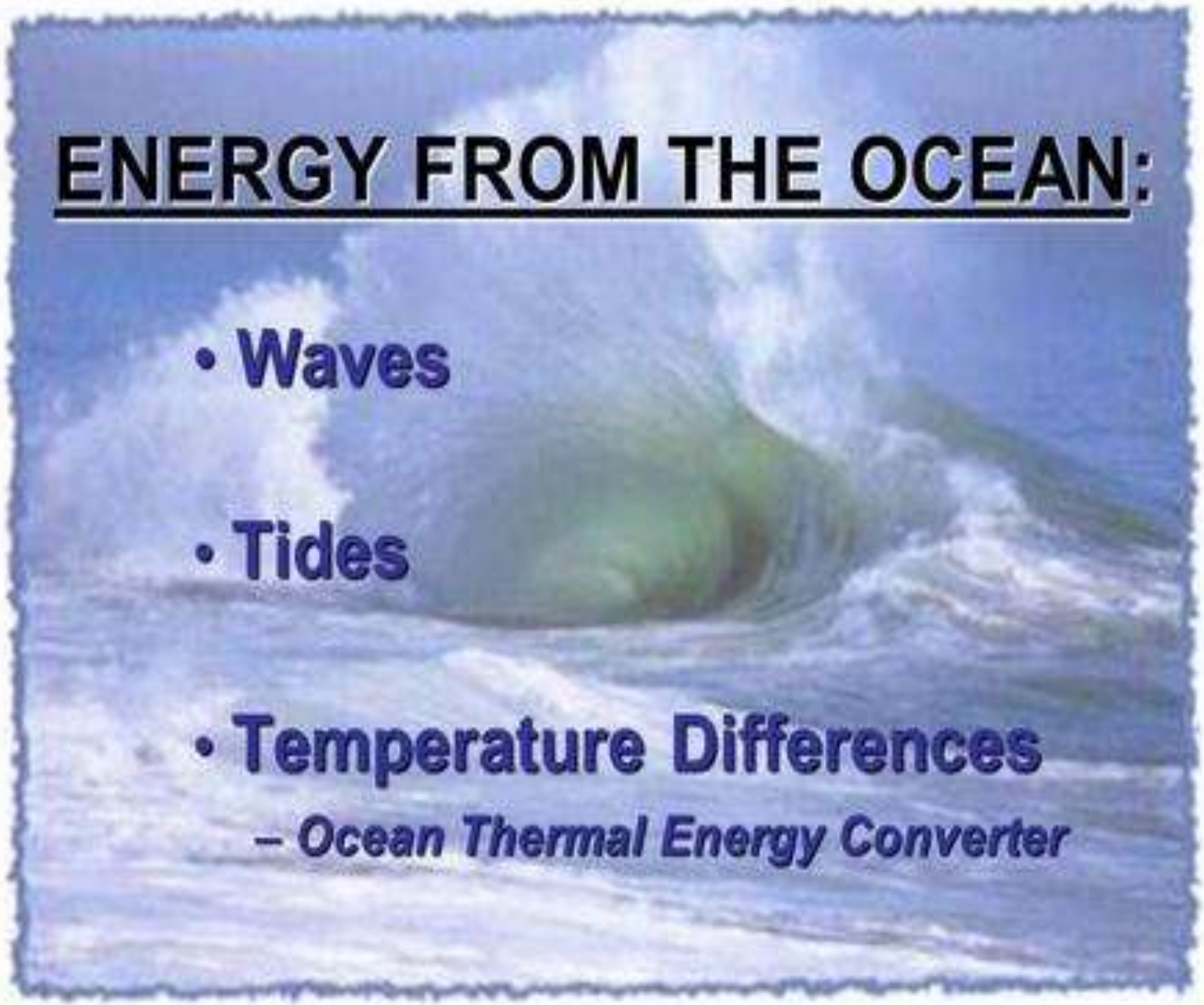
OCEAN ENERGY

- Oceans cover more than 70% of Earth's surface, making them the world's largest solar collectors.
- Ocean energy draws on the energy of ocean waves, tides, or on the thermal energy (heat) stored in the ocean

Introduction

- Ocean waves are both clean and renewable sources of energy with a tremendous worldwide potential of generating electricity.
- If fully exploited, about 40% of the world's power demand could be supplied by this resource – equivalent to as much as 800 nuclear power plants.


ENERGY FROM THE OCEAN:
• Waves
• Tides
• Temperature Differences
– Ocean Thermal Energy Converter

Energy from the Oceans

- **Hydro power** – solar heating evaporates water from the surface of the oceans, form clouds, condenses as rain, falls over land, causes rivers to flows to feed dams that generate electricity
- **Wave energy** – winds generate large ocean waves that can be used to generate power from its potential and kinetic energy.
- **Ocean temperature energy conversion (OTEC)** – temperature gradient between the surface and bottom of the ocean can be utilized in a heat engine to generate power
- **Tidal energy** – caused by lunar and solar gravitational forces acting together with that from the earth on the ocean waters to create tidal flows manifested by the rise and fall of waters that vary daily and seasonally from a few centimeters up to 8-10 meters in some parts of the world. The potential energy of the tides is tapped to generate power.

OCEAN THERMAL ENERGY

- Thermal energy from Sun's heat and mechanical energy from tides and waves
- Largest solar collectors (covers more than 70% of earth surface)
- Warms the surface but not into deep ocean water
- Temperature difference around 20 degree celcius can generate energy
- 1000m depth

INTRODUCTION

- Ocean Thermal Energy Conversion (OTEC) is a technology for generating renewable energy that uses the temperature difference between the deep cold and relatively warmer surface waters of the ocean to generate baseload electricity.
- Since OTEC exploits renewable solar energy, recurring costs to generate electrical power are minimal.
- The high fixed costs dominate the economics of OTEC to the extent that it currently cannot compete with conventional power systems.

Introduction

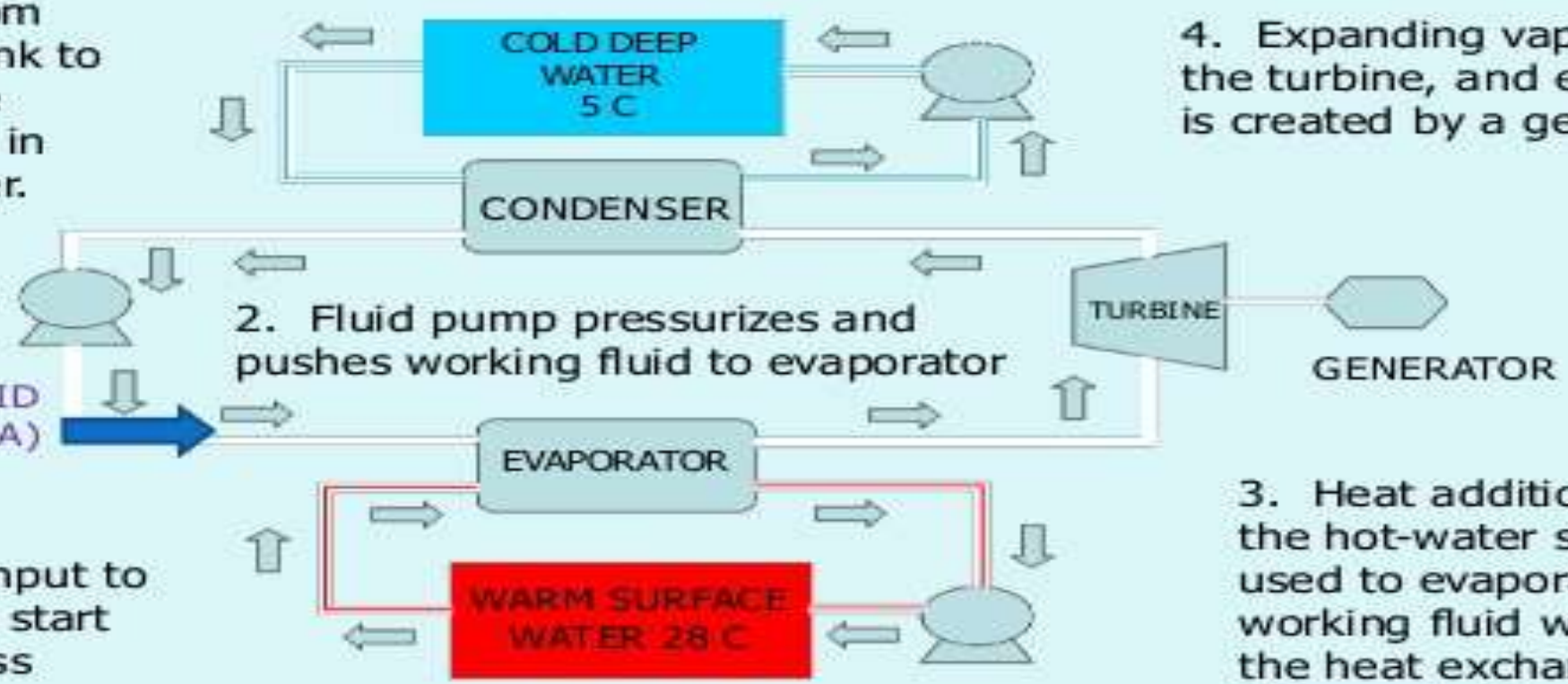
- Ocean Thermal Energy Conversion (OTEC) is a process which utilizes the heat energy stored in the tropical ocean.
- OTEC utilizes the difference in temperature between warm surface seawater and cold deep seawater to produce electricity.
- Because the oceans are continually heated by the sun and cover nearly 70% of the Earth's surface, this temperature difference contains a vast amount of solar energy which could potentially be tapped for human use.

BASIC PRINCIPAL

- ✓ OTEC is Manifestation of solar energy
- ✓Top layers of ocean receive solar heating
- ✓Bottom layers receive water from polar regions
- ✓OTEC Uses the vertical temperature gradient in the ocean as a heat sink/source
- ✓OTEC system is based on the Rankine Cycle

OTEC PROCESS

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



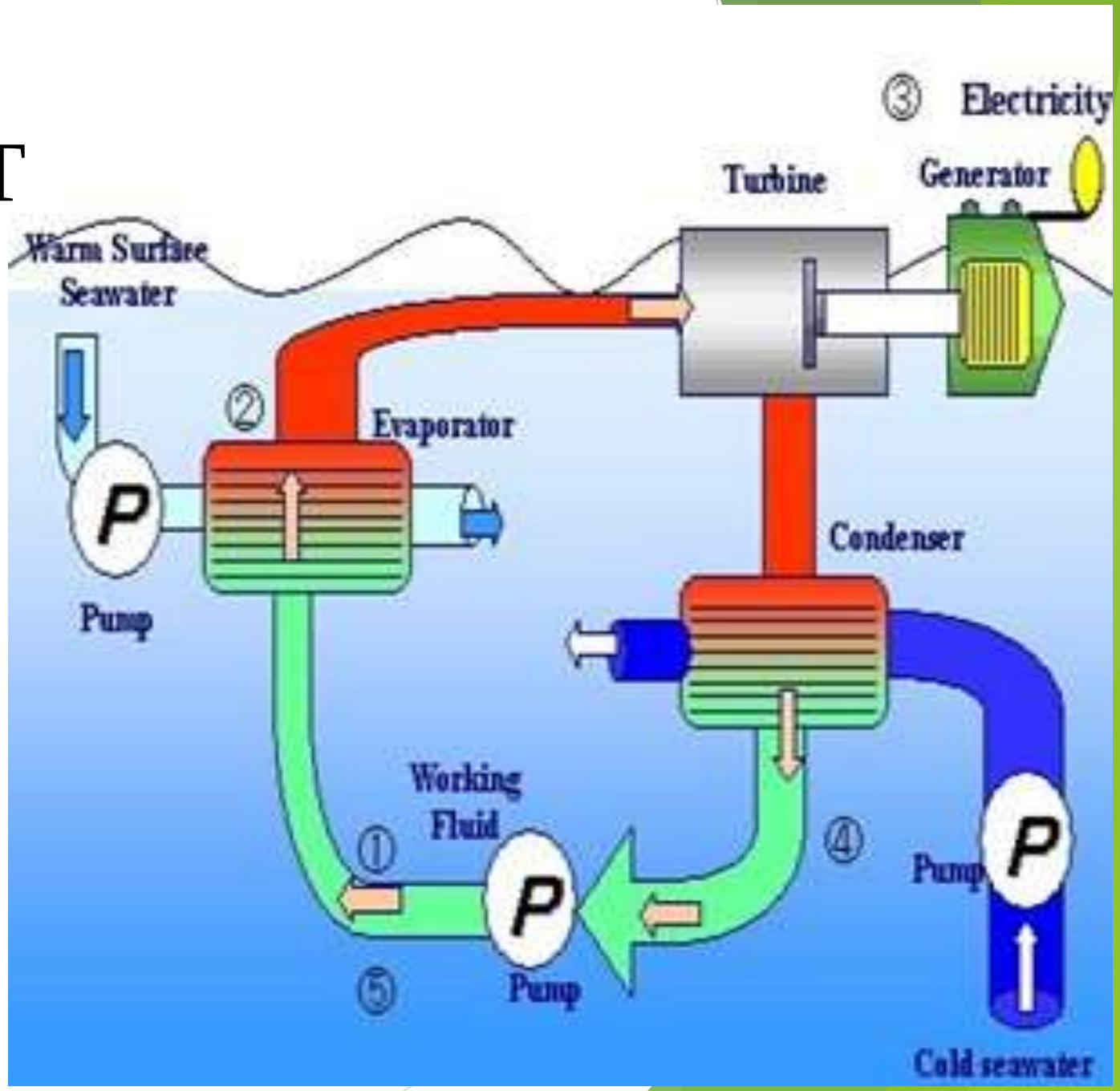
4. Expanding vapor drive the turbine, and electricity is created by a generator

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 COMPONENT

- Evaporators
- Condensers
- Turbines
- Working fluid
- Cold-water pipe



How OTEC Works

- The warm surface ocean water is pumped to the evaporator, which transfers heat to the working fluid
- Working fluid is turning into a high-pressure vapor.
- The turbine generator spins as the vapor rushes through it.
- In the low-pressure condenser, the vapor is cooled by the nearly freezing water brought up from the ocean depths.
- After condensing, the working fluid is sent back to the boiler to be reused and to repeat the cycle.

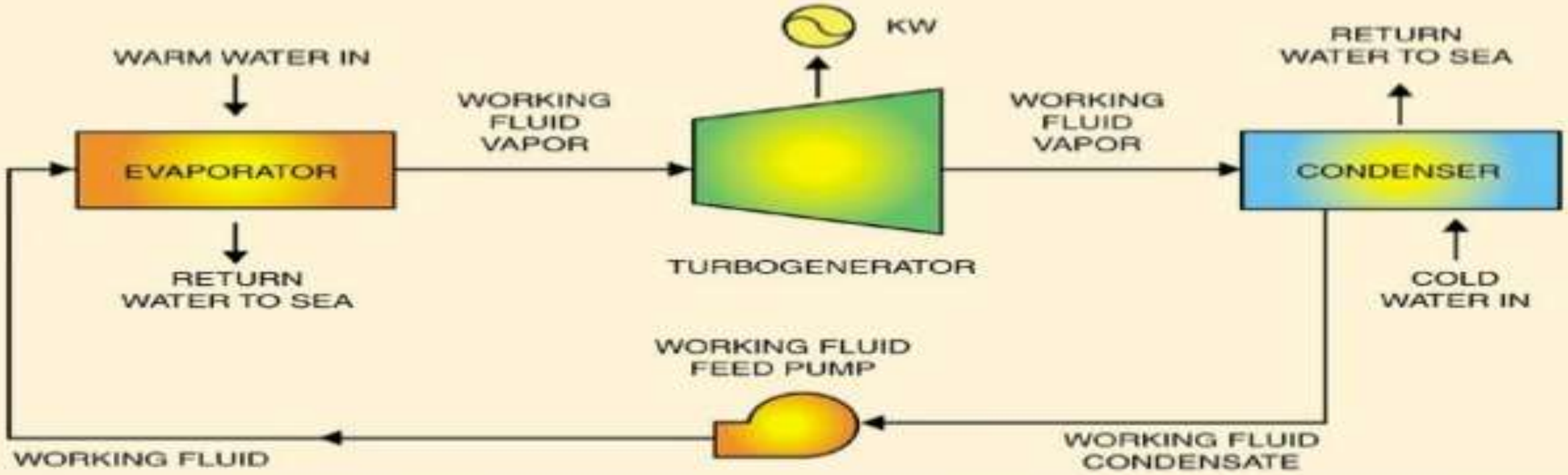
ELECTRICITY PRODUCTION

3 basic OTEC system designs have been demonstrated to generate electricity:

Closed cycle
Open cycle
Hybrid Cycle

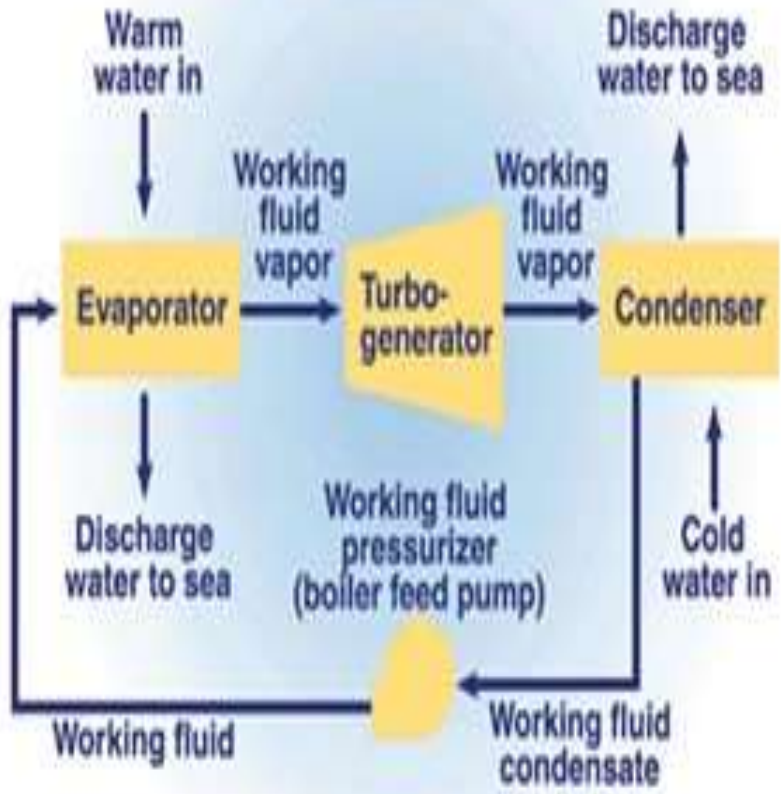
Closed-loop OTEC

- Closed cycle system use fluid with a low boiling point, such as ammonia to power a turbine to generate electricity.



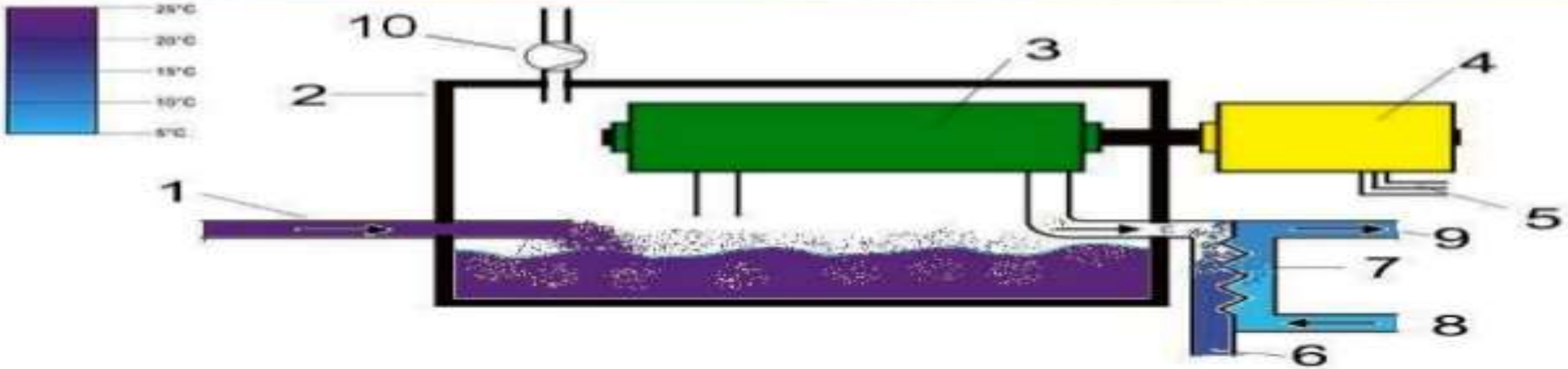
CLOSED CYCLED

- In the closed-cycle OTEC system, warm seawater vaporizes a working fluid, such as ammonia, flowing through a heat exchanger (evaporator).
- The vapor expands at moderate pressures and turns a turbine coupled to a generator that produces electricity.
- The vapor is then condensed in condenser using cold seawater pumped from the ocean's depths through a cold-water pipe.
- The condensed working fluid is pumped back to the evaporator to repeat the cycle.
- The working fluid remains in a closed system and circulates continuously



Open-loop OTEC cycle

- Georges Claude Constructed first OTEC plant in 1929 in Cuba.
- The Claude Plant used an open cycle in which seawater itself plays the multiple role of heat source, working fluid, coolant, & heat sink.

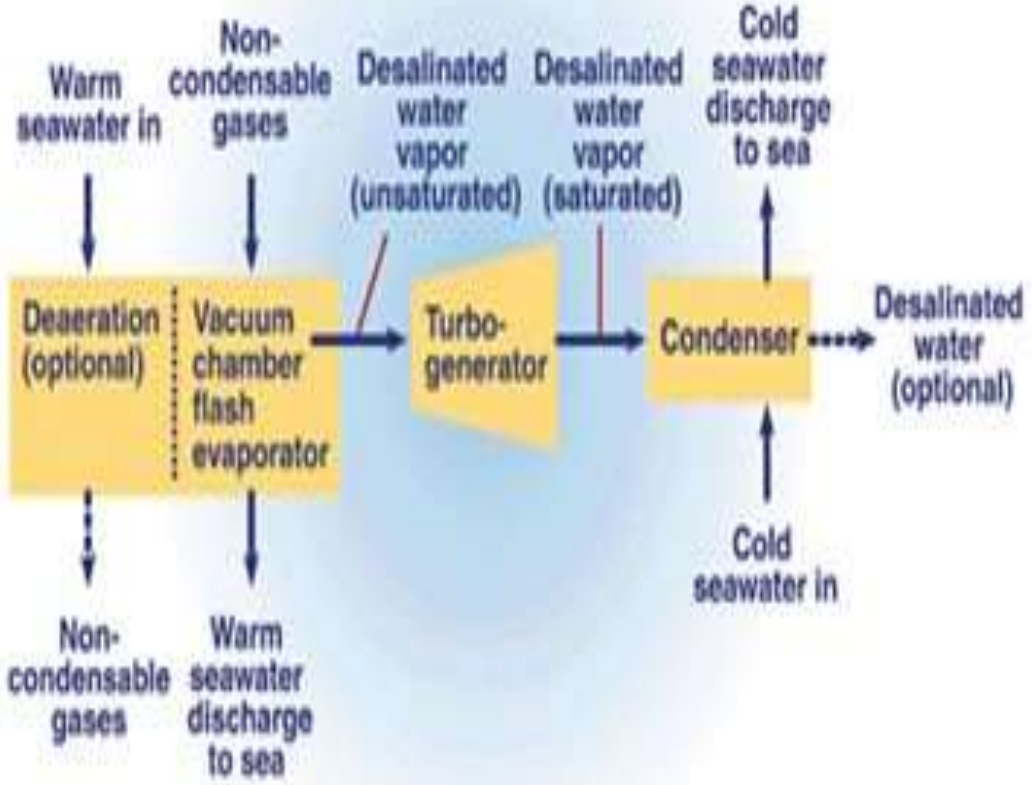


1 Surface water ~ 25°C
2 Vacuum chamber, 3 % to 1 % of atmospheric pressure
3 Turbine
4 Generator
5 Line to the grid

6 Desalinated water ~ 23°C
7 Condenser
8 Deep water ~ 5°C
9 Waste water ~ 7°C
10 Vacuum pump

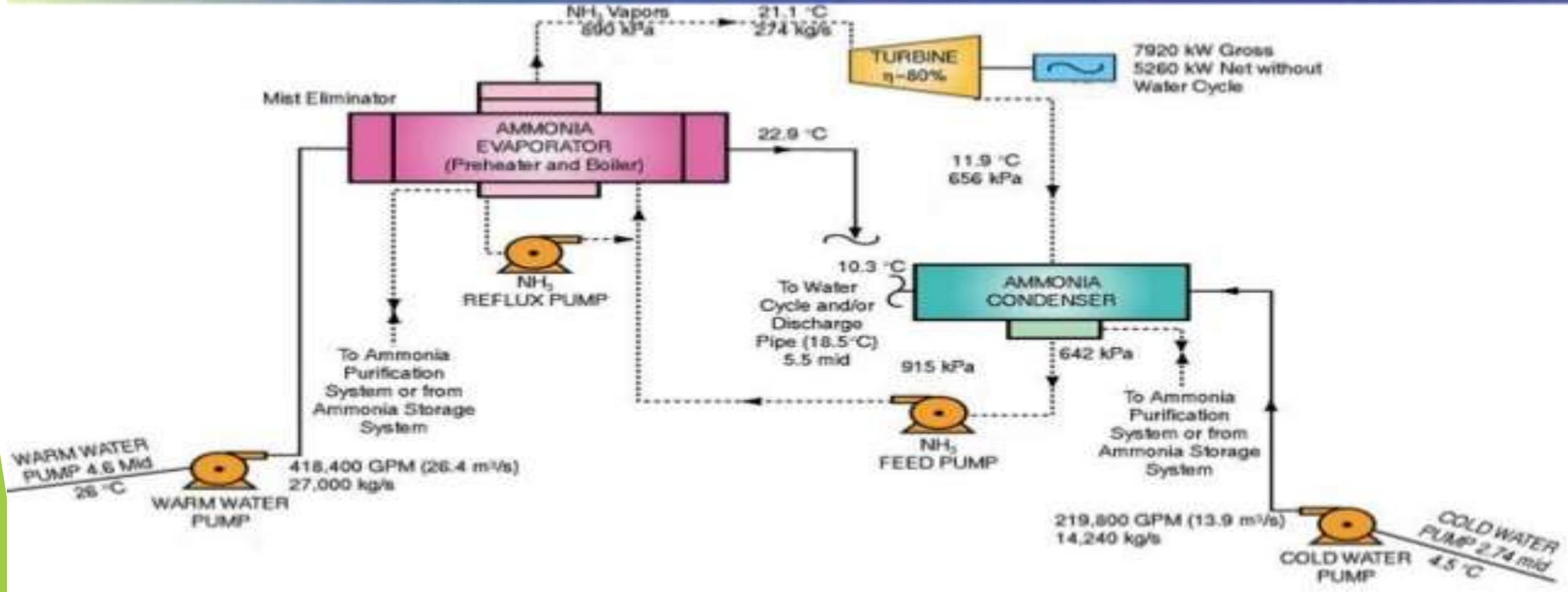
OPEN CYCLE

- In an open-cycle OTEC system, warm seawater is the working fluid.
- The warm seawater is "flash"-evaporated in a vacuum chamber to produce steam at an absolute pressure of about 2.4 kilopascals (kPa).
- The steam expands through a low-pressure turbine that is coupled to a generator to produce electricity.
- The steam exiting the turbine is condensed by cold seawater pumped from the ocean's depths through a cold-water pipe.
- If a surface condenser is used in the system, the condensed steam remains separated from the cold seawater and provides a supply of desalinated water.



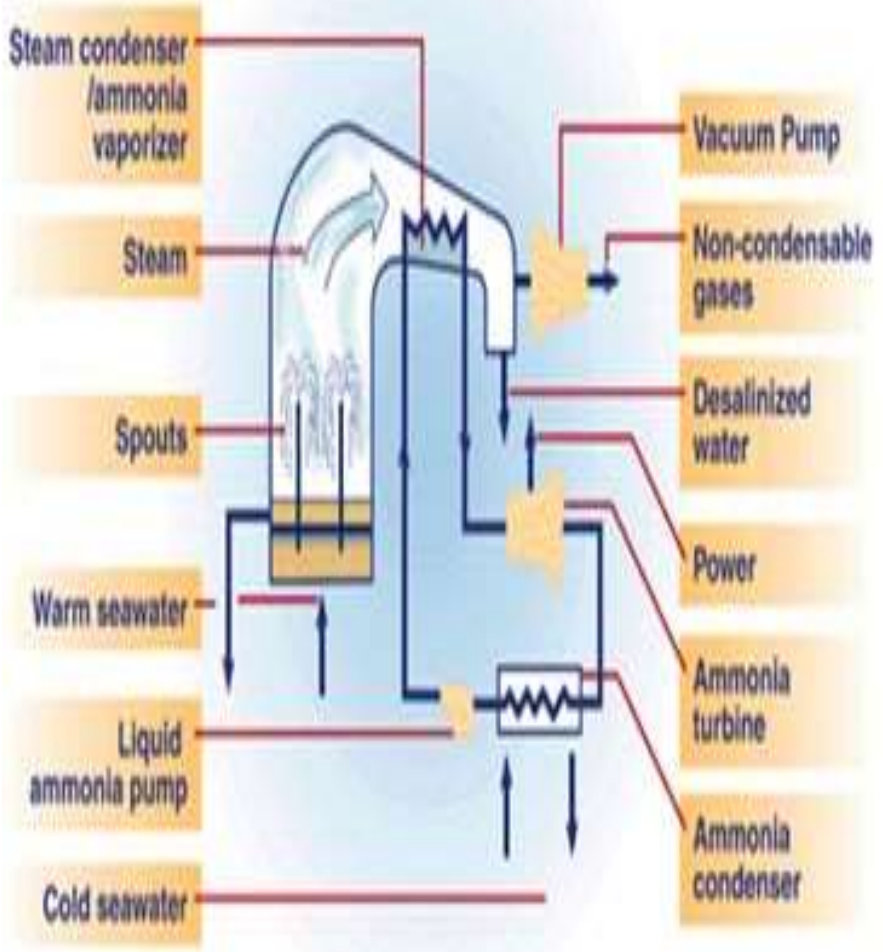
Hybrid OTEC cycle

- A Hybrid cycle combines the features of both the closed & Open Cycle System.



HYBRID CYCLE

- A hybrid cycle combines the features of both the closed-cycle and open-cycle systems.
- In a hybrid OTEC system, warm seawater enters a vacuum chamber where it is flash-evaporated into steam, which is similar to the open-cycle evaporation process.
- The steam vaporizes the working fluid of a closed-cycle loop on the other side of an ammonia vaporizer.
- The vaporized fluid then drives a turbine that produces electricity.
- The steam condenses within the heat exchanger and provides desalinated water.

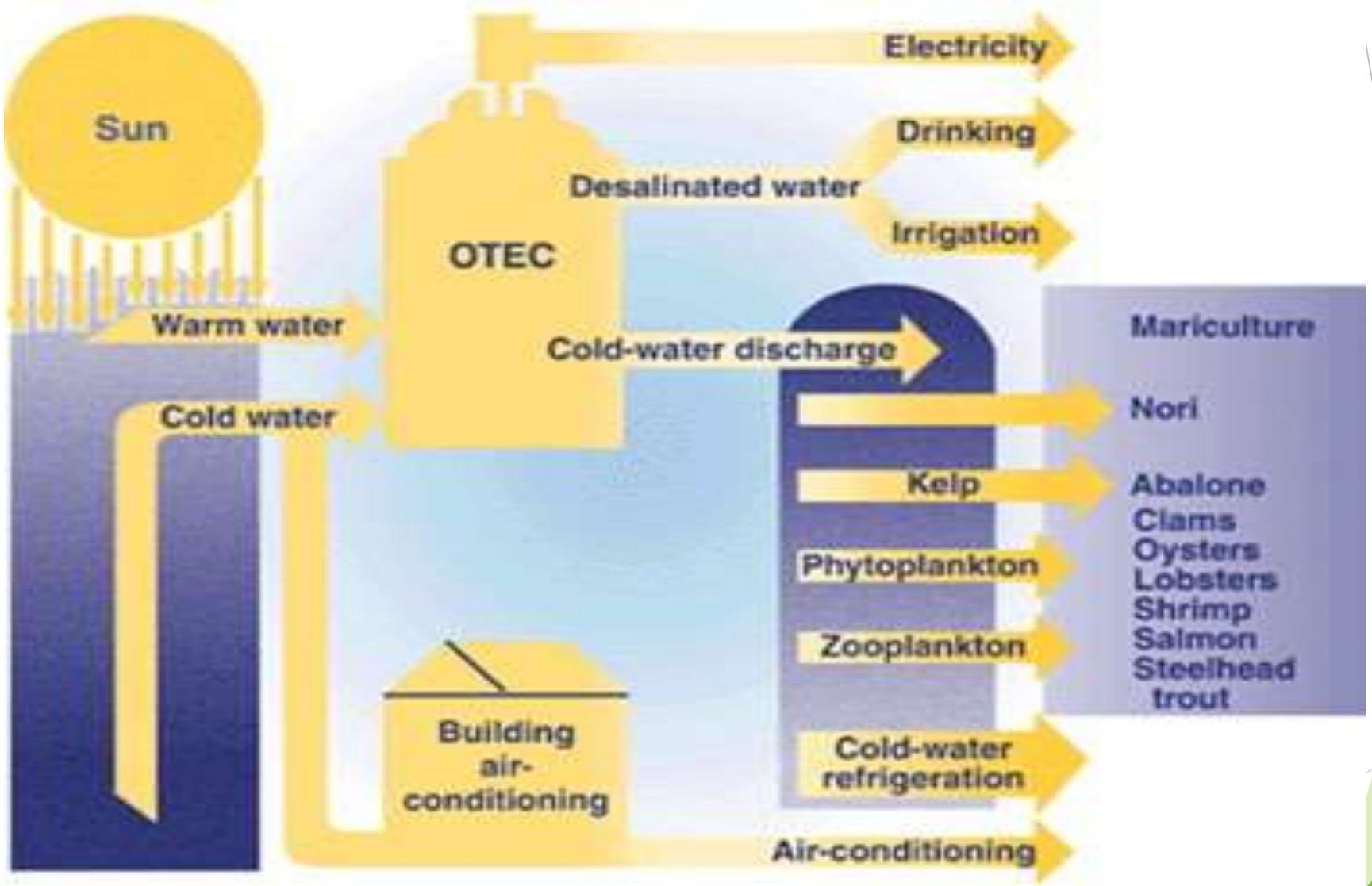


Site Consideration Factors to be considered while choosing a site:

- 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

OTEC APPLICATION

- ✓ Ocean thermal energy conversion (OTEC) systems have many applications or uses.
- ✓ OTEC can be used to :
- generate electricity,
- desalinate water,
- support deep-water mariculture,
- provide refrigeration and air-conditioning
- mineral extraction.
- ✓ These complementary products make OTEC systems attractive to industry and island communities even if the price of oil remains low
- ✓ OTEC can also be used to produce methanol, ammonia, hydrogen, aluminum, chlorine, and other chemicals.


Sun
Electricity
Drinking
Desalinated water
Irrigation
OTEC
Warm water
Cold-water discharge
Mariculture
Cold water
Nori
Kelp
Abalone
Clams
Oysters
Lobsters
Shrimp
Salmon
Steelhead
trout
Phytoplankton
Zooplankton
Building
air-
conditioning
Cold-water
refrigeration
Air-conditioning

Deep-Water-Supported Mariculture

- Deep-drawn seawater from an OTEC plant is cold, rich in nutrients, relatively free of pathogens, and available in large quantity.
- It is an excellent medium for growing phytoplankton and microalgae, which in turn support a variety of commercially valuable fish and shellfish.
- The large, constant flow of water pumped from an OTEC plant will reduce disease and contamination in the ponds; marine life, therefore, can be grown in high densities.
- In addition, deep-drawn cold water can be mixed with warm surface water, allowing local communities to culture a broad variety of species.

Desalinated Water

- Desalinated water can be produced in open- or hybrid-cycle plants using surface condensers.
- In a surface condenser, the spent steam is condensed by indirect contact with the cold seawater.
- This condensate is relatively free of impurities and can be collected and sold to local communities where natural freshwater supplies for agriculture or drinking are limited.

Refrigeration and Air-Conditioning

- The cold [5°C (41ºF)] seawater made available by an OTEC system creates an opportunity to provide large amounts of cooling to operations that are related to or close to the plant.
- The cold seawater delivered to an OTEC plant can be used in chilled-water coils to provide air-conditioning for buildings.

BENEFIT OF OTEC

- No fuel burned , carbon di oxide emission - less than 1% of fossil fuel plant : has significant potential to provide clean, cost-effective electricity for the future
- Nutrient rich cold water promotes mariculture
- Produces desalinated water for industrial, agricultural, and residential uses.
- Cold water for air conditioning
- Fishing - Cold water, drawn from the depths, is nutrient-rich and can significantly increase fishing yields
- Fresh water production (1 MW plant -> 4500 m3)

DISADVANTAGE

1. An OTEC facility requires a substantial initial capital outlay
2. OTEC has not been demonstrated at full scale over a prolonged period with integrated power, mariculture, fresh-water, and chill-water production.
3. OTEC is only feasible at relatively isolated sites (deep tropical oceans); from such sites, the power and marine products must be transported to market.
4. OTEC is ecologically controversial--at least untested--in large scale and over a long period.

Disadvantages of OTEC

- OTEC produced electricity at present would cost more than electricity generated from fossils fuels at their current costs.
- No energy company put money in this project because it only had been tested in a very small scale.
- Construction of OTEC plants and lying of pipes in coastal waters may cause localized damage to reefs and near-shore marine ecosystem.

Market of OTEC

Ocean thermal energy conversion (OTEC) plants may be competitive :

1. In the small island with the relatively high cost of diesel-generated electricity and desalinated water
2. For floating, closed-cycle plants rated at 40 MWe or larger that house a factory or transmit electricity to shore via a submarine power cable.

CONCLUSSION

1. OTEC uses the difference in temperature between warm surface seawater and cold deep seawater to produce electricity.
2. With Ocean cover 70% of earth’s surface that’s absorb sunlight, OTEC is a prospective alternative source of energy for human use.
3. Beside can be used to generate electricity, OTEC can also be used to desalinate water, support deep-water mariculture, provide refrigeration and air-conditioning and mineral extraction.
4. The capital cost of installation is still extremely high and at the present time the technology remains at the planning/feasibility study stage.