Ocean Thermal Energy Conversion

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https://www.youtube.com/watch?v=AtxuoR6M8LU

https://www.youtube.com/watch?v=FHBVgRWAt3c

https://www.youtube.com/watch?v=Jd6pNrjMxBc

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Introduction

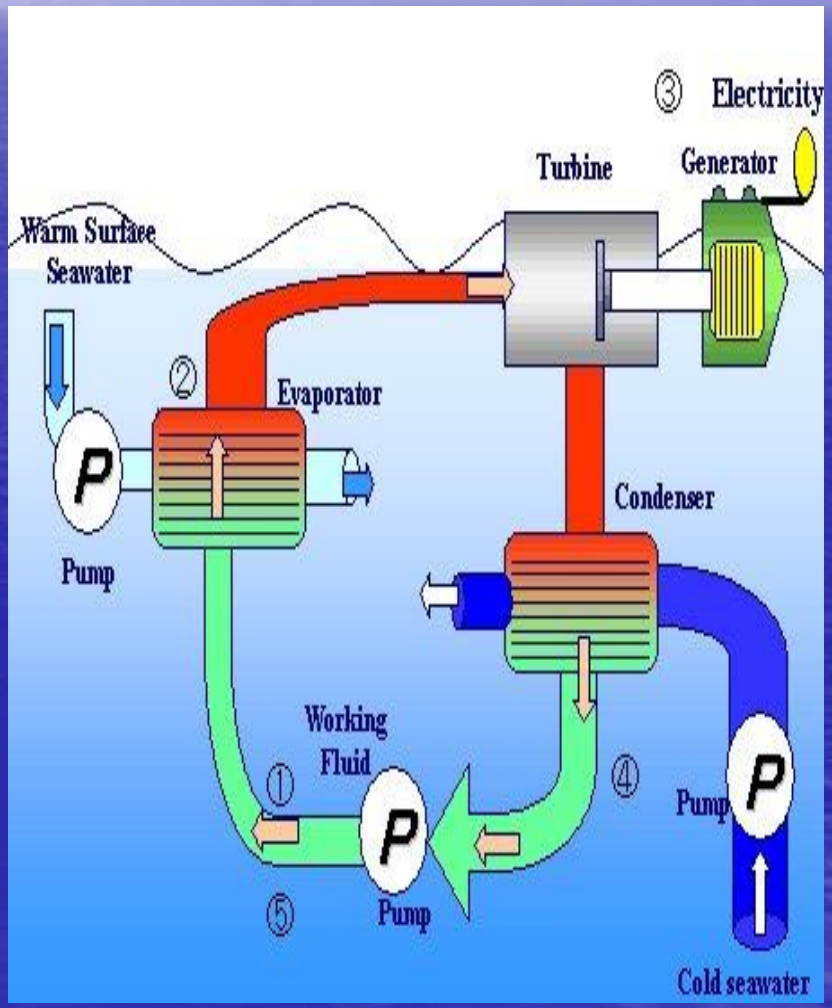
- Ocean Thermal Energy Conversion (OTEC) is a process which utilizes the heat energy stored in the tropical ocean.
- OTEC utilizes the difference in temperature between warm surface seawater and cold deep seawater to produce electricity.
- Because the oceans are continually heated by the sun and cover 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

Main Component

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



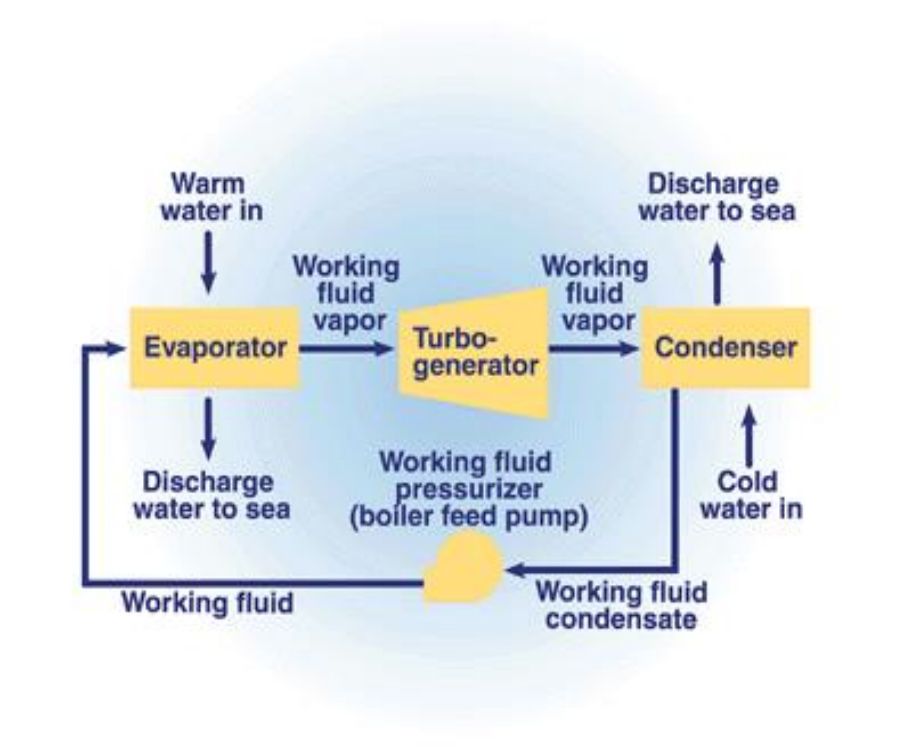
How OTEC Works

- 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

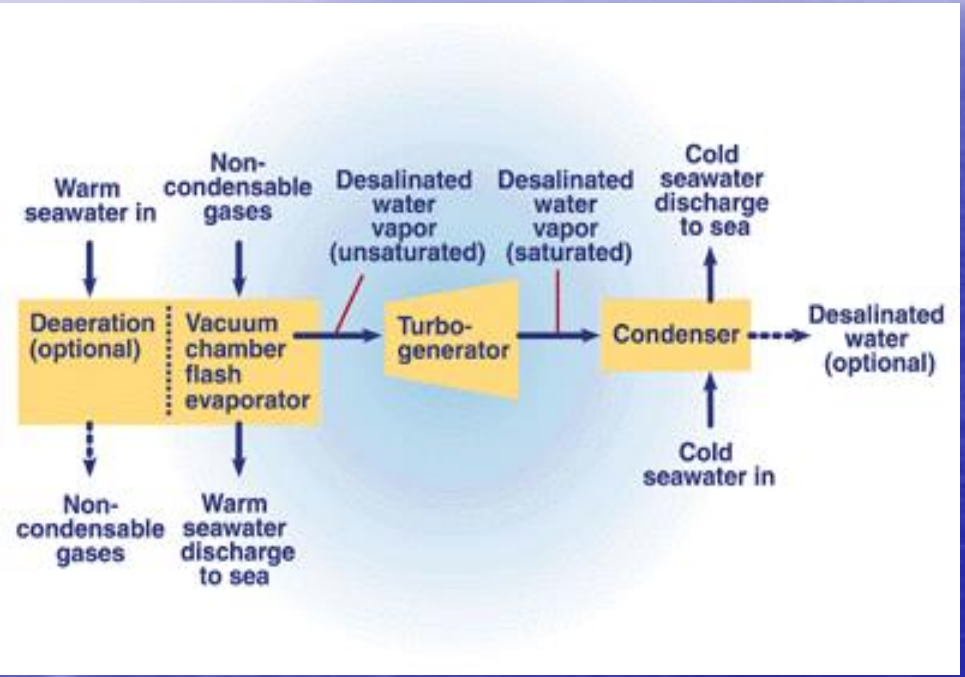
- 3 basic OTEC system designs have been demonstrated to generate electricity:
  - Closed cycle
  - Open cycle
  - Hybrid Cycle

Closed Cycled



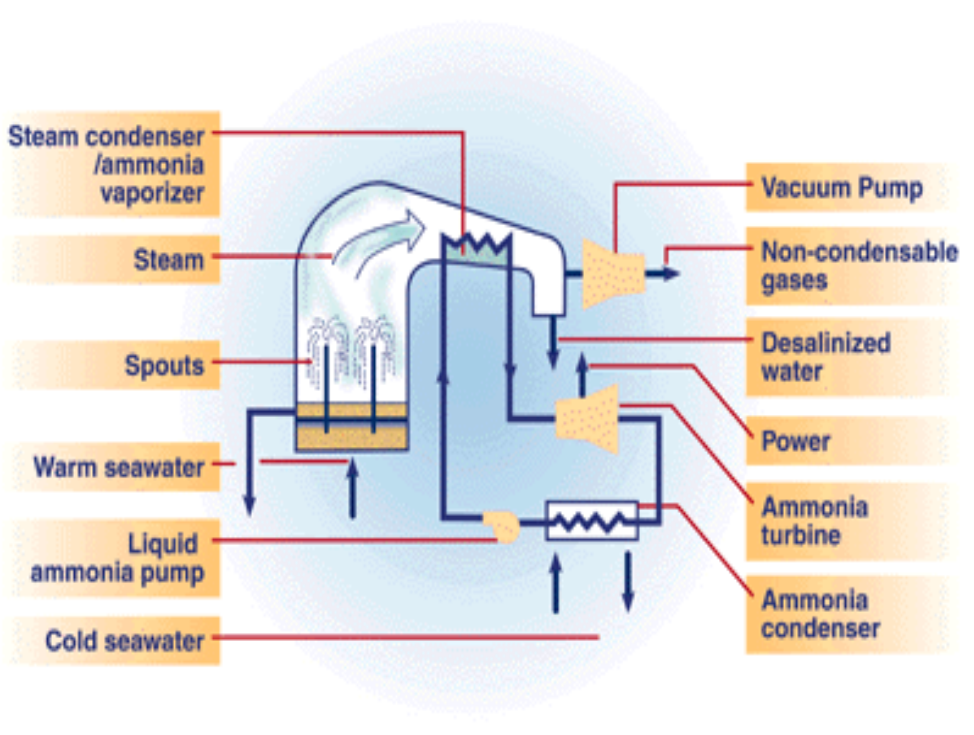
- In the closed-cycle OTEC system, warm seawater vaporizes a working fluid, such as ammonia, flowing through a heat exchanger (evaporator).
- The vapor expands at moderate pressures and turns a turbine coupled to a generator that produces electricity.
- The vapor is then condensed in condenser using 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 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.

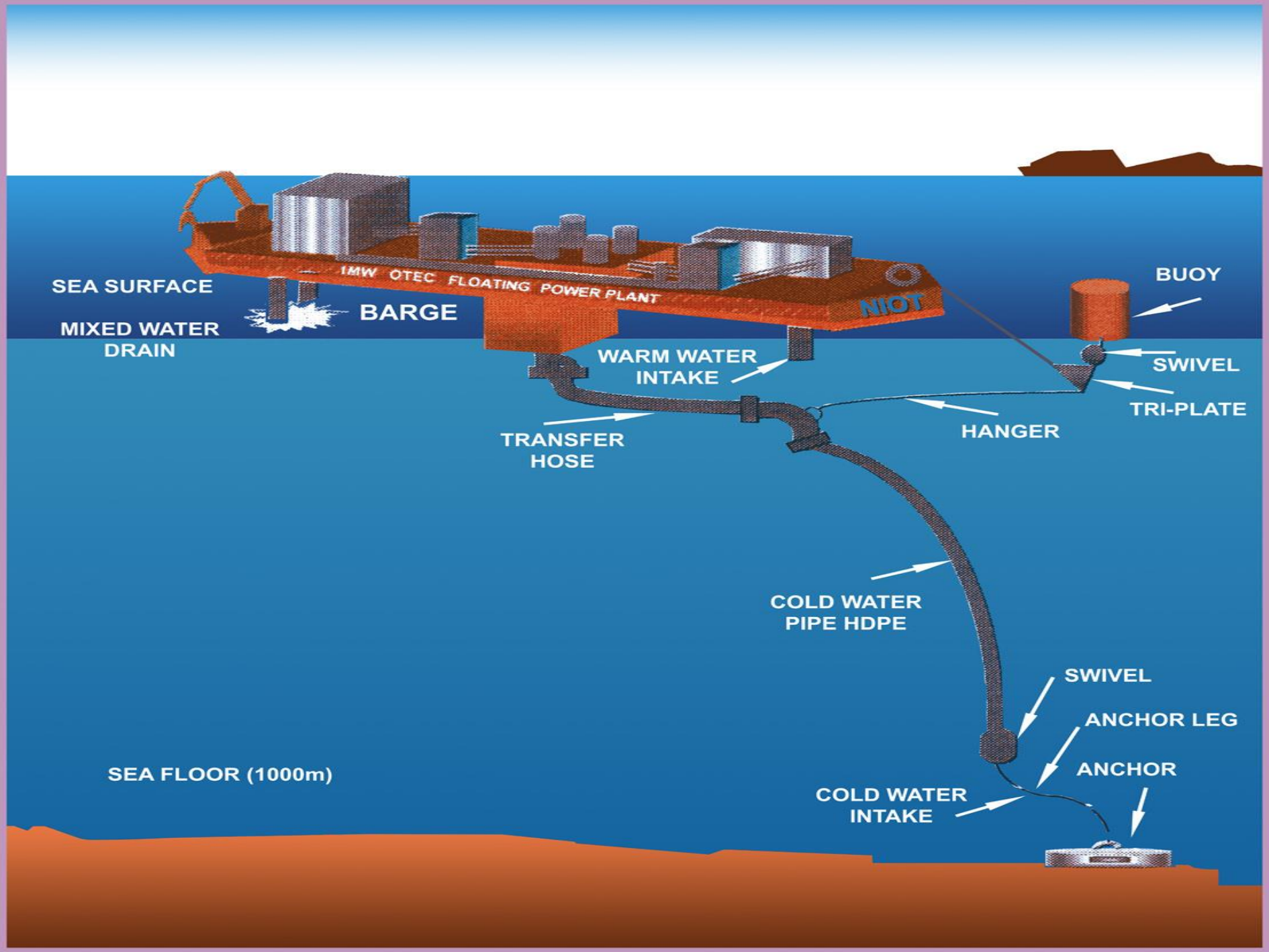
Hybrid Cycle



- 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.

OTEC Classification

- **Depending on the location**
  - Land based plant
  - Shelf based plant
  - Floating plant
  - Submerged plant
- **Depending on the cycle used**
  - Open cycle
  - Closed cycle
  - Hybrid cycle


SEA SURFACE
MIXED WATER DRAIN
1MW OTEC FLOATING POWER PLANT
NIOT
BARGE
BUOY
SWIVEL
TRI-PLATE
HANGER
WARM WATER INTAKE
TRANSFER HOSE
COLD WATER PIPE HDPE
SWIVEL
ANCHOR LEG
ANCHOR
COLD WATER INTAKE
SEA FLOOR (1000m)

Site Consideration

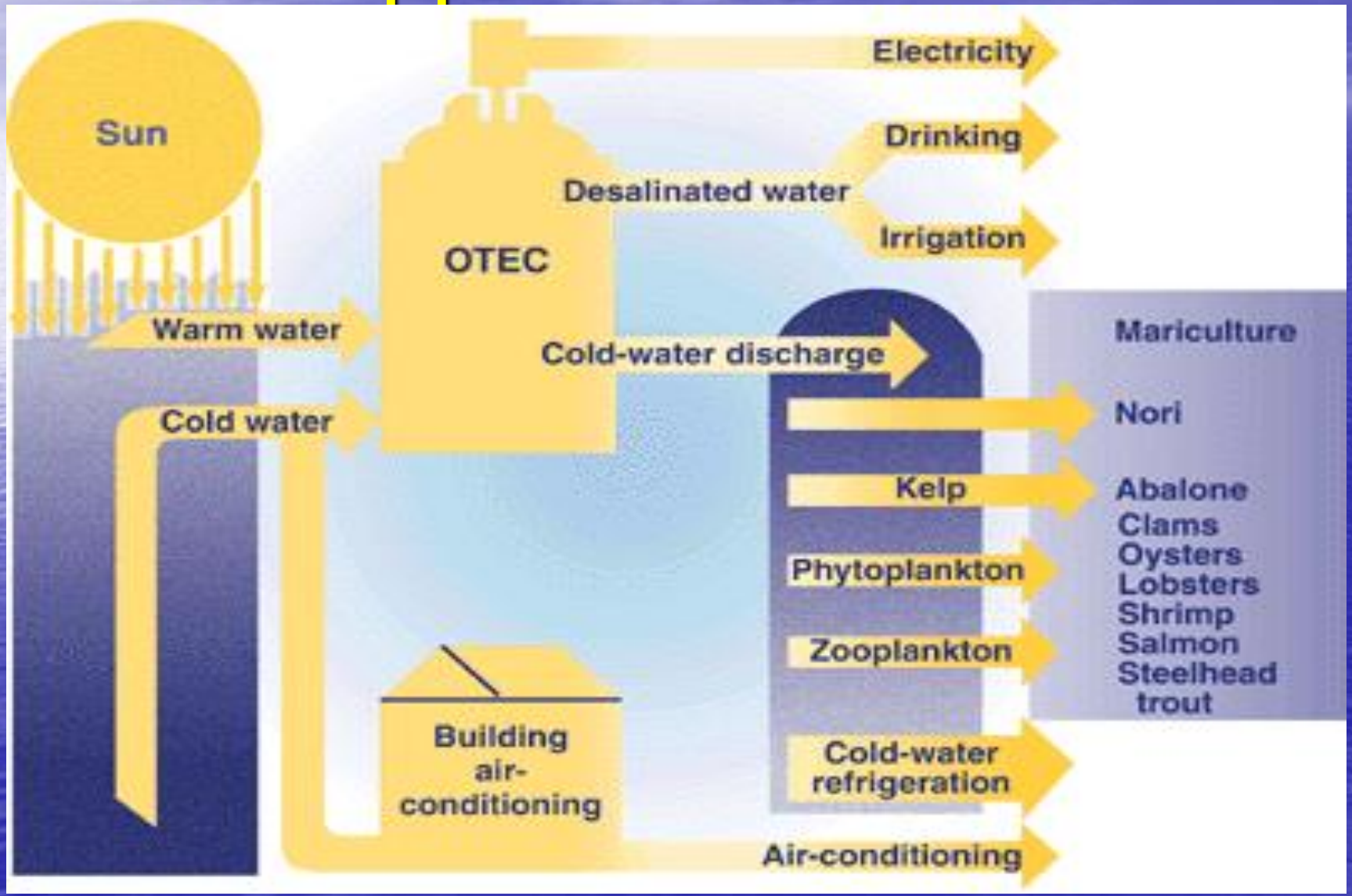
Factors to be considered while choosing a site:

- **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.

OTEC Application



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

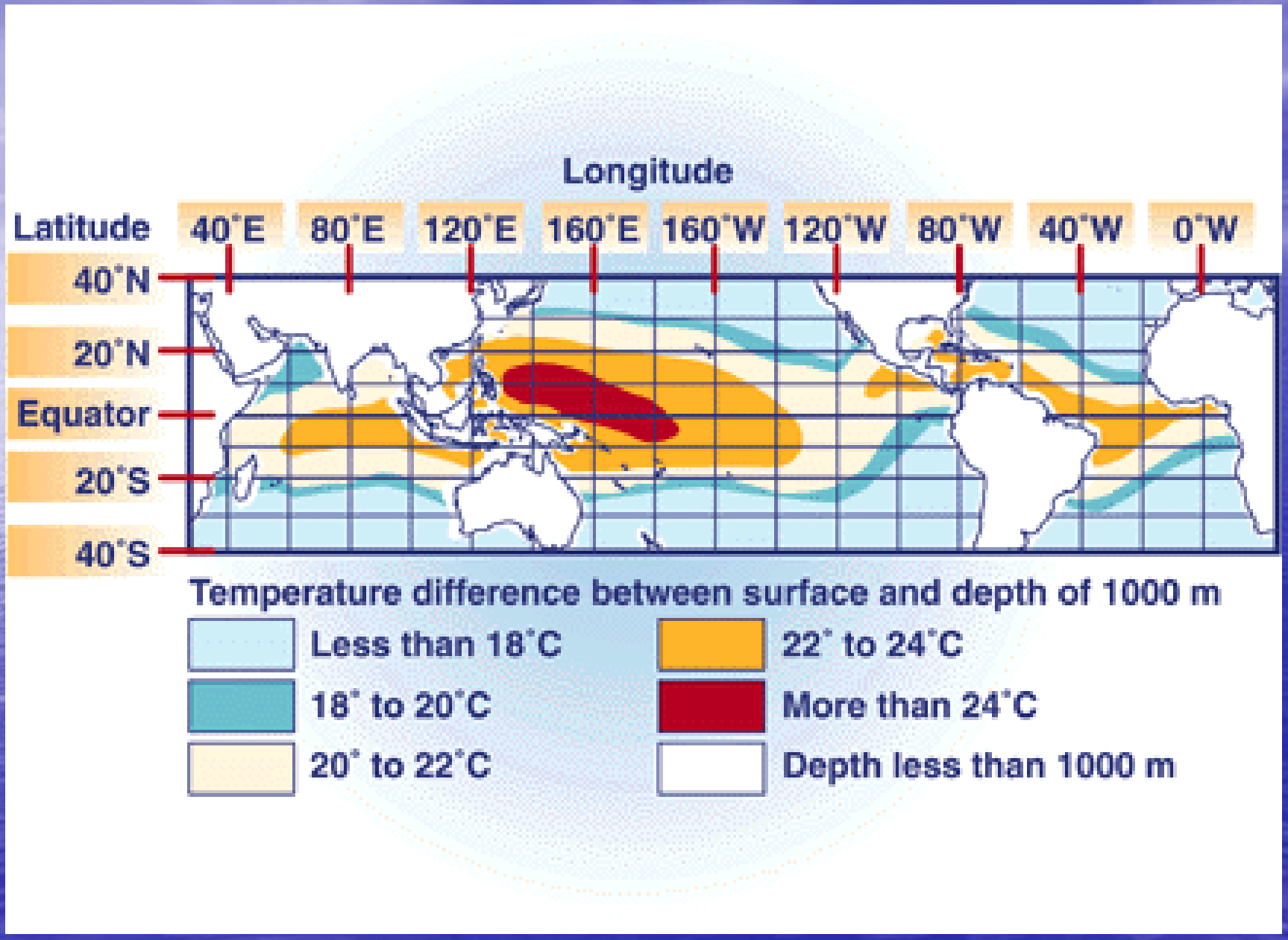
- The cold [5°C (41°F)] seawater made available by an OTEC system creates an opportunity to provide large amounts of cooling to operations that are related to or close to the plant.
- The cold seawater delivered to an OTEC plant can be used in chilled-water coils to provide air-conditioning for buildings.

Benefit of OTEC

- No fuel burned , carbon dioxide 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 m^3)

Disadvantage

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


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

Market of OTEC

- Ocean thermal energy conversion (OTEC) plants may be competitive :
  - In the small island with the relatively high cost of diesel-generated electricity and desalinated water
  - 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.

Conclusion

- OTEC uses the difference in temperature between warm surface seawater and cold deep seawater to produce electricity.
- With Ocean cover 70% of earth's surface that's absorb sunlight, OTEC is a prospective alternative source of energy for human use.
- 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.
- The capital cost of installation is still extremely high and at the present time the technology remains at the planning/feasibility study stage.