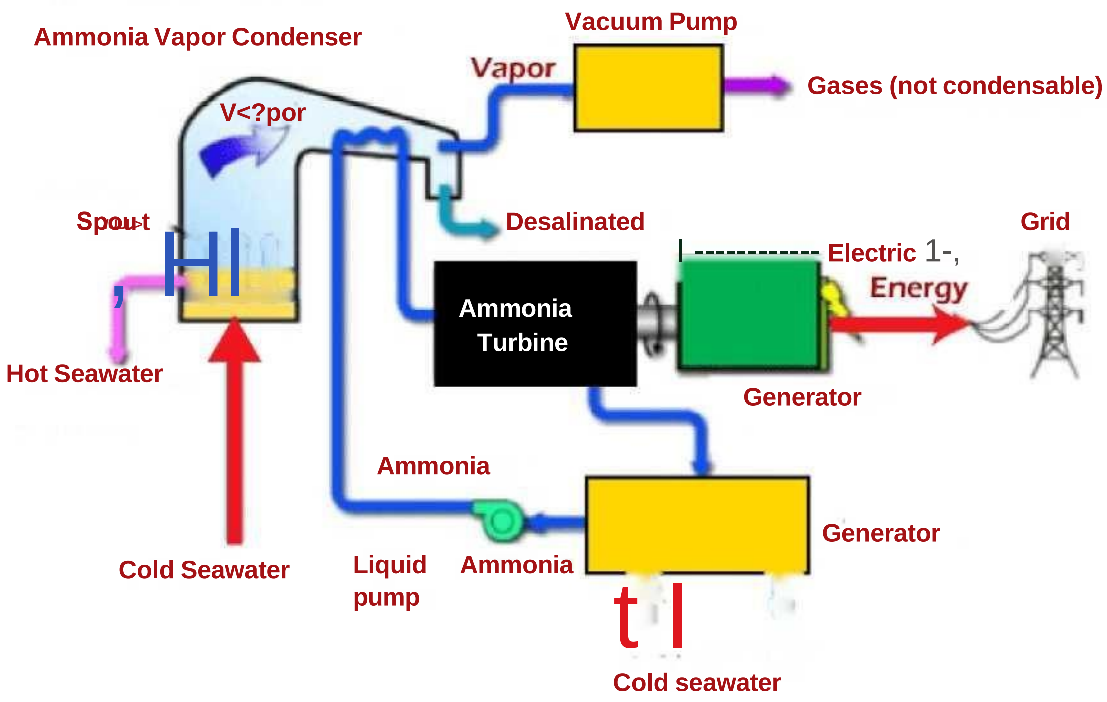
1. **Closed-Cycle OTEC:** Uses a working fluid with a low boiling point, such as ammonia, which is vaporized and condensed in a closed system.



2. **Open-Cycle OTEC:** Uses the warm surface seawater itself as the working fluid. The seawater is vaporized in a vacuum chamber, and the steam generated drives the turbine. The steam is then condensed using cold seawater.



3. **Hybrid OTEC:** Combines both closed and open-cycle processes to improve efficiency and energy output.



Advantages of OTEC:

- **Renewable Energy Source:** Utilizes the abundant and consistent thermal energy of the ocean.
- **Base Load Power:** Provides continuous and predictable energy, unlike some other renewable sources that depend on weather conditions.

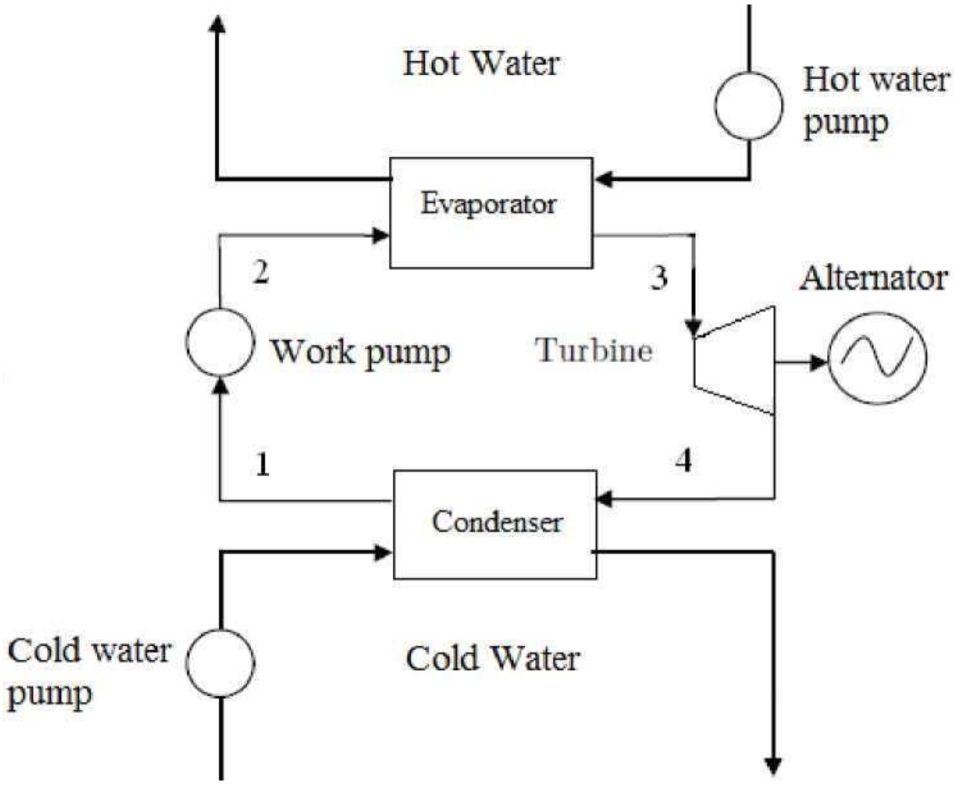
- **Byproducts:** Can produce fresh water as a byproduct in open-cycle systems, which can be beneficial for arid regions.

Challenges:

- **High Initial Costs:** Building OTEC plants and the infrastructure required is expensive.
- **Environmental Impact:** Potential impacts on marine ecosystems and thermal pollution.
- **Technical Complexity:** Requires advanced technology to operate efficiently and reliably in harsh ocean environments.

Rankine Cycle

The Rankine cycle is a thermodynamic cycle used in OTEC systems to convert thermal energy into mechanical work and subsequently into electrical energy. OTEC systems exploit the temperature difference between warm surface seawater and cold deep seawater to drive the Rankine cycle.



Principle of Working:

1. **Warm Surface Seawater:**

    - Warm seawater, typically around 25°C to 30°C, is pumped through an evaporator.
    - In the evaporator, this warm seawater heats a working fluid with a low boiling

point (such as ammonia or a refrigerant), causing it to vaporize.

2. **Evaporation (Heat Addition):**

    - The working fluid absorbs heat from the warm seawater and changes from a liquid to a vapor.
    - This vapor expands and increases in pressure as it absorbs the thermal energy.

3. **Turbine (Work Output):**

    - The high-pressure vapor drives a turbine, which is connected to a generator, producing electricity.
    - As the vapor expands through the turbine, it loses some of its thermal energy and pressure, converting it into mechanical work.

4. **Cold Deep Seawater:**

    - Cold seawater, drawn from depths of around 1000 meters where the temperature is approximately 4°C to 5°C, is pumped through a condenser.

5. **Condensation (Heat Rejection):**

    - In the condenser, the cold seawater absorbs heat from the vaporized working fluid, causing the vapor to condense back into a liquid.
    - The working fluid releases its latent heat to the cold seawater, thus cooling and condensing it.

6. **Pump (Pressure Increase):**

    - The condensed working fluid is then pumped back to the evaporator to repeat the cycle.
    - The pump increases the pressure of the liquid working fluid, preparing it to absorb heat again in the evaporator.

Components of an OTEC Rankine Cycle:

1. **Evaporator:** Heat exchanger where the working fluid is vaporized by warm surface seawater.
2. **Turbine:** Converts the thermal energy of the vapor into mechanical energy.
3. **Condenser:** Heat exchanger where the working fluid is condensed by cold deep seawater.

4. **Pump:** Circulates the working fluid through the cycle, increasing its pressure after condensation.

Advantages:

- **Renewable Energy Source:** Utilizes the natural thermal gradient of the ocean.
- **Continuous Power Generation:** Provides base load power due to the constant temperature difference in tropical regions.
- **Scalability:** Can be implemented at various scales, from small experimental plants to large commercial facilities.

Challenges:

- **Technical Complexity:** Requires advanced technology and materials to operate efficiently.
- **High Initial Costs:** Significant investment needed for construction and maintenance of OTEC plants.
- **Environmental Concerns:** Potential impact on marine ecosystems due to the intake and discharge of seawater.

OTEC Power Stations in the World

Location	Power output planned	Specifics available	Developer
Hawaii	103 kW	Closed cycle, One of the oldest installations installed in 1979 kW	NELHA Natural Energy Laboratory
Hawaii	1 MW	Open cycle, operated between 1993 and 1998. Power generation, also focused on use of water for aquaculture; a land-based plant	OTEC International LLC and NELHA Natural Energy Laboratory Hawaii
Hawaii	10 MW Lockheed Martin Command	Closed cycle, near shore platform, planned to be in function in 2013, but shelved. Funded with a grant of USD 4.4 million of	Lockheed Martin Naval Facility Engineering Engineering Command

		the Naval Facility Engineering Command, meant to also serve as a pilot for further development in isolated areas/islands- military basis/ remote settlements. Prior to 2009, Lockheed Martin was also awarded USD 12.2 million for preparatory OTEC design and exploration.	
Japan/ Nauru	120 kW	Closed cycle, operated in 1982 and 1983 for scientific research; around 90% goes to pumping and energy used to operate the plant.	Japan Institute for Ocean Energy Research
Japan, Imari	30 kW	Demonstration plant; several others have been built in earlier stages by Saga University. The multi-purpose 30 kW is from 2003.	Saga University; other partners
Japan/ Okinawa	50 kW	Completed on 16 June 2013 - a research, development and demonstration plant near Kumejima Island- land-based plant used for electricity generation and research on other OTEC applications,	Xenesys Incorporated, IHI, and Yokogawa

		aquaculture, agriculture, cooling; later possible scaling up to 125 MW could take place as estimated by Xenesys.	
India- Tuticorin	1 MW	Ammonia-based closed cycle, started in 2000, but not completed due to problems with the pipes for pumping the seawater; floating plant.	Indian Government/ Indian Institute of Technology
Southern China On	10 MW	13 April 2013, agreement signed for development of a 10 MW landbased OTEC installation on the Southern Coast of China, between Beijing Based Reignwood Group and Lockheed Martin.	Lockheed Martin, Reignwood Group (Lockheed Martin, 2013)
Martinique/ Bellefontaine	10 MW	Floating platform of DCNS Consortium - planning in more progressed state as of 2014, focusing on 2016 for operation. Also other sites are being thought of, e.g., Reunion. A second plant is also considered.	DCNS France
South Korea	20 kW	Installed in 2013.	KISOT
Bahamas/ Baha Mar	NA	USD 104 million project providing cooling for Baha Mar Resort; permit	Ocean Thermal Energy Conversion Corporation

		issues/infrastructural and ecological issues - conflicts with navigation issues and cabling, coast protection issues, seemed to have stalled the project -at least temporarily.	
Kingdom of Bora Bora, Island in French Polynesia	NA	Land-based, used for air conditioning only, no power generation.	Intercontinental Hotel Bora Bora
Tetiaroa, Island in French Polynesia	NA	Land-based, used for air conditioning only, no power generation.	The Brando Hotel, Tetiaroa

Advantages and Disadvantages of Ocean Thermal Energy Conversion (OTEC)

Advantages:

1. **Renewable and Sustainable Energy Source:** OTEC utilizes the natural temperature gradient of the ocean, making it a renewable source of energy that can be harnessed continuously in tropical regions.
2. **Base Load Power Generation:** Unlike some other renewable energy sources (e.g., solar and wind), OTEC can provide a consistent and stable power supply, serving as a reliable base load energy source.
3. **Environmental Benefits:** OTEC generates clean energy without burning fossil fuels, reducing greenhouse gas emissions and helping to mitigate climate change.
4. **Energy Independence:** Countries with access to warm ocean waters can reduce their dependence on imported fossil fuels, enhancing energy security and economic stability.
5. **Desalination Potential:** OTEC systems can be integrated with desalination processes, providing fresh water as a valuable byproduct.
6. **Additional Byproducts:** The cold, nutrient-rich water brought to the surface can be used for mariculture (fish farming) and air conditioning, adding further economic and environmental benefits.
7. **Scalability:** OTEC plants can be built in various sizes, from small pilot projects to large commercial facilities, allowing for gradual scaling up of the technology.

Disadvantages:

1. **High Initial Costs:** The construction and maintenance of OTEC plants require significant capital investment, which can be a barrier to widespread adoption.

2. **Technical Challenges:** OTEC technology involves complex engineering and advanced materials to handle the harsh marine environment and large volumes of seawater.
3. **Environmental Impact:** Potential ecological impacts include the disruption of marine habitats, changes in local water temperatures, and the potential release of cold, nutrient-rich water that can affect local ecosystems.
4. **Geographic Limitations:** OTEC is most effective in tropical regions where there is a significant temperature difference between surface and deep ocean water. This limits the geographic locations where OTEC can be feasibly implemented.
5. **Efficiency Concerns:** The overall efficiency of OTEC systems is relatively low compared to other energy generation methods due to the small temperature differential utilized in the Rankine cycle.
6. **Maintenance and Durability:** Operating in a marine environment subjects OTEC systems to corrosion, biofouling, and other wear and tear, requiring regular maintenance and robust materials.
7. **Energy Transmission:** Transmitting electricity from offshore OTEC plants to the mainland requires undersea cables, which can be costly and complex to install and maintain.

Problems Associated with OTEC

1. **High Initial Costs:** OTEC plants require significant capital investment for construction and deployment. The costs associated with advanced materials, engineering, and marine infrastructure are high, making it difficult to compete with other energy sources initially.
2. **Technical Challenges:** The technology involves complex engineering and materials capable of withstanding the harsh marine environment. Corrosion, biofouling, and structural integrity are major concerns that require innovative solutions.
3. **Low Efficiency:** The thermal efficiency of OTEC systems is relatively low due to the small temperature differential between warm surface water and cold deep water, typically resulting in an efficiency of around 3-4%.
4. **Environmental Impact:** Potential ecological impacts include disruption of marine habitats, changes in local water temperatures, and the release of nutrient-rich deep water, which could affect local ecosystems and biodiversity.
5. **Geographic Limitations:** OTEC is most viable in tropical regions where there is a significant temperature gradient between surface and deep ocean water. This geographical limitation restricts the widespread implementation of OTEC technology.

6. **Energy Transmission:** Transmitting electricity from offshore OTEC plants to the mainland requires undersea cables, which are costly and complex to install and maintain.
7. **Maintenance and Durability:** OTEC systems are subject to the corrosive marine environment, requiring regular maintenance and robust materials to ensure long-term operation. Biofouling and other marine growths can also impair system performance.

Case Studies of OTEC

1. **Natural Energy Laboratory of Hawaii Authority (NELHA), USA:**

- **Location:** Kona, Hawaii
- **Details:** NELHA is one of the most prominent OTEC test sites. It operates a smallscale OTEC plant that provides insights into the technology's feasibility and efficiency.
- **Outcomes:** NELHA has successfully demonstrated the use of OTEC for electricity generation, seawater air conditioning, and desalination. It also serves as a research hub for OTEC technology development and optimization.

2. **Kume Island, Japan:**

- **Location:** Okinawa Prefecture, Japan
- **Details:** Kume Island hosts a small-scale OTEC plant designed to provide electricity and support aquaculture through the use of nutrient-rich deep ocean water.
- **Outcomes:** The project has proven successful in providing renewable energy and promoting local economic development through mariculture and other byproducts. It serves as a model for integrating OTEC technology with local industries.

3. **Martinique OTEC Plant, France:**

- **Location:** Martinique, Caribbean Sea
- **Details:** The French naval defense and energy company, DCNS, planned a 10 MW OTEC plant in Martinique to demonstrate commercial-scale feasibility.
- **Outcomes:** The project aimed to provide sustainable energy and reduce dependence on fossil fuels in the Caribbean region. However, high costs and technical challenges have delayed full-scale implementation.

4. **Nauru OTEC Plant, South Pacific:**

- **Location:** Nauru, Micronesia
- **Details:** Nauru aimed to establish a 100 kW OTEC plant as part of its efforts to transition to renewable energy sources.
- **Outcomes:** The project faced significant funding and technical challenges, highlighting the difficulties small island nations face in adopting OTEC technology despite its potential benefits.

5. **Makai Ocean Engineering, USA:**

- **Location:** Hawaii, USA
- **Details:** Makai operates a pilot-scale OTEC plant, primarily focusing on research and development.

- **Outcomes:** The facility has successfully generated electricity and provided valuable data for scaling up OTEC technology. It continues to be a key site for advancing OTEC research.

GEOTHERMAL ENERGY

Introduction

The Geothermal energy is enormous and last for several millions of years. Hence it is called renewable energy. There is the large amount of heat lying in earth's interior in the form of Volcanoes, geysers and hot springs. This thermal energy contained in the interior of the earth is called geothermal energy. Magma is the molten rock within the earth is pushed up towards the surface where the heat of the magma is being conducted upward through an overlying rock layer. The hot magma near the surface solidifies into igneous rock. The heat of the magma is conducted upward to this igneous rock. Ground water which finds its way down to this rock through cracks is heated by the heat of the rock or by mixing with hot gases and steam coming from magma. The heated water convectively rise upward and into a porous and permeable reservoir above the igneous rock.

Direct usage of Geothermal Energy

- Space heating
- Air conditioning
- Industrial processes
- Drying
- Greenhouses
- Aquaculture
- Hot water
- Resorts and pull
- Melting snow

Working Principle of Geothermal Power Plants

1. Direct sources function by sending water down a well to be heated by the Earth's surface.
2. A heat pump is used to take the heat from the underground water to the substance that heats the house.
3. Cold water is injected back into the Earth.

1. Dry Steam Plants

In this system the conversion device is the steam turbine which uses directly the low pressure, high-volume fluid produced in the steam field. This plant commonly use condensing turbine and the condensate is re-injected in wet cooling towers. It uses steam of 150^0 C.

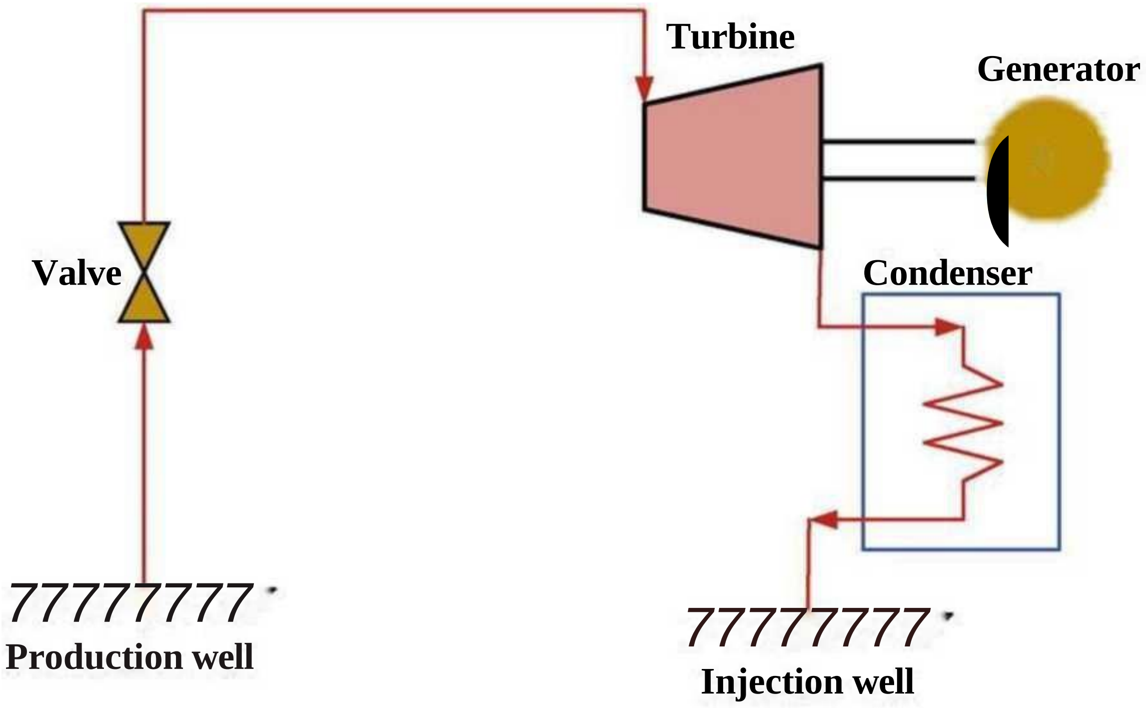


Figure: 1. Dry Steam Plant

2. Flash Plant

This power plant is similar to dry stream plant. The steam is obtained from separation process and then directed to the turbines after that the re-injection takes place at lower pressure. Flash plants vary in size depending on whether they are single, double or triple-flash.

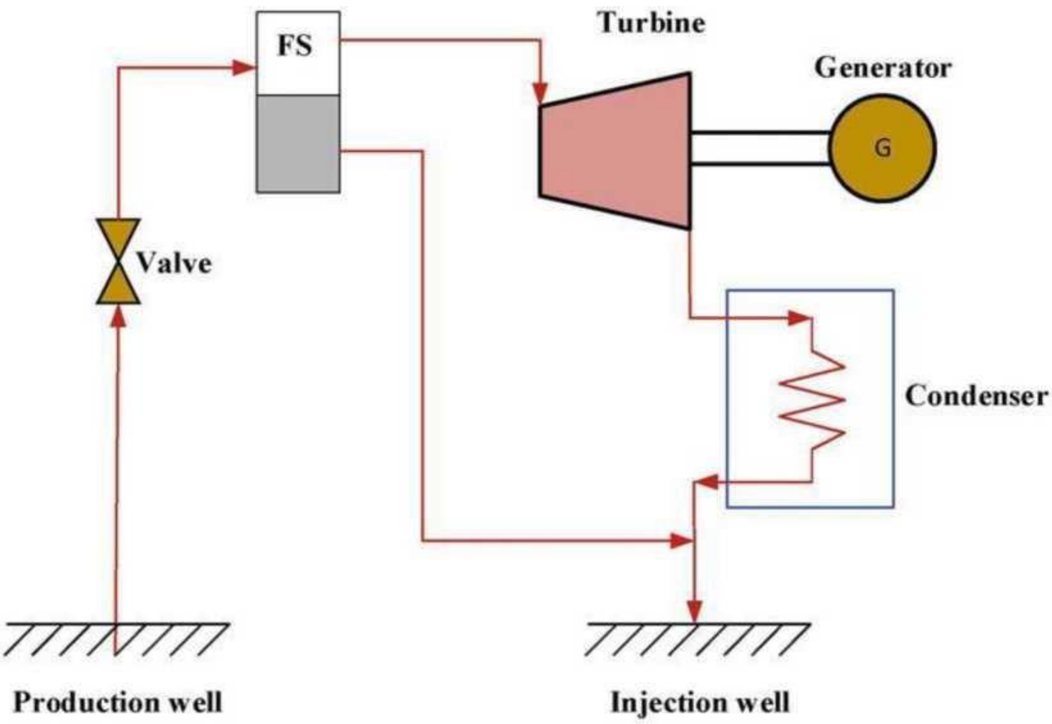


Figure: 2. Flash Steam Plant

3. Binary Plants

It is basically a Rankine cycle with organic working fluid. To transfer a fraction of the brine enthalpy to vaporize the secondary working fluid. These plants are usually applied to low or medium enthalpy geothermal fields where the resource fluid is used, via heat exchanger, to heat a process fluid in a closed loop having boiling and condensation points that match the geothermal resource temperature. Binary plants range in size from less than 1MW to 50MW.

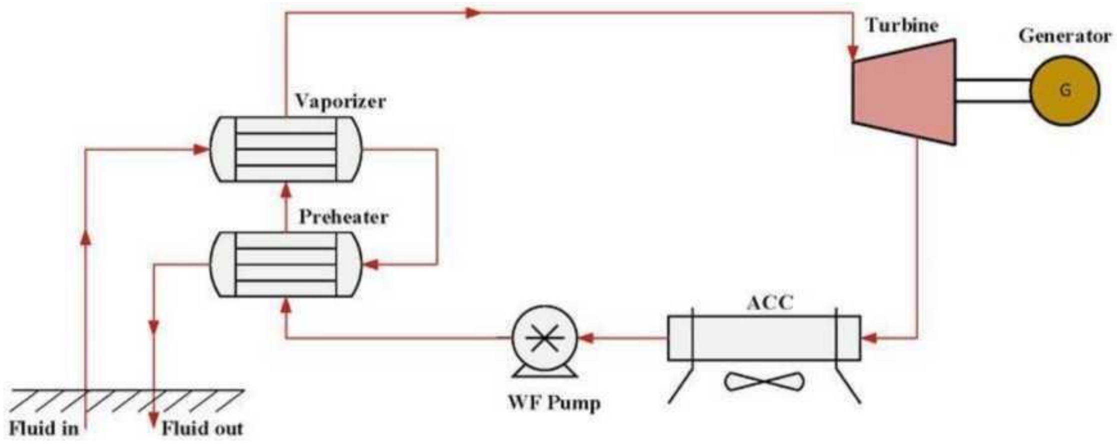


Figure: 3. Binary Plant

4. Combined Cycle or Hybrid Plant

This type of power plants use combined cycle which adds a traditional Rankine cycle to produce electricity from what otherwise would become waste heat from a binary cycle. Using two cycle provides relatively high electric efficiency. fig.(4).The same basics are used by the Hybrid geothermal power plant as a standalone geothermal power plant but combine a different heat source into the process.

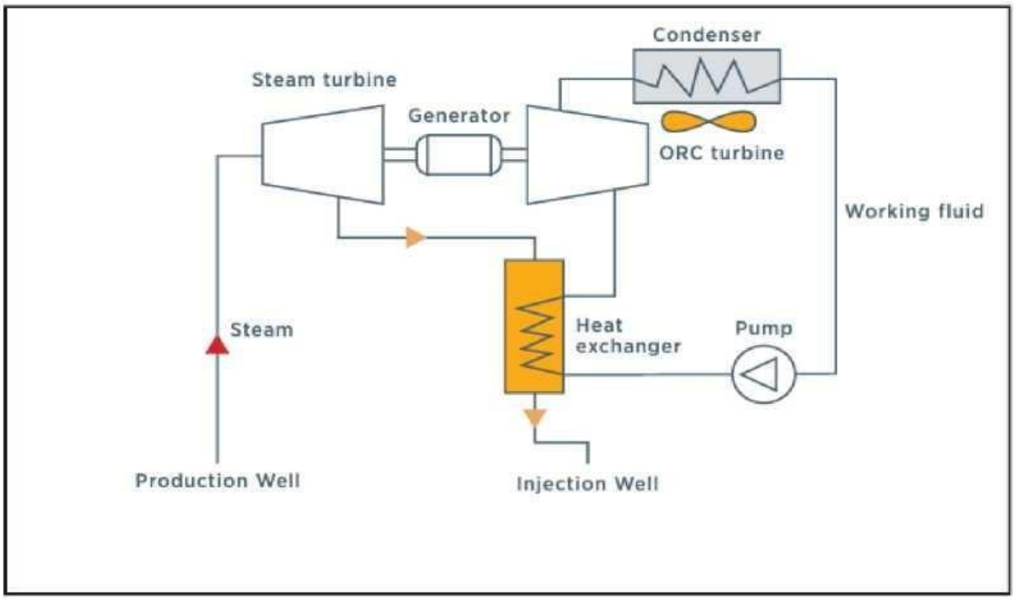


Figure: 4. Combined Cycle Plant

Estimates of Geothermal Power

1. Global Geothermal Power Capacity

- As of recent estimates, the global geothermal power capacity is over 14 gigawatts (GW).
- The leading countries in geothermal power production are the United States, Indonesia, the Philippines, Turkey, and New Zealand.
- The potential for geothermal energy is vast, with estimates suggesting that it could provide up to 200 GW of power worldwide if fully developed.

2. Geothermal Power in India

- India's geothermal power potential is estimated to be around 10,000 megawatts (MW).
- Key geothermal sites in India include the Puga Valley in Jammu and Kashmir, Tattapani in Chhattisgarh, and Manikaran in Himachal Pradesh.
- India is still in the early stages of developing its geothermal resources, with pilot projects and exploration activities ongoing.

Nature of Geothermal Fields

Geothermal fields are areas where the Earth's heat is concentrated and can be accessed for various uses. The nature of these fields depends on several factors:

1. **Geological Setting**: Geothermal fields are often found in regions with volcanic activity, tectonic plate boundaries, or where there are significant heat flow anomalies. Common locations include volcanic arcs, rift zones, and areas with significant crustal stretching or faulting.
2. **Temperature Gradient**: The geothermal gradient, which is the rate at which temperature increases with depth, is higher in geothermal fields compared to normal geothermal gradients. This means the temperature increases more rapidly with depth in these fields.
3. **Heat Source**: The primary sources of heat in geothermal fields are magmatic activity (magma chambers), radioactive decay of minerals, and residual heat from the Earth's formation.

Geothermal Resources

Geothermal resources refer to the heat energy stored beneath the Earth's surface that can be extracted for various uses. They are typically categorized based on their temperature and type:

1. **Hydrothermal Resources**: These are the most commonly exploited geothermal resources and consist of hot water and steam found in permeable rock formations. They can be further classified into high-temperature and low-temperature resources.

2. **Geopressured Resources**: These are geothermal resources found at significant depths and under high pressure. They are often associated with natural gas deposits, which can be co-produced with geothermal energy.
3. **Hot Dry Rock (HDR) Resources**: Also known as Enhanced Geothermal Systems (EGS), these resources are found in dry rock formations with high heat content but low natural permeability. They require artificial stimulation, such as hydraulic fracturing, to create a reservoir of hot water or steam.
4. **Magma Resources**: These involve accessing the Earth's magma directly. They are highly experimental and not yet commercially viable due to the extreme conditions and technical challenges.

Hydrothermal Resources

Hydrothermal resources are characterized by the presence of hot water or steam in permeable rock formations. They can be categorized into:

1. **High-Temperature Hydrothermal Resources**:
   - **Characteristics**: Temperatures typically exceed 150°C (302°F). These resources are associated with active volcanic regions and are often used for electricity generation.
   - **Examples**: The Geysers in California, USA; the Krafla Geothermal Field in Iceland.
   - **Usage**: Primarily used for generating electricity via steam turbines.
2. **Low-Temperature Hydrothermal Resources**:
   - **Characteristics**: Temperatures are below 150°C (302°F). These resources are often found in less geologically active areas and are used for direct use applications.
   - **Examples**: The geothermal hot springs in New Zealand; the hot springs used for bathing in Japan.
   - **Usage**: Used for district heating, greenhouse heating, and industrial processes.

Geopressured Resources

Geopressured resources are found at great depths where the pressure is high due to the weight of overlying rock. These resources often contain:

- **Characteristics**: High-pressure conditions and high temperatures. They may also contain significant amounts of natural gas dissolved in the geothermal fluids.
- **Usage**: The natural gas co-produced with geothermal energy can be used as an additional energy source, enhancing the economic viability of geothermal projects.
- **Examples**: The Gulf Coast of the United States is known for its geopressured

geothermal resources.

Hot Dry Rock (HDR) Resources

Hot Dry Rock (HDR) or Enhanced Geothermal Systems (EGS) are geothermal resources where the rock is hot but lacks sufficient natural permeability to allow for efficient fluid flow. To make these resources usable, several techniques are employed:

1. **Characteristics**: High-temperature rock (above 150°C or 302°F) with low natural permeability.
2. **Techniques**:
    - **Hydraulic Fracturing**: Creating artificial fractures in the rock to enhance fluid flow.
    - **Hydrothermal Stimulation**: Injecting water into the rock to create or enhance a geothermal reservoir.
3. **Examples**: Experimental projects in the United States and Europe, such as the Enhanced Geothermal Systems (EGS) projects in the Desert Peak and Soultz-sous- Forets fields.
4. **Usage**: Potential for both electricity generation and direct use applications, though commercial viability is still developing.

Magma Resources

Magma resources involve tapping into molten rock or magma chambers directly. These are highly experimental and face significant technical and safety challenges:

- **Characteristics**: Extremely high temperatures (above 700°C or 1292°F) and highly corrosive environments.
- **Challenges**: Drilling into magma requires overcoming extreme heat and pressure conditions, which poses significant technical difficulties.
- **Research**: Some experimental projects are being conducted in areas like Iceland, where magma chambers are relatively accessible due to active volcanic systems.

Interconnection of Geothermal and Fossil Systems

Geothermal and fossil energy systems can be interconnected in several ways:

- **Hybrid Systems**: Combining geothermal energy with fossil fuel-based power plants to enhance reliability and efficiency. For instance, a geothermal power plant can provide base-load power, while a fossil fuel plant can be used for peak-load or backup power.
- **Co-production**: In some geothermal fields, natural gas or oil is co-produced with geothermal fluids. This co-production can enhance the economic feasibility of geothermal projects.

- **Geothermal Enhancement**: In some cases, geothermal energy can be used to enhance oil recovery by providing additional heat to increase the flow of crude oil in reservoirs.

Advantages and Disadvantages of Geothermal Energy

Advantages:

1. **Renewable and Sustainable**: Geothermal energy is derived from the Earth's internal heat, which is continuously replenished by natural processes. This makes it a sustainable and reliable source of energy over the long term.
2. **Low Greenhouse Gas Emissions**: Geothermal power plants produce minimal greenhouse gases compared to fossil fuel-based plants. They have a significantly lower carbon footprint, contributing to the reduction of climate change.
3. **Base Load Power**: Unlike solar and wind energy, which are intermittent, geothermal energy can provide a constant and reliable supply of power, making it suitable for base load electricity generation.
4. **Low Operating Costs**: Once a geothermal power plant is established, its operating and maintenance costs are relatively low compared to fossil fuel plants, as the fuel (heat from the Earth) is free.
5. **Minimal Land Footprint**: Geothermal power plants have a smaller land footprint compared to large solar or wind farms. This makes them suitable for locations with limited available land.
6. **Direct Use Applications**: Geothermal energy can be used directly for heating applications, such as district heating, greenhouse heating, and industrial processes, without needing to convert it to electricity.

Disadvantages:

1. **High Initial Costs**: The development of geothermal power plants involves significant upfront investment for exploration, drilling, and plant construction. This can be a barrier to entry.
2. **Site Specific**: Geothermal resources are geographically specific. Not all locations have accessible and economically viable geothermal resources, limiting their applicability.
3. **Environmental and Structural Risks**: Geothermal energy extraction can lead to land subsidence, induced seismicity (earthquakes), and the release of trace gases from the geothermal reservoirs. These risks need to be carefully managed.
4. **Resource Depletion**: If not managed properly, geothermal resources can become depleted or experience a decrease in productivity over time. Sustainable management practices are required to prevent this.
5. **Limited to Certain Areas**: Effective geothermal energy production is often limited to regions with high geothermal activity, such as volcanic areas or tectonic plate boundaries, which may not be accessible or feasible in many regions.

Geothermal Stations around the World

1. The Geysers, California, USA:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 1.5 GW.
- **Details**: One of the largest geothermal power complexes in the world. It has been in operation since the 1960s and remains a significant source of renewable energy in the United States.

2. Hellisheidi Geothermal Power Station, Iceland:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 303 MW of electricity and 133 MW of thermal energy.
- **Details**: Located near Reykjavik, it is one of the largest geothermal power plants in Iceland, providing both electricity and district heating.

3. Krafla Geothermal Power Station, Iceland:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 60 MW.
- **Details**: Located in the Krafla volcanic area, it is part of a larger geothermal development project that includes multiple power plants and direct use applications.

4. Larderello Geothermal Complex, Italy:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 770 MW.
- **Details**: One of the oldest geothermal power plants in the world, with a history dating back to the early 20th century. It is located in Tuscany and remains a key player in Italy's renewable energy sector.

5. Cerro Prieto Geothermal Power Station, Mexico:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 1 GW.
- **Details**: One of the largest geothermal power plants in the world, located in the Mexicali Valley. It plays a crucial role in Mexico's renewable energy strategy.

6. Wairakei Power Station, New Zealand:

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 160 MW.

- **Details**: The first major geothermal power plant in New Zealand, it has been in operation since the 1950s and is part of a broader geothermal energy development in the Taupo Volcanic Zone.

7. **Soultz-sous-Forets, France:**

- **Type**: Enhanced Geothermal System (EGS).
- **Capacity**: Approximately 1.5 MW (experimental).
- **Details**: One of the pioneering EGS projects in Europe, focusing on developing techniques for extracting heat from deep, hot dry rock formations.

8. **Olkaria Geothermal Power Station, Kenya:**

- **Type**: High-temperature hydrothermal.
- **Capacity**: Approximately 380 MW.
- **Details**: Located in the Rift Valley, it is one of the largest geothermal projects in Africa and plays a significant role in Kenya's renewable energy landscape.