OCEAN THERMAL ENERGY CONVERSION

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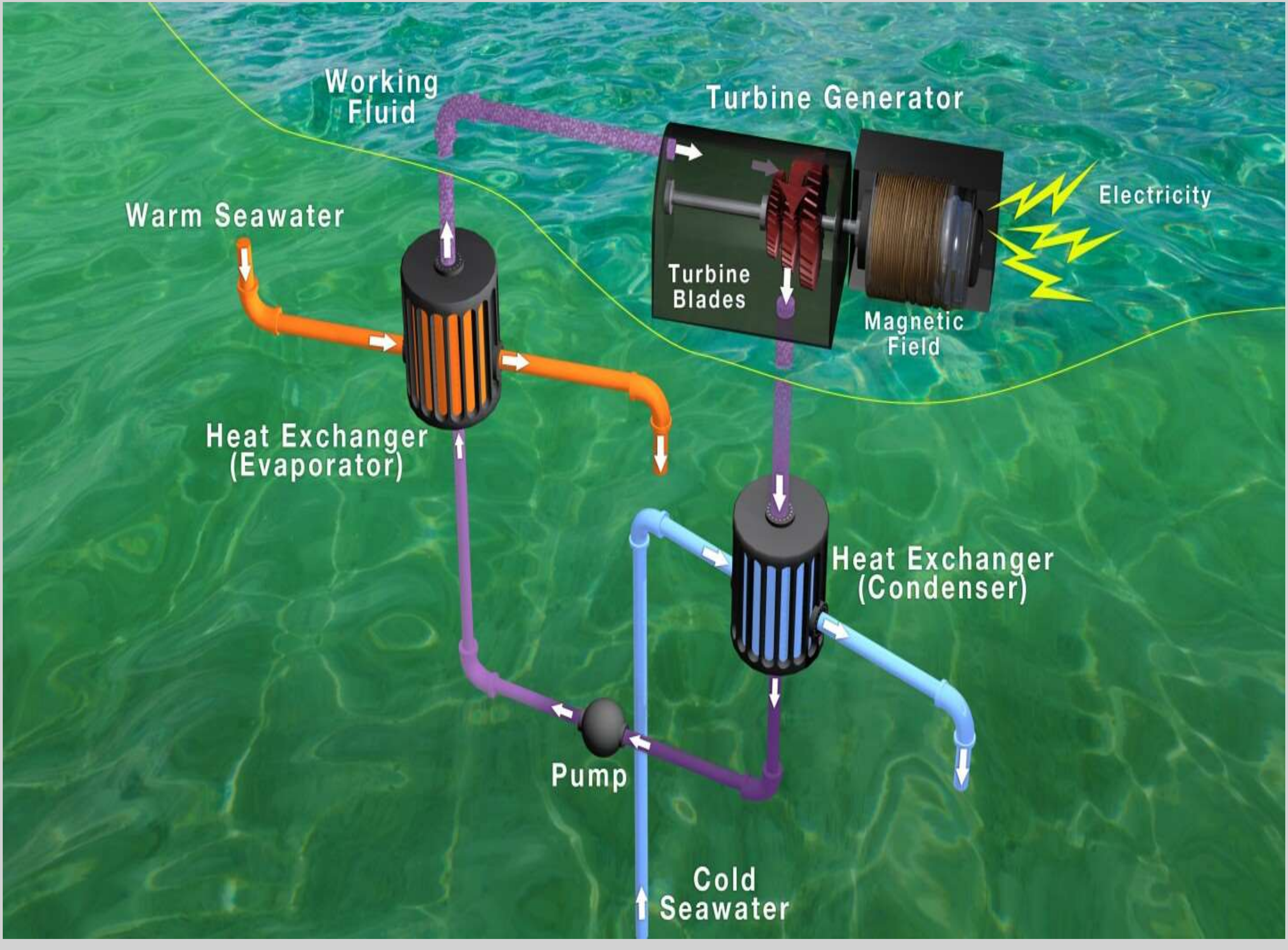
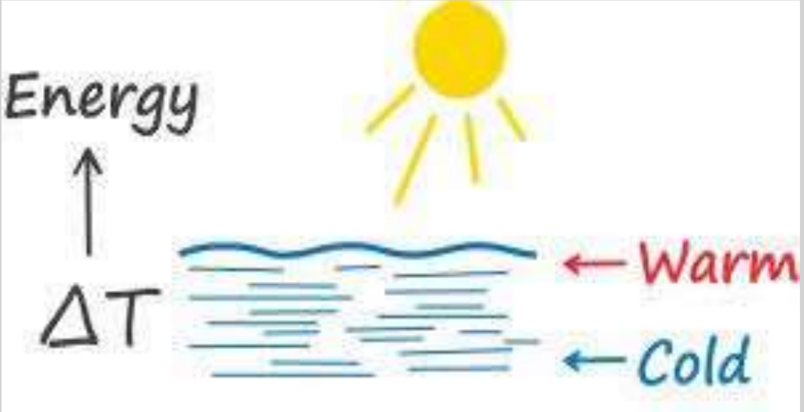

Working Fluid
Turbine Generator
Electricity
Warm Seawater
Turbine Blades
Magnetic Field
Heat Exchanger (Evaporator)
Heat Exchanger (Condenser)
Pump
Cold Seawater

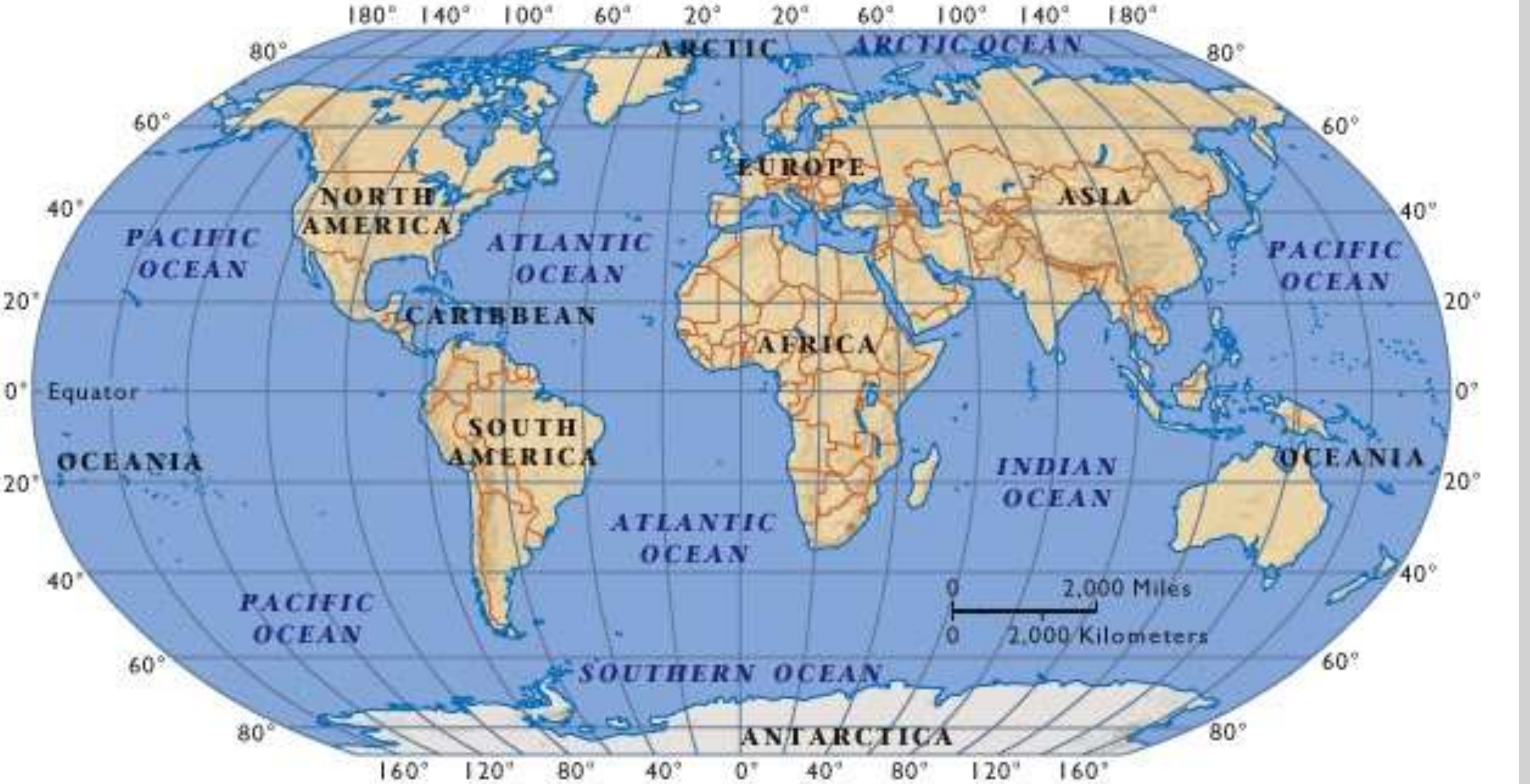
INTRODUCTION

- Ocean Thermal Energy Conversion (OTEC) is an energy technology that converts solar energy stored in oceans into electric power.
- OTEC system uses the ocean's natural thermal gradient — the high temperature at the surface and the low temperature at the depth — to drive a power producing cycle.



- As long as the temperature difference between the warm surface water and the cold deep water is about 20°C, an OTEC system can produce a significant amount of power with little impact on the surrounding environment.
- The distinctive feature of OTEC systems is that the end products include not only energy in the form of electricity, but also several other synergistic products.

- On an average day, 60 million square kilometers of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil, while 85 million barrels a day is used all over the world, that is, 3000 times less than this absorbed energy.
- The solar energy that irradiates the earth surface annually is said to be 83.6 trillion kilowatts.
- Since two-thirds of the earth surface is covered by ocean, 55.1 trillion kilowatts of solar energy strike the ocean surface.
- If OTEC could use just 2% of this energy, one trillion kilowatts of electricity could be produced.
- This figure is slightly on higher side, because there are many places in the ocean where the temperature difference of seawater is negligible, which would considerably reduce the actual figure.


180° 140° 100° 60° 20° 20° 60° 100° 140° 180°
80°
ARCTIC
ARCTIC OCEAN
60°
EUROPE
NORTH AMERICA
ASIA
40°
PACIFIC OCEAN
ATLANTIC OCEAN
20°
CARIBBEAN
AFRICA
0° Equator
SOUTH AMERICA
OCEANIA
INDIAN OCEAN
ATLANTIC OCEAN
0 2,000 Miles
0 2,000 Kilometers
SOUTHERN OCEAN
ANTARCTICA
160° 120° 80° 40° 0° 40° 80° 120° 160°

HISTORY OF OCEAN THERMAL ENERGY

- Ocean thermal energy has been recognized as a source of power for more than one century.
- The fictitious character of Captain Nemo provides the first documented reference to the use of ocean temperature differences to produce electricity in Jules Verne's classic "*Twenty Thousand Leagues Under the Sea*" that was published in 1870.

- ***"I was determined to seek from the sea alone the means of producing my electricity."***
- ***"From the sea?"***
- ***"Yes, Professor, and I was at no loss to find these means. It would have been possible, by establishing a circuit between two wires plunged to different depths, to obtain electricity by the difference of temperature to which they would have been exposed...."***


20000
Leagues Under the Sea
Jules Verne

- Eleven years after Jules Verne, the French physicist Jacques Arsene d’Arsonval proposed to use the warm (24-30°C) surface water of the tropical oceans to vaporize pressurized ammonia through an evaporator and use the resulting vapor to drive a turbogenerator.
- The cold (4-8°C) ocean water pumped to the surface from depths of around 1000 m depths was to be used to condense the ammonia vapor through condenser.
- The concept was called closed-cycle OTEC as the ammonia circulates in a closed loop.
- Forty years after d’Arsonval, his student Georges Claude proposed to use the ocean water as the working fluid in an open-cycle system.
- In Claude’s cycle the surface water is flash-evaporated in a vacuum chamber.
- The resulting low-pressure steam is used to drive a turbogenerator and the relatively colder deep seawater is used to condense the steam after it has passed through the turbine.
- This cycle can, therefore, be configured to produce desalinated water as well as electricity.

- In 1930, Georges Claude built the first actual OTEC plant in Cuba that produced 22 kilowatts of electricity with a low-pressure turbine.
- In 1956, French scientists designed a 3 MW plant for Ivory Coast, but the plant was never completed because new discoveries of large amounts of cheap crude oil made it uneconomical.
- From 1960, a father-son engineering team of J. Hilbert Anderson and James H. Anderson, Jr. took up a serious study of a closed cycle plant.
- They focused on increasing component efficiency and infact patented a new "closed cycle" design in 1967.
- Japan is a major contributor to the development of OTEC technology.
- Beginning in 1970, Japan successfully built and deployed a 100 kW closed-cycle OTEC plant on the island of Nauru.
- The plant became operational in 1981 with about 120 kW of electricity production.
- This was the first OTEC system in the world where the electricity generated was sent to a real power grid.
- The United States entered in OTEC research in 1974 with the establishment of the Natural Energy Laboratory of Hawaii Authority.

- This Makai laboratory at Hawaii is considered as one among the leading test facilities for OTEC technology.
- India built a 1 MW floating OTEC pilot power plant near Tamil Nadu with active government support to continue research.

SOLAR ENERGY ABSORPTION BY WATER

- Solar energy absorption by the water takes place according to **Lambert's law of absorption**, which states that each layer of equal thickness absorbs the same fraction of light that passes through it.

$$-\frac{dI_x}{dx} = kI$$

- Here x (meter) is the distance travelled by light through the water,
- I_x (W/m^2) is intensity of light transmitted through the water at a distance x below the surface, and
- k (m^{-1}) is the absorption coefficient of the water.
- Solving the above differential equation,

$$I_x = I_0 . e^{-kx}$$

- Here I_0 is intensity of light striking at the surface ($x = 0$).

- The absorption coefficient k has values of 0.05 m^{-1} for very clear fresh water, 0.27 for turbid fresh water, and 0.50 m^{-1} for very salty water.
- Since the intensity falls exponentially with depth x, heat absorption is concentrated at the top layers.
- Calculations with Lambert law show that virtually 95% of the solar radiation is absorbed by the upper 1 m layer of ocean water.
- The temperature difference between the warm surface water and the cold deep water varies with latitude and season, with the maximum in tropical, subtropical, and equatorial waters.
- Typically in the tropical waters, surface temperature values are in excess of 25°C, while at 1000 m depth, the temperature is about 5–10°C. Hence the tropics are generally the best OTEC locations.
- The warm light water at the surface means there are no thermal convection currents.
- Due to the small temperature gradients, heat transfer by conduction is too low to equalize the temperatures.
- The ocean is thus both a practically infinite heat source and a practically infinite heat sink.

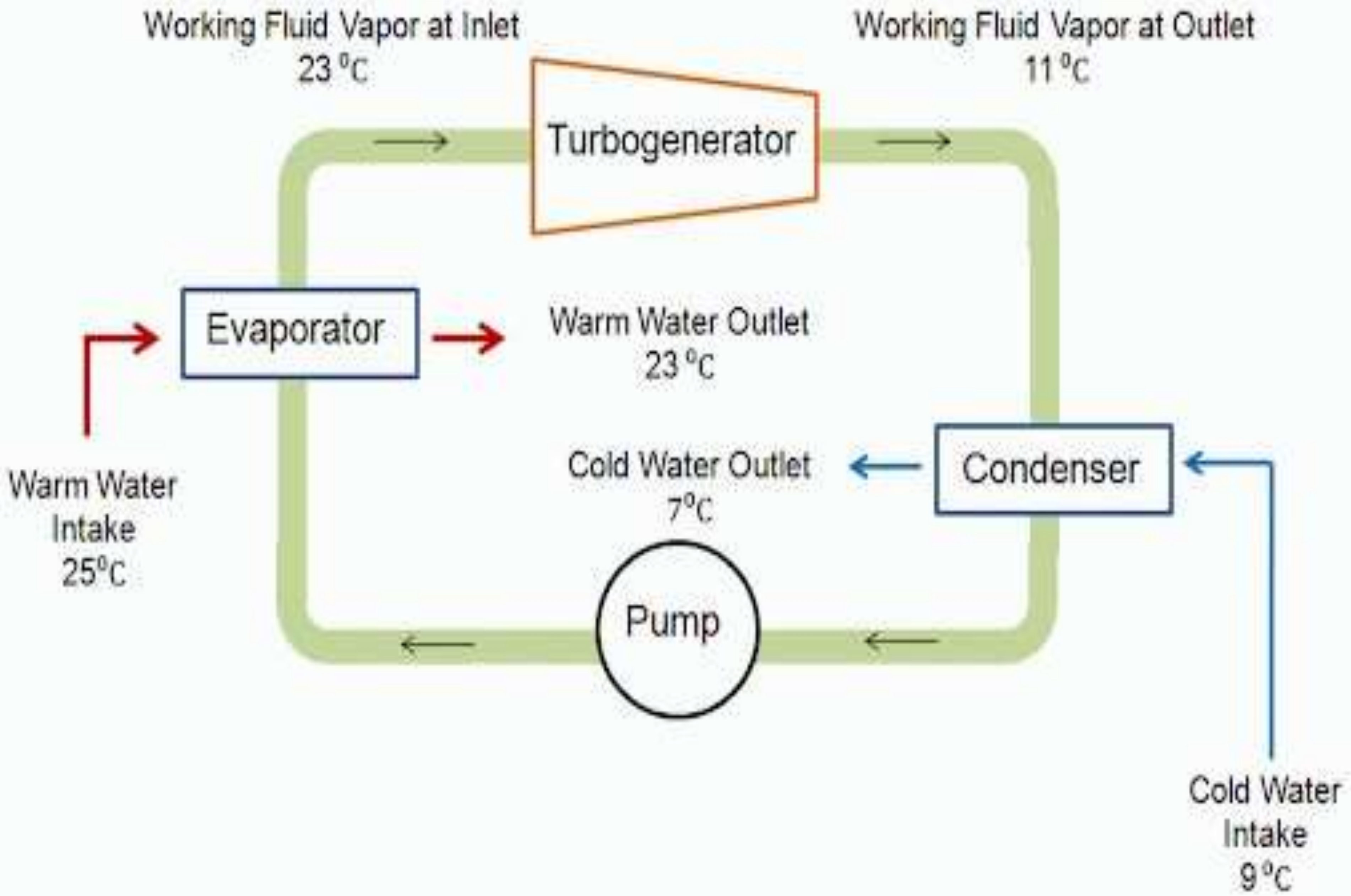
CYCLE TYPES

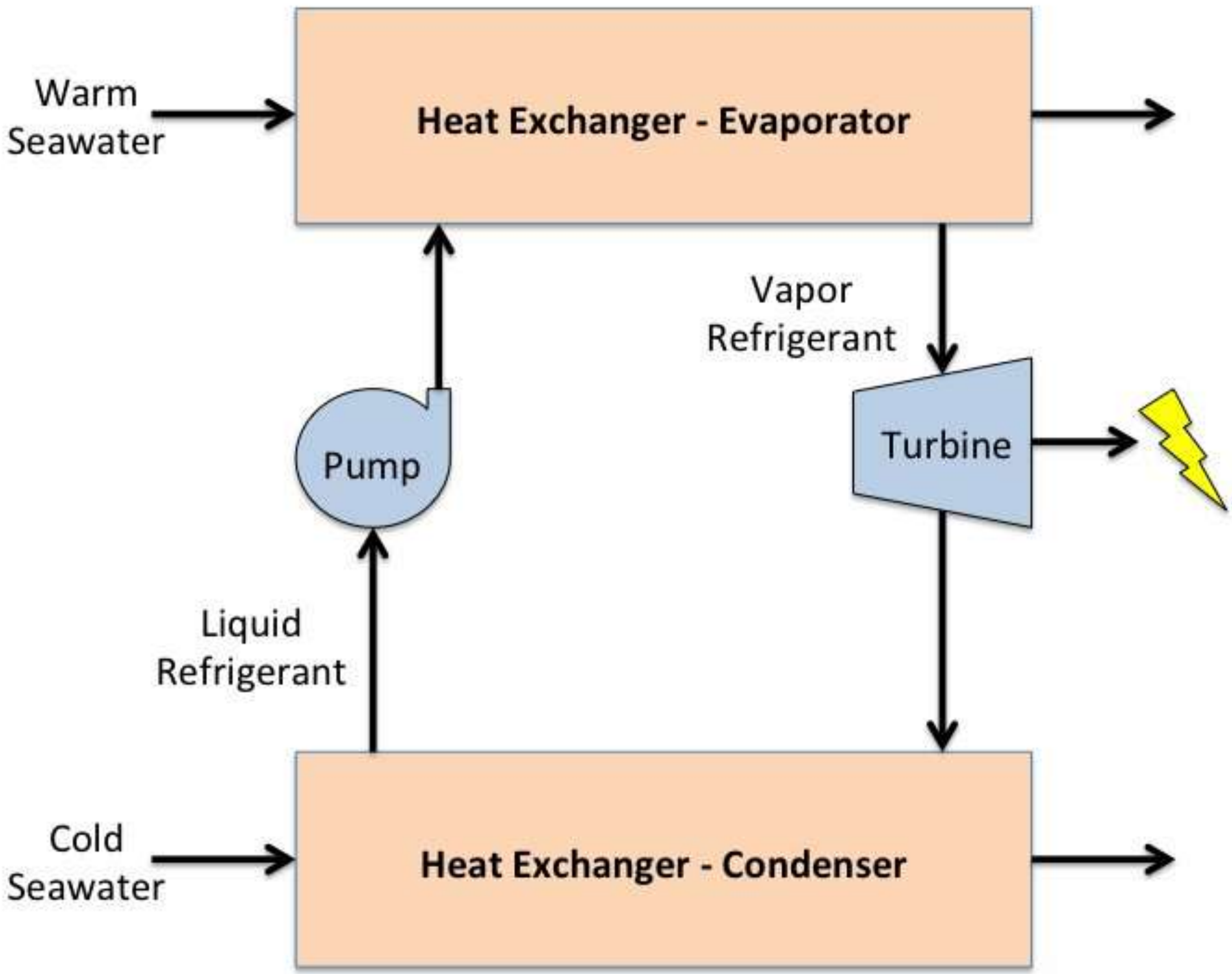
- OTEC power systems operate as cyclic heat engines.
- They receive thermal energy from ocean surface water warmed by the sun, and transform a portion of this energy to electrical power.
- The Second Law of Thermodynamics precludes the complete conversion of thermal energy in to electricity.
- A portion of the heat extracted from the warm surface water must be rejected to a colder thermal sink.
- The thermal sink in an OTEC power system is cold seawater drawn from the depths by means of a submerged pipeline.
- The maximum theoretical efficiency of a cyclic heat engine depends on the temperature difference between the hot thermal source and cold sink.
- For OTEC power systems, this temperature difference is very small and overall conversion efficiency is quite low (6-8%), compared to state-of-the-art thermal power systems, which tap much higher temperature energy sources and are theoretically capable of converting more than 60% of the extracted thermal energy into electricity.

- The low efficiency of OTEC systems mean that more than 90% of the thermal energy extracted from the ocean’s surface is ‘wasted’ and must be rejected to the cold deep seawater.
- This necessitates large heat exchangers and seawater flow rates to produce relatively small amounts of electricity.
- An OTEC power plant may be configured following the closed-cycle design by J.A. d’Arsonval, or the open-cycle design by G. Claude, or the hybrid cycle.
- The Rankine cycle is the most commonly used heat cycle in these systems.
- The size of an OTEC power plant depends upon the vapor pressure of the working fluid.
- With increasing vapor pressure the size of the turbine and heat exchangers decreases, while the wall thickness of the pipe and heat exchangers increase to endure high pressure especially on the evaporator side.

Closed-cycle OTEC

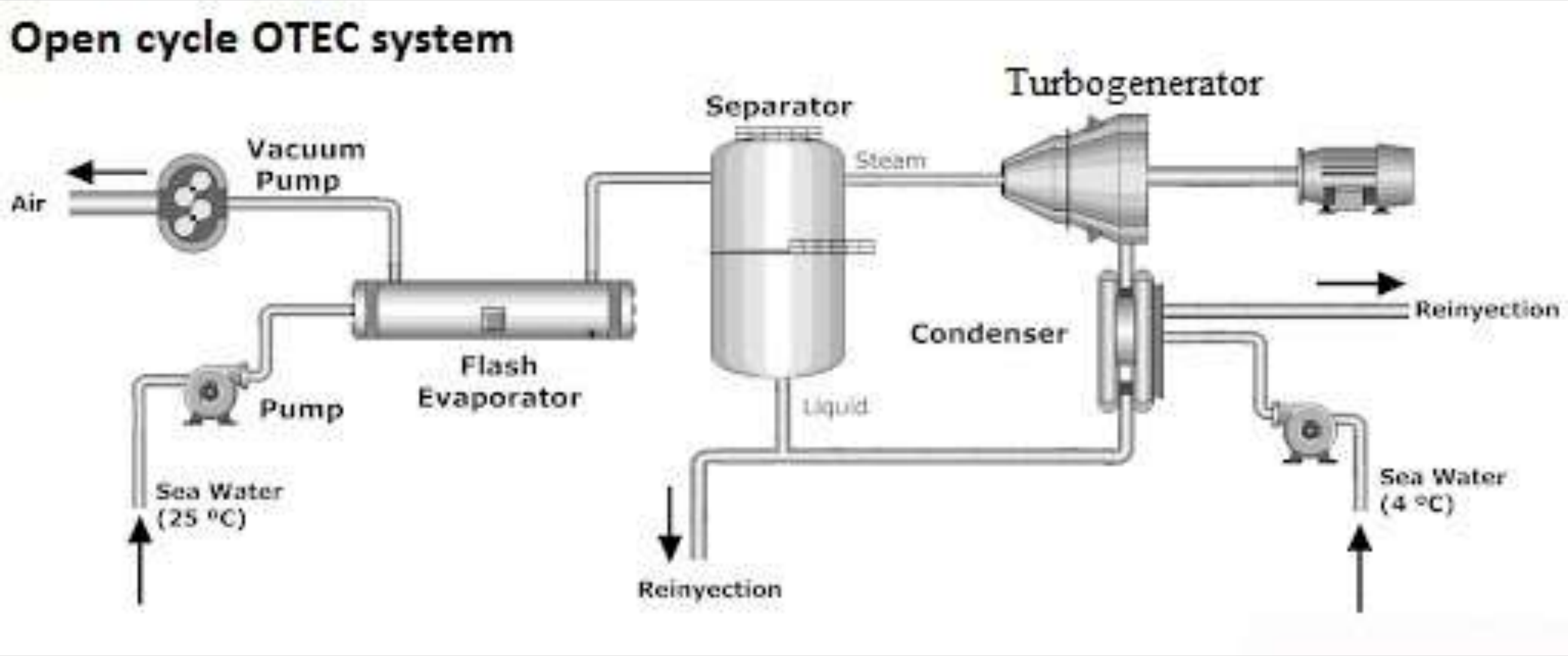
- Closed-cycle OTEC plant uses low boiling point working fluid to rotate a turbine to generate electricity.
- Warm surface seawater is pumped through a heat exchanger (evaporator) to vaporize the fluid.
- The vapor expands at moderate pressures and turns the turbine coupled with a generator that produces electricity.
- The exhaust vapor is then condensed in another heat exchanger (condenser) using cold deep seawater.
- The condensed working fluid is recycled to the evaporator to repeat the process.
- The working fluid remains in a closed cycle and circulates continuously.
- The principal components are the heat exchangers, turbogenerator, and seawater supply system, which accounts for most of the parasitic power consumption and a significant fraction of the capital expense.
- Closed-cycle OTEC power systems, which operate at elevated pressures, require smaller turbines than open-cycle systems.


Working Fluid Vapor at Inlet
23 °C
Turbogenerator
Working Fluid Vapor at Outlet
11 °C
Evaporator
Warm Water Outlet
23 °C
Warm Water
Intake
25°C
Cold Water Outlet
7°C
Condenser
Pump
Cold Water
Intake
9 °C


Warm Seawater
Heat Exchanger - Evaporator
Vapor Refrigerant
Turbine
Pump
Liquid Refrigerant
Cold Seawater
Heat Exchanger - Condenser

Open-cycle OTEC

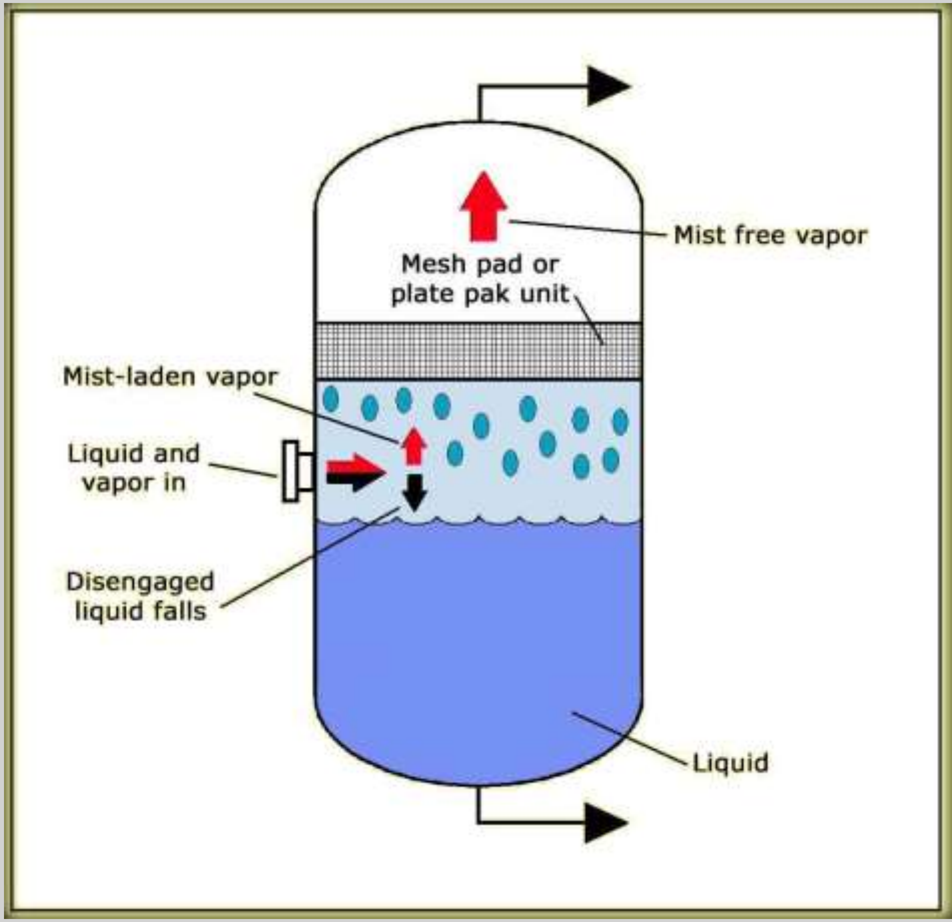
- The open-cycle OTEC plant uses warm surface water as the working fluid to make electricity.
- The warm seawater is flash evaporated in a vacuum chamber to produce steam at an absolute pressure of about 2.4 kPa.
- The steam expands through a low-pressure turbine coupled with a generator that produces electricity.
- The exhaust steam is condensed back into liquid by cold deep seawater pumped from the depth 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 desalinated fresh water suitable for drinking or irrigation.
- Fig. 2 presents a schematic diagram of open-cycle OTEC system.
- The evaporator, turbine, and condenser operate in partial vacuum ranging from 3% to 1% atmospheric pressure. This poses a number of practical concerns that must be addressed.



- **First**, the system must be carefully sealed to prevent in-leakage of atmospheric air that can severely degrade or shut down operation.
- **Second**, the specific volume of the low-pressure steam is very large compared to that of the pressurized working fluid used in closed cycle system. This means that components must have large flow areas to ensure that steam velocities do not attain excessively high values.

- **Finally**, gases such as oxygen, nitrogen and carbon dioxide that are dissolved in seawater (essentially air) come out of solution in a vacuum.
- These gases are non-condensable and must be exhausted from the system.
- In spite of these complications, the Claude cycle enjoys certain benefits from the selection of water as the working fluid.
- Water, unlike ammonia, is non-toxic and environmentally benign.
- Moreover, since the evaporator produces desalinated steam, the condenser can be designed to yield fresh water.
- In many potential sites in the tropics, potable water is a highly desired commodity that can be marketed to offset the price of OTEC-generated electricity.
- **Flash evaporation** is a distinguishing feature of open-cycle OTEC system.
- Flash evaporation involves complex heat and mass transfer processes.
- The warm seawater is pumped into a chamber through spouts designed to maximize the heat-and-mass-transfer surface area by producing a spray of the liquid.
- The pressure in the chamber (1% to 3% of atmospheric) is less than the saturation pressure of the warm seawater.

- Exposed to this low-pressure environment, water in the spray began to boil.
- As in thermal desalination plants, the vapor produced is relatively pure steam.
- As steam is generated, it carries away its heat of vaporization.
- This energy comes from the liquid phase and results in lowering of the liquid temperature and the cessation of boiling.
- Thus flash evaporation may be seen as a transfer of thermal energy from the bulk of the warm seawater to the small fraction of mass that is vaporized to become the working fluid.
- Approximately 0.5% of the mass of warm seawater entering the evaporator is converted into steam.



- A large turbine is required to accommodate the huge volumetric flow rates of low-pressure steam needed to generate good amount of electrical power.
- The existing technology limits the power that can be generated by a single turbine module to about 2.5 MW.
- Unless significant efforts are made to develop new, specialized turbines; an increase in the gross power generating capacity of a Claude cycle plant above 2.5 MW will require multiple modules.
- Condensation of the low-pressure working fluid leaving the turbine occurs by heat transfer to the cold seawater.
- This heat transfer may occur in a direct contact condenser where the seawater is sprayed directly over the vapor, or in a surface condenser that does not allow contact between the coolant and the condensate.
- Direct contact condensers are relatively inexpensive and have good heat transfer characteristics due to the lack of a solid thermal boundary between the warm and cold fluids.
- The surface condensers for OTEC applications are relatively expensive to fabricate, but they permit the production of desalinated water.

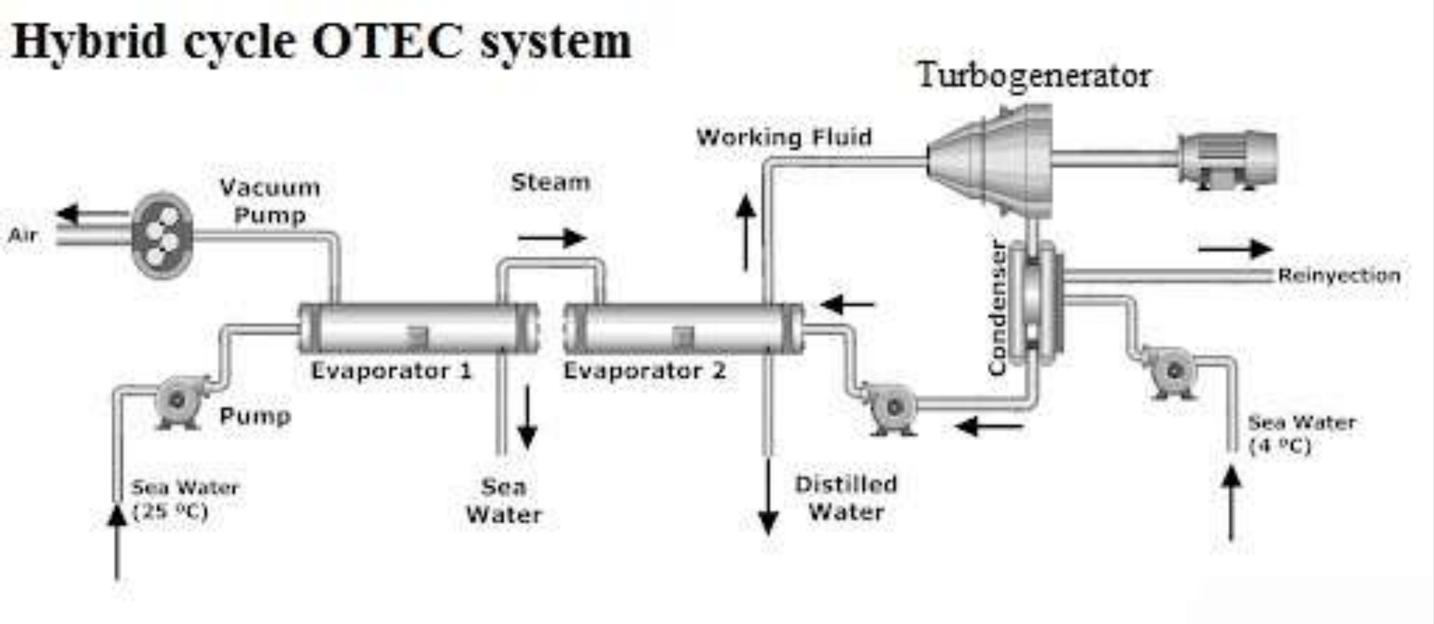
- Analysis of the open cycle OTEC system:

Heat added from seawater (J/s)	$q_w = \dot{m}_{ww} C_p (T_{wwi} - T_{wwo})$
Steam generation rate (kg/s)	$\dot{m}s = \frac{q_w}{h_{fg}}$
Turbine work (J/s)	$W_T = \dot{m}_s (h_3 - h_5) = \dot{m}_s \eta_T (h_3 - h_{5s})$
Heat discharged into seawater (J/s)	$q_c = \dot{m}_{cw} C_p (T_{cwo} - T_{cwi})$

- Here $\dot{m}_{ww}$ is the mass flow rate of warm water; C_p the specific heat; T_{wwi} and T_{wwo} the seawater temperature at the inlet and outlet of the heat exchanger; h_{fg} the heat of evaporation; and the enthalpies at the indicated points are given by *h*, with the subscript *s* referring to constant entropy.
- The turbine isentropic efficiency is given by η_T.
- The subscript *cw* refers to the cold water.

Hybrid Cycle

- A hybrid cycle combines the features of both the closed-cycle and open-cycle systems.
- In a hybrid system, warm surface seawater enters a vacuum chamber where it is flash evaporated into steam, like the open-cycle evaporation process.
- This low pressure steam flows into a heat exchanger where it vaporizes the low boiling point working fluid (ammonia) in a closed-cycle that drives a turbine to produce electricity.
- The steam condenses in the heat exchanger and provides desalinated water.



- The exhaust working fluid vapor is condensed using cold deep seawater.

SELECTION OF WORKING FLUIDS

- The proper selection of a suitable working fluid is a critical factor for achieving an efficient and a safe operation.
- Each working fluid has its own range of applicability according to its thermo-physical properties under the considerations of a high efficiency and a safe operation.
- Important factors of the working fluids needed to be considered are given here:

1) **Toxicity of working fluid:** All organic fluids are inevitably toxic. A working fluid with a low toxicity should be used to protect the personnel from the threat of contamination in case of a fluid leakage.
2) **Chemical stability:** Under a high pressure and temperature, organic fluids tend to decompose, resulting in material corrosion and possible detonation and ignition. Therefore a chemically-stable working fluid operated under working conditions should be selected.
3) **Specific heat:** High value of specific heat represents a high load for the condenser. Hence a working fluid with a low specific heat should be used.

4) **Boiling temperature:** Some of the organic fluids have a very low boiling temperature under atmospheric pressure. For those fluids, the temperature of cooling water in the condenser should be reduced. This can result in a more stringent requirement for the selection of the condenser.

5) **Flash point:** A working fluid with a high flash point should be used in order to avoid flammability.

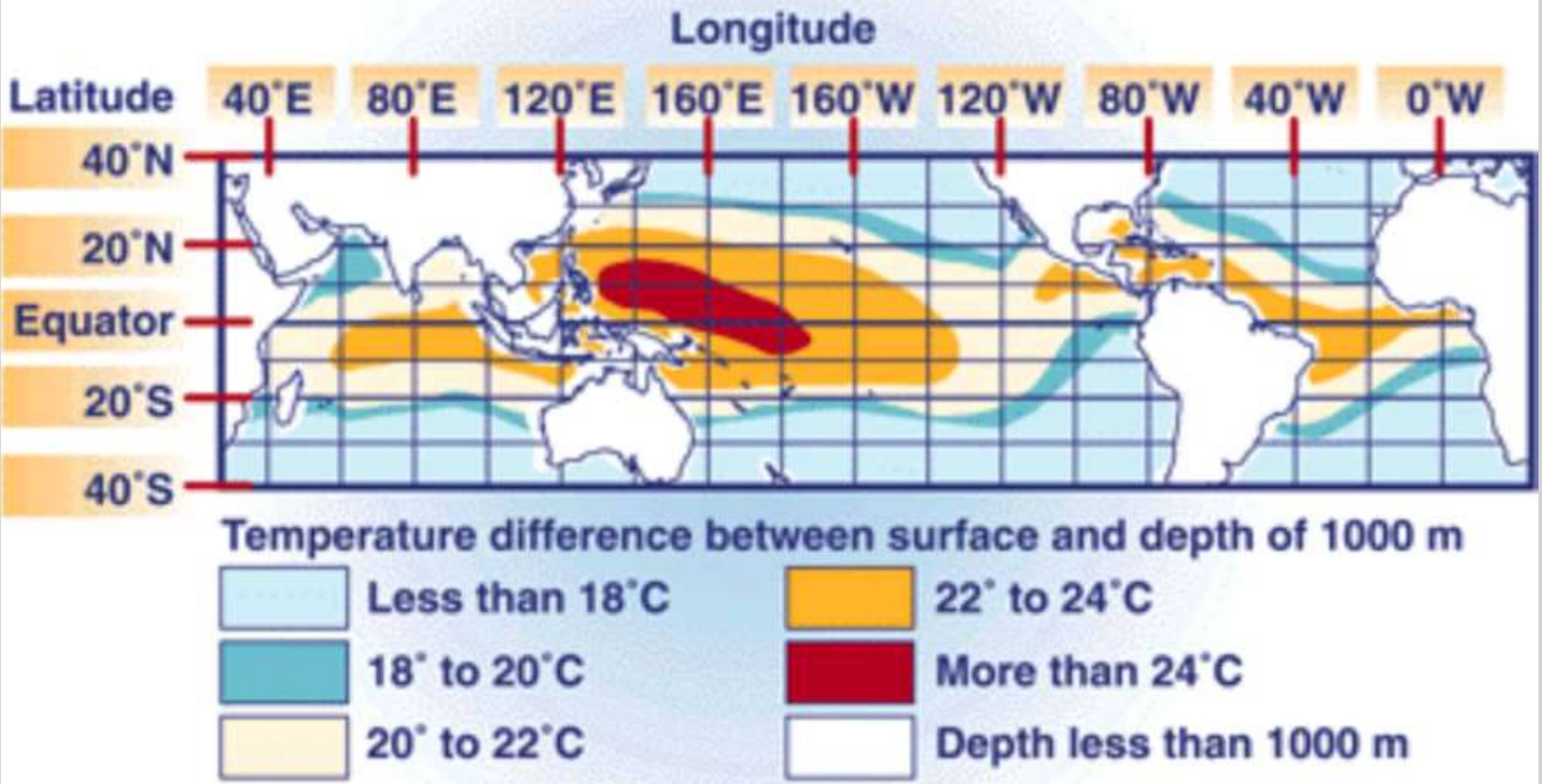
6) **Latent heat:** A working fluid with a high latent heat should be used in order to raise the efficiency of heat recovery.

7) **Thermal conductivity:** A high conductivity represents a better heat transfer in heat-exchange components.

- Ammonia is the most popular working fluid for closed-cycle systems because of its low cost, easy availability, superior transport properties, and compatibility with system materials; however, Ammonia is toxic and flammable.
- Fluorinated carbons such as CFCs and HCFCs can be used as they are non toxic and non flammable, but they have been banned by the Montreal Protocol because they deplete stratospheric ozone.
- H/Cs are good candidates, but they are highly flammable & in short supply.

POTENTIAL SITES AND PLANT DESIGN

- Commercial OTEC plants must be located in a stable environment for efficient system operation.
- The temperature of the warm surface seawater must differ about 20°C from that of the cold deep seawater that is no more than about 1000 meters below the surface.
- The natural ocean thermal gradient necessary for OTEC operation is generally found in Equatorial waters lying between 10°N and 10°S (except the west coast of South America), and Tropical waters extending from 20°N to 20°S (except the west coasts of South America and South Africa).
- The physical factors like thermal resource and seafloor bathymetry affect the OTEC site selection and greatly restrict the number of desirable sites along the shoreline of major continents. The best land-based OTEC sites consist of island locations.
- The severe constraints of a favorable bathymetric profile can be relaxed to a considerable extent for floating type OTEC plants.


Longitude
Latitude
40°E
80°E
120°E
160°E
160°W
120°W
80°W
40°W
0°W
40°N
20°N
Equator
20°S
40°S
Temperature difference between surface and depth of 1000 m
Less than 18°C
18° to 20°C
20° to 22°C
22° to 24°C
More than 24°C
Depth less than 1000 m

Land-based and Near-shore Facilities

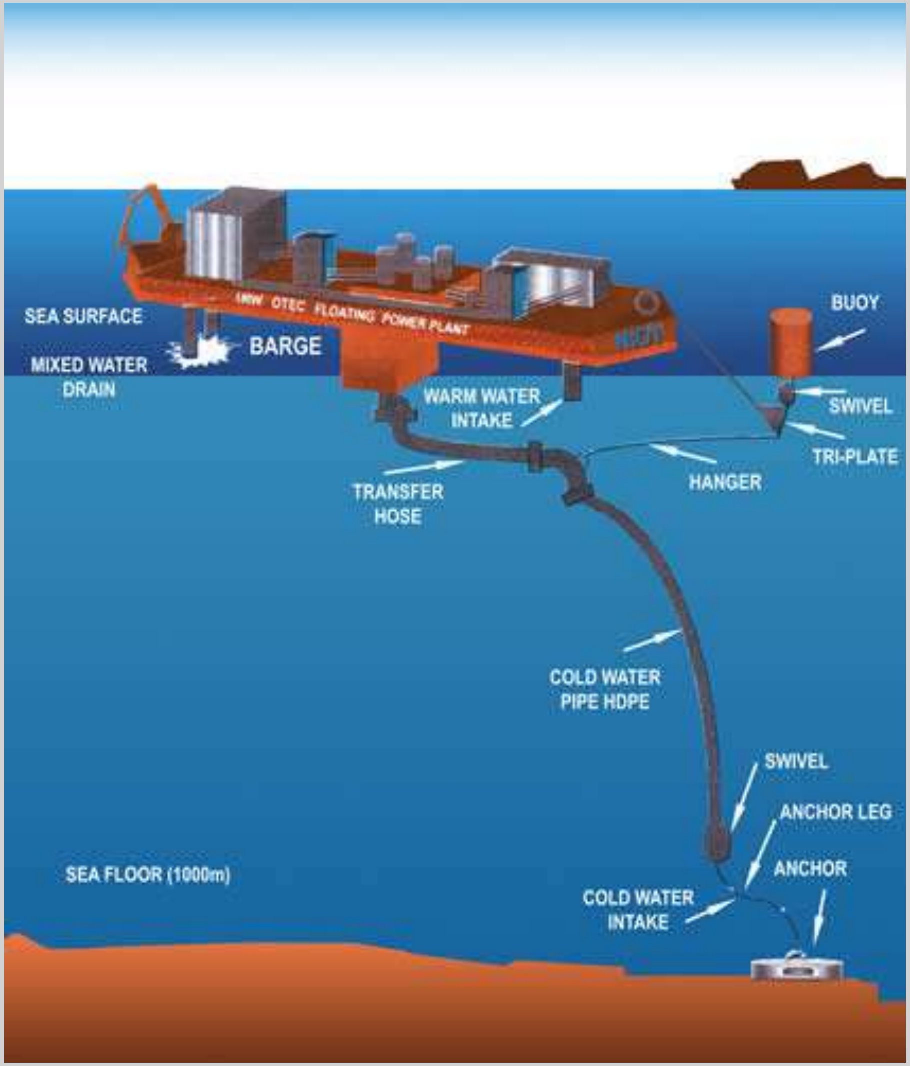
- Land-based and near-shore facilities do not require sophisticated mooring, lengthy power cables, long cold water intake pipe, and the extensive maintenance associated with open-ocean environments.
- The easy access for construction and operation helps to reduce the power generation cost.
- Favored locations include narrow volcanic islands, steep offshore slopes, and smooth sea floors which are quite safe from storms and heavy seas.
- Electricity, desalinated water, and cold nutrient-rich seawater could be transmitted from near-shore facilities via trestle bridges or causeways.
- In addition, land-based and near-shore facilities support several related industries such as mariculture or those that require desalinated water.
- One disadvantage of land-based facilities arises from the turbulent wave action in the surf zone.
- Unless the plant water supply and discharge pipes are buried in protective trenches, they will be subject to extreme stress conditions during storms.
- Also, the mixed discharge of cold and warm seawater may need to be carried several hundred meters offshore to reach the proper depth before it is released. This arrangement requires additional expense in construction and maintenance.

Shelf-mounted Facilities

- To avoid the turbulent surf zone and to have closer access to the cold-water resource, 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 affixed to the sea bottom.
- This type of construction is already used for offshore oil rigs.
- Although the complexities of operating an OTEC plant in deeper water may make shelf-mounted facilities less desirable and more expensive than land-based facilities.
- The major problems with shelf-mounted facilities are stress of open-ocean conditions and more difficult product delivery.
- Addressing strong ocean currents and large waves adds engineering and construction expense.
- Platforms require extensive pilings to maintain a stable base for OTEC plant.
- The cost of power delivery would also increase because of the long underwater cables required to reach land.
- For these reasons, shelf-mounted facilities are less attractive.

Floating Facilities

- Floating type OTEC plants are large capacity systems that are designed to operate off-shore.
- These plants need to remain relatively stationary for various reasons like continuous operation and power delivery, but they are more difficult to stabilize.
- Mooring is an acceptable method, but current mooring technology is limited to depths of about 2000 meters.
- Even at shallower depths, the cost of mooring may be too high for commercial installations.

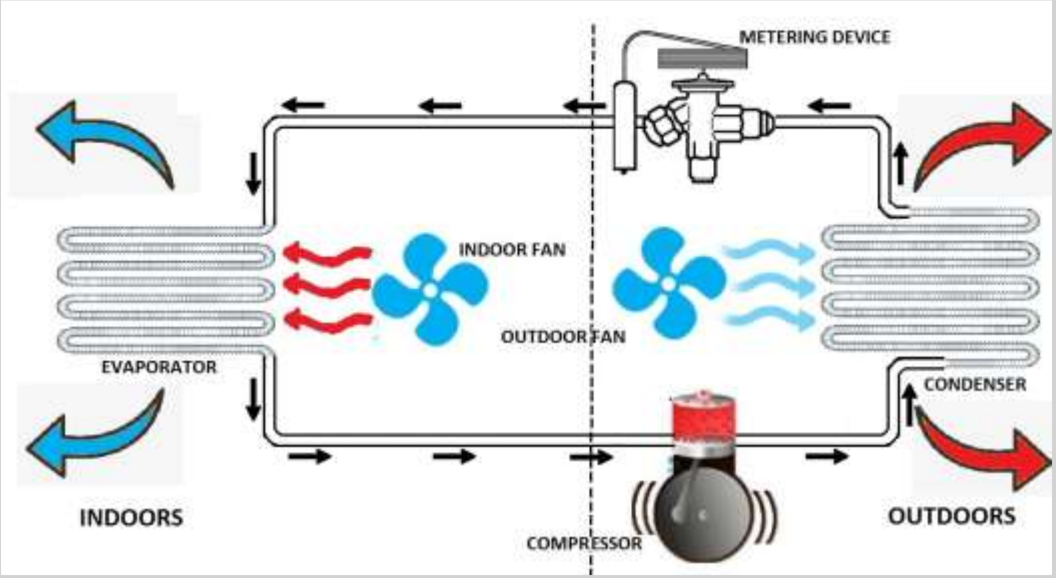


- Cables attached to floating platforms are more susceptible to damage, particularly during storms.
- Cables at depths greater than 1000 meters are difficult to maintain and repair.
- Riser cables used to connect the sea bed and the plant need to be constructed to resist entanglement.
- Major storms and heavy seas can break the vertically suspended cold-water pipe and interrupt the intake of warm water as well.
- To help prevent these problems, pipes can be made of flexible polyethylene attached to the bottom of the platform and gimballed with joints or collars.
- Pipes may need to be uncoupled from the plant to prevent the damage from storm.
- As an alternative to a warm-water pipe, surface water can be drawn directly into the platform.
- In such case, the intake flow requires to be protected from being damaged or interrupted during violent motions of the platform caused by heavy seas.

APPLICATIONS OF OTEC

Air Conditioning

- OTEC power plants provide air conditioning facility to nearby buildings as a valuable byproduct.
- The 5°C spent seawater made available by an OTEC power plant is passed through a heat exchanger where it cools freshwater in a closed loop system.
- This freshwater is then pumped to buildings and directly cools the air.
- A 30 cm diameter pipe can deliver 18000 liters/minute of water.
- This water could provide more than enough air-conditioning for a large building resulting in a significant reduction in energy bills annually.

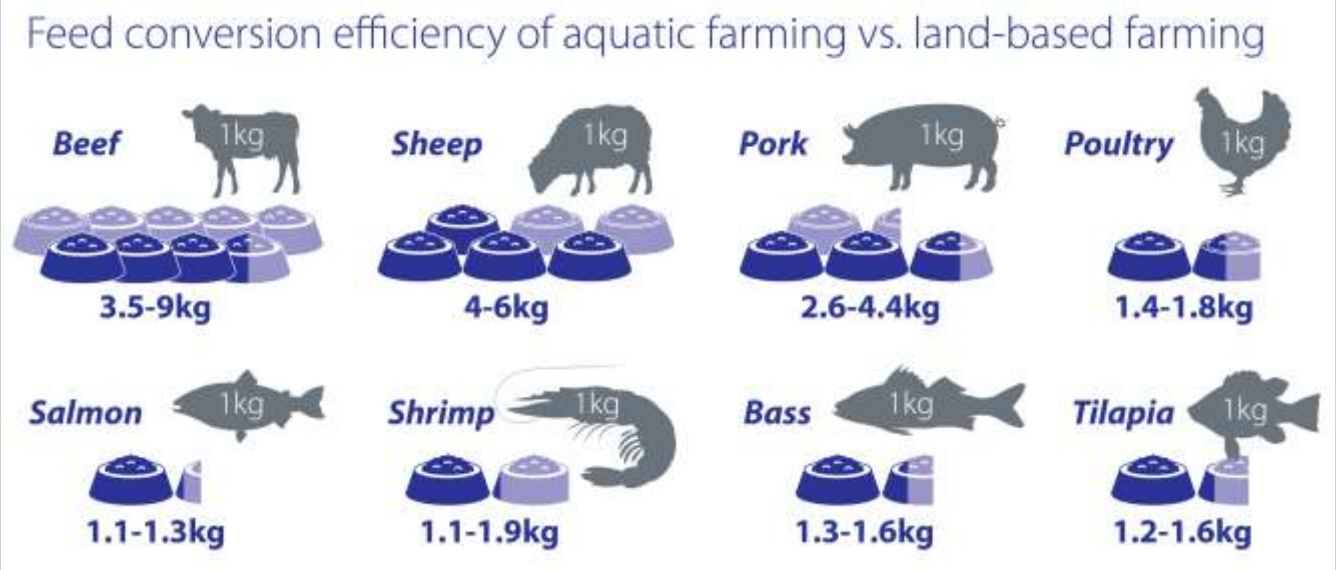


Cold-bed (Chilled-soil) Agriculture

- When cold seawater flows through the pipes beneath the surface of the soil, it chills the surrounding soil and lowers the temperature of plant roots.
- The temperature difference between plant roots in the cool soil and leaves in the open warm air allows many temperate-zone crops (such as certain leafy greens, fruits, and legumes) to grown in the subtropics.
- The reason may be the high insolation or perhaps because keeping the roots at a significantly lower temperature than the leaves facilitates transpiration or other metabolic processes.
- The production of these crops in the tropics reduces transportation costs in bringing these crops to tropical consumers.
- In addition to cold-bed agriculture, OTEC can produce abundant fresh water that can be used for irrigation of crops which is otherwise severely limited in tropical regions.

Aquaculture

- Aquaculture is perhaps the most known byproduct of OTEC, because it reduces the financial and energy costs of pumping large volumes of water from the deep ocean.
- Deep ocean water contains high concentrations of essential nutrients that are depleted in surface waters due to biological consumption.
- The upwelling of these nutrients with deep cold seawater fertilizes and supports the marine ecosystems.
- Spirulina platensis, microalgae known as the richest natural source of protein, iron, vitamins, minerals and pro-vitamin A, also can be cultivated.
- Non-native species such as salmon, lobster, abalone, trout, oysters, and clams can be raised in nutrient-rich seawater pools supplied by OTEC facility.
- This extends the variety of fresh seafood products available for nearby markets.
- In addition, the low cost refrigeration can be used to store the seafood products, that otherwise deteriorate quickly in warm tropical regions.

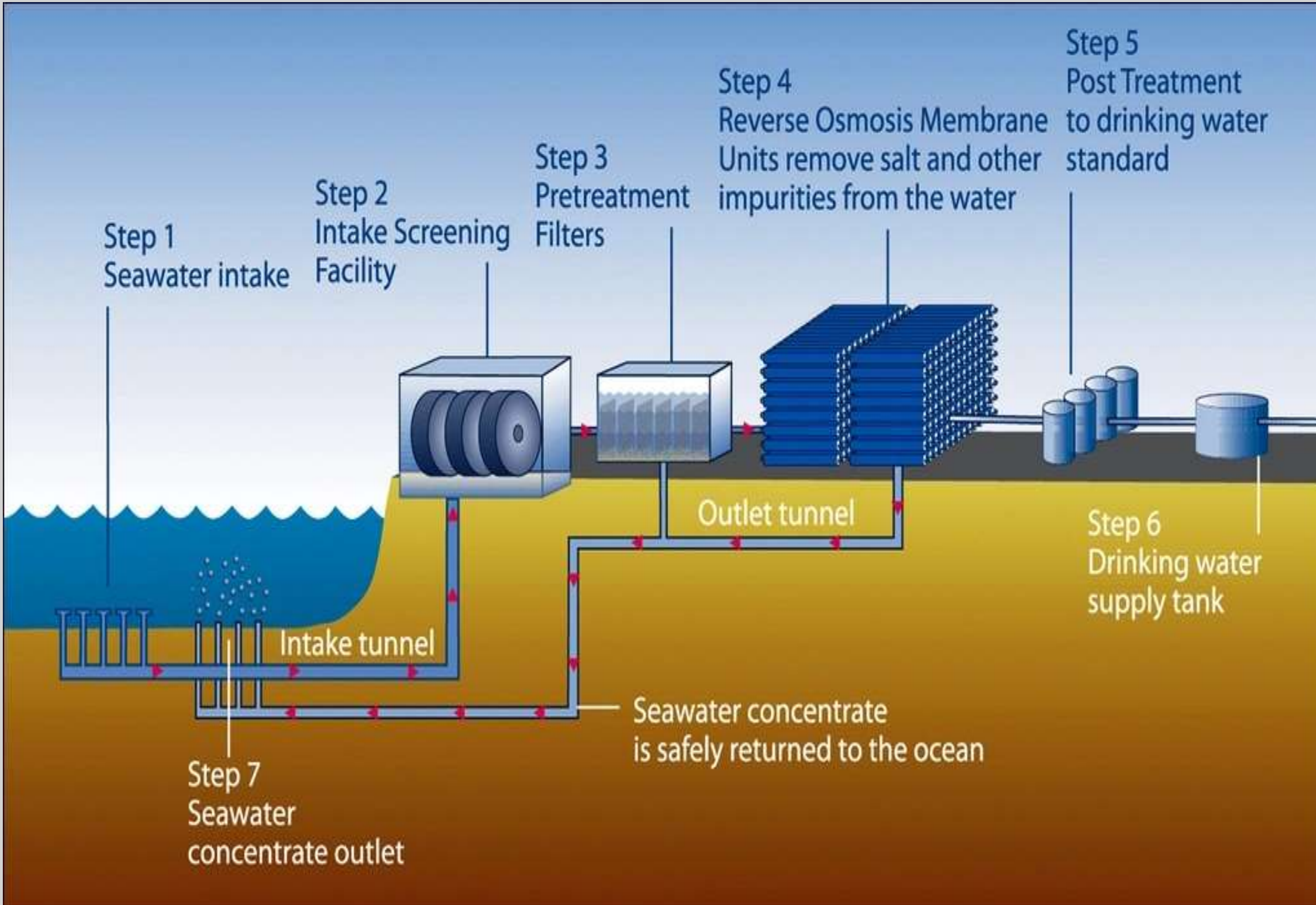

Feed conversion efficiency of aquatic farming vs. land-based farming
Beef
1kg
3.5-9kg
Sheep
1kg
4-6kg
Pork
1kg
2.6-4.4kg
Poultry
1kg
1.4-1.8kg
Salmon
1kg
1.1-1.3kg
Shrimp
1kg
1.1-1.9kg
Bass
1kg
1.3-1.6kg
Tilapia
1kg
1.2-1.6kg

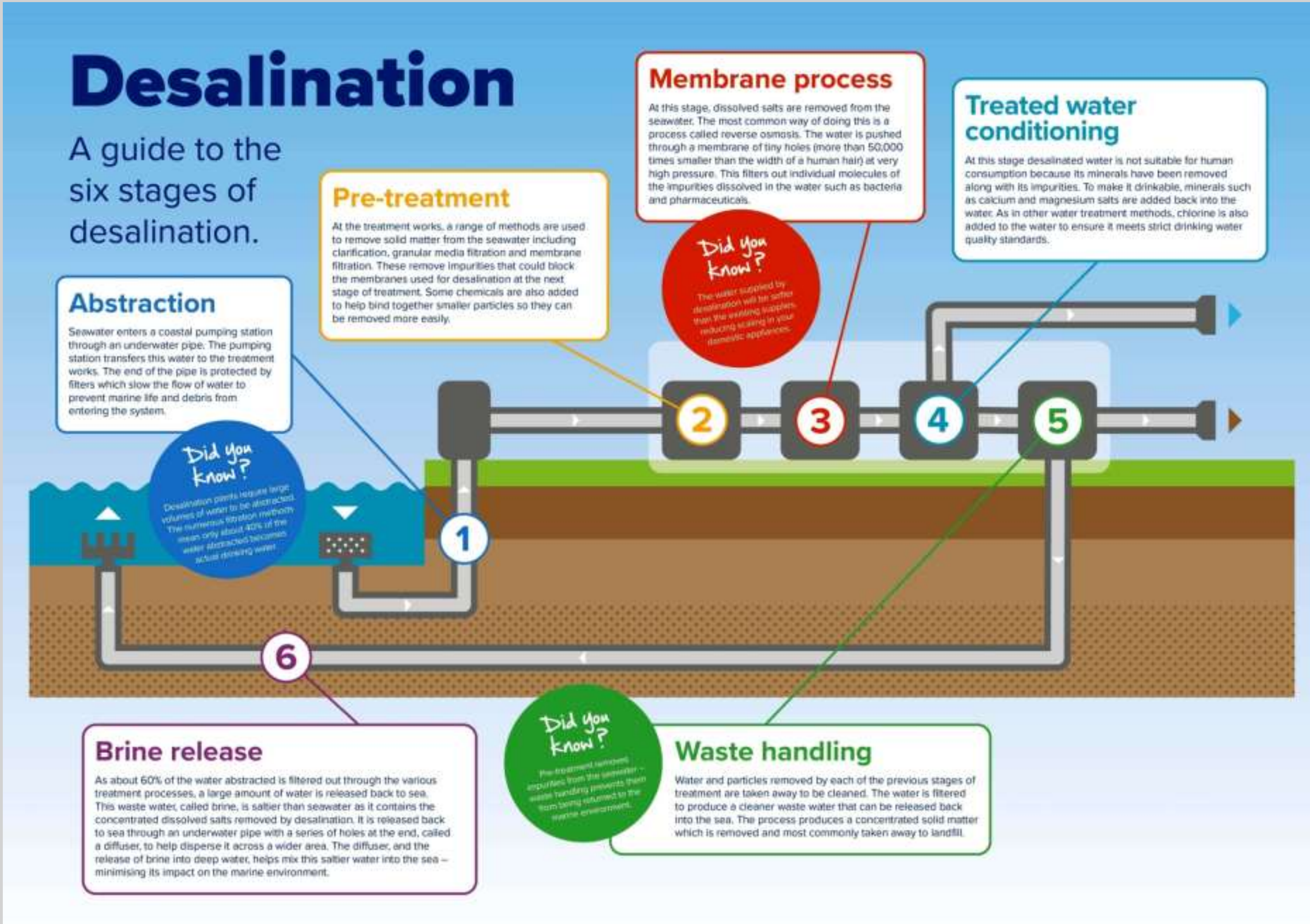
Desalination

- The open cycle or hybrid cycle OTEC plants produce potable water from evaporated seawater in surface condensers.
- It is estimated that a 2 MW plant could produce about 43 lakhs (4.3 million) of desalinated water each day.

Mineral Extraction

- The ocean water contains 57 trace elements in salts and other forms.
- Mining the ocean for dissolved minerals would require pumping of large volumes of water and the expense of separating the minerals from seawater.
- With OTEC plants already pumping the water, the only remaining economic challenge is to reduce the cost of the extraction process.


Step 1
Seawater intake
Step 2
Intake Screening
Facility
Step 3
Pretreatment
Filters
Step 4
Reverse Osmosis Membrane
Units remove salt and other
impurities from the water
Step 5
Post Treatment
to drinking water
standard
Outlet tunnel
Step 6
Drinking water
supply tank
Intake tunnel
Seawater concentrate
is safely returned to the ocean
Step 7
Seawater
concentrate outlet


Desalination
A guide to the six stages of desalination.
Abstraction
Seawater enters a coastal pumping station through an underwater pipe. The pumping station transfers this water to the treatment works. The end of the pipe is protected by filters which slow the flow of water to prevent marine life and debris from entering the system.
Did you know?
Desalination plants require large volumes of water to be abstracted. The numerous filtration methods mean only about 40% of the water abstracted becomes actual drinking water.
Pre-treatment
At the treatment works, a range of methods are used to remove solid matter from the seawater including clarification, granular media filtration and membrane filtration. These remove impurities that could block the membranes used for desalination at the next stage of treatment. Some chemicals are also added to help bind together smaller particles so they can be removed more easily.
Membrane process
At this stage, dissolved salts are removed from the seawater. The most common way of doing this is a process called reverse osmosis. The water is pushed through a membrane of tiny holes (more than 50,000 times smaller than the width of a human hair) at very high pressure. This filters out individual molecules of the impurities dissolved in the water such as bacteria and pharmaceuticals.
Did you know?
The water supplied by desalination will be softer than the existing supplies, reducing scaling in your domestic appliances.
Treated water conditioning
At this stage desalinated water is not suitable for human consumption because its minerals have been removed along with its impurities. To make it drinkable, minerals such as calcium and magnesium salts are added back into the water. As in other water treatment methods, chlorine is also added to the water to ensure it meets strict drinking water quality standards.
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Brine release
As about 60% of the water abstracted is filtered out through the various treatment processes, a large amount of water is released back to sea. This waste water, called brine, is saltier than seawater as it contains the concentrated dissolved salts removed by desalination. It is released back to sea through an underwater pipe with a series of holes at the end, called a diffuser, to help disperse it across a wider area. The diffuser, and the release of brine into deep water, helps mix this saltier water into the sea – minimising its impact on the marine environment.
Did you know?
Pre-treatment removes impurities from the seawater – waste handling prevents them from being returned to the marine environment.
Waste handling
Water and particles removed by each of the previous stages of treatment are taken away to be cleaned. The water is filtered to produce a cleaner waste water that can be released back into the sea. The process produces a concentrated solid matter which is removed and most commonly taken away to landfill.

ADVANTAGES OF OTEC SYSTEMS

1) The OTEC energy resources are vast and naturally self-renewing.
2) It produces desalinated water for industrial, agricultural, and residential uses.
3) It is a key resource to many on-shore and near-shore mariculture operations.
4) The OTEC has potential to mitigate greenhouse gas emissions resulting from combustion of fossil fuels.
5) The OTEC plant byproduct chill-water is utilized for air conditioning and cold-bed agriculture purposes.
6) The OTEC plant enhances energy independence and energy security by generating clean and cost-effective base load electrical energy.
7) In small island nations, the benefits of OTEC include self-sufficiency, minimal environmental impacts, and improved sanitation and nutrition, which result from the greater availability of desalinated water and mariculture products.

8) The preservation of coral reefs and hurricane amelioration is possible by limiting temperature rise of the ocean surface through energy extraction and artificial upwelling of cold deep seawater.

9) OTEC is non-polluting; infact it is ecologically positive since it enriches nutrient-poor surface water and tends to “sink” carbon. The nitrogen, phosphorus, silica, and other nutrients raised from the deep are combined via photosynthesis with atmospheric and ocean-dissolved carbon dioxide to produce increased biomass and reduce atmospheric carbon load.

DISADVANTAGES OF OTEC SYSTEMS

- The recurring costs to generate electricity from an OTEC plant are minimal. However, the initial investment is quite high ($4-$10 for one Watt) because large pipelines and heat exchangers are needed to produce relatively small amounts of electricity. The private firms may be unwilling to make such enormous investment without active government support.
- The majority of potential sites are at relatively isolated locations and the transportation of power and marine products to consumers from such isolated locations will not be commercially economical.
- The discharge of large amounts of mixed waters may put negative impacts on ocean temperatures and marine life.
- OTEC plants have not been tested at full capacity over long periods with integrated power, mariculture, fresh water, and chilled water production.

STATUS OF OTEC IN INDIA

- Indian government put strong emphasis on power generation by OTEC technology.
- The National Institute of Ocean Technology (NIOT), a Chennai based government research organization and in charge of technical development of ocean energy in India, has long been pursuing roads for commercial application of the open cycle and closed cycle variations of ocean energy.
- The studies carried out by NIOT estimates that 1.5×10^6 m^2 of Indian coast lines may have potential of 180,000 MW of power generation.
- India’s first ocean thermal energy conversion facility named “Sagar Shakti” has been commissioned off the west coast of India.
- The 1 MW capacity plant is housed on a 68.5 m long, 16 m broad, and 4 m deep barge anchored off the port of Tuticorin, and uses a Rankine cycle.
- The cold deep seawater is collected through 1200 m long pipeline suspended vertically in sea by means of sold ballast and mooring buoy.
- The OTEC barge has one of the deepest single point mooring systems in the world.

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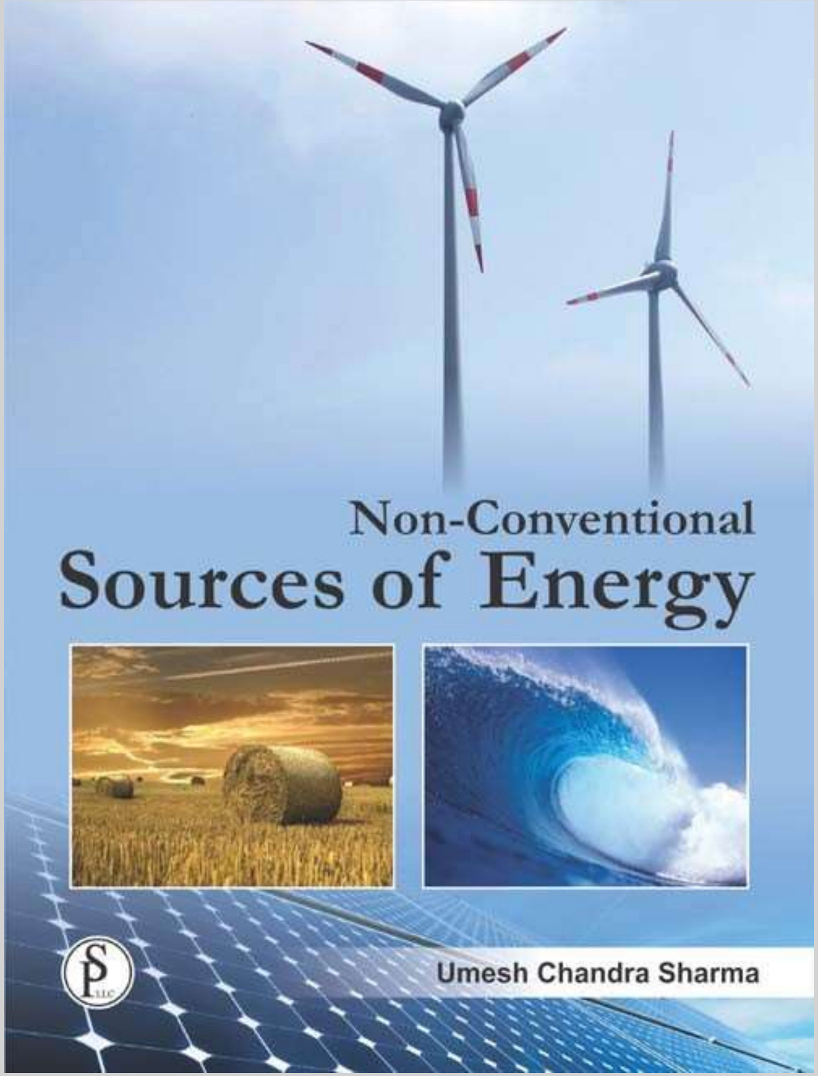

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Thank You