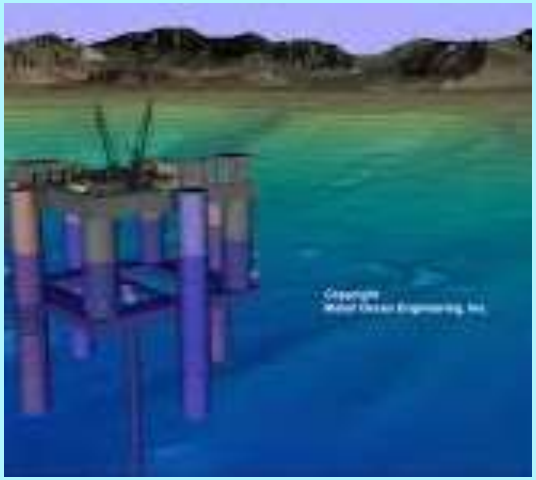
# Unit 5:- Other Alternate Sources

*Ocean Thermal Energy Conversion*



# Syllabus…Unit 5

- **Other Alternate Sources:** Ocean Thermal Energy Conversion, Geothermal, Tidal, Wave Energy, MHD, Fuel Cells, environmental issues of energy services.

# Books …


- Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley - IEEE
Press, August 2004.
- Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
- Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

**Supplementary Reading:**

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

# Lecture 1 Ocean Thermal Energy Conversion (OTEC)

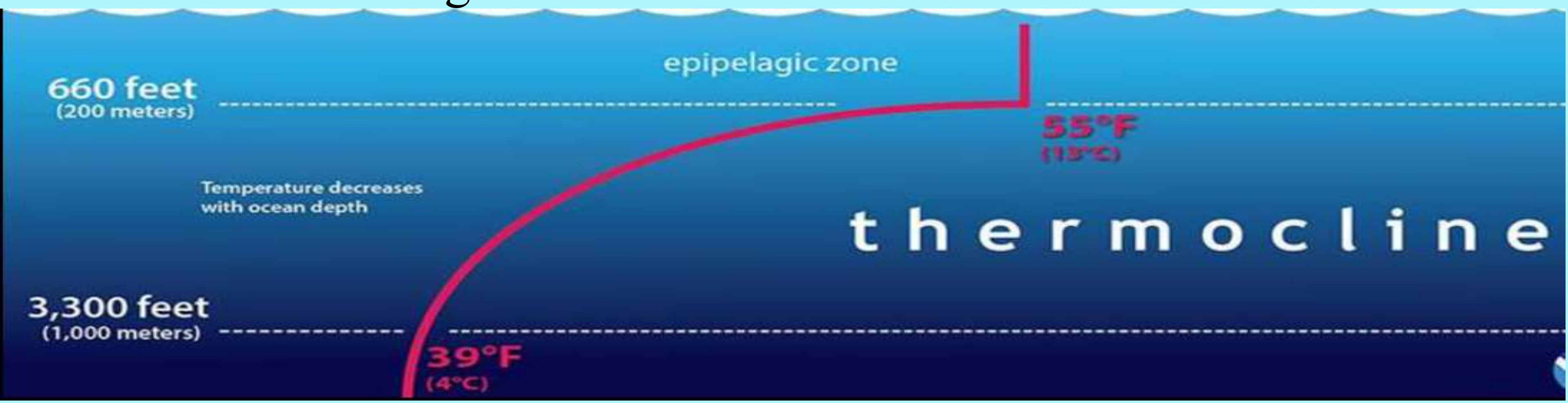
- Ocean Thermal Energy Conversion
- O T E C Characteristics
- Ocean Thermal Temperature
- OTEC History
- OTEC Plants
- OTEC Advantages
- OTEC Disadvantages
- OTEC Plant Theory
- OTEC Plant Classification
- Closed Cycle
- Open Cycle
- Land based OTEC Plant
- Off shore OTEC Plant
- Other Uses, Benefits
- Limitations

# Ocean Thermal Energy Conversion

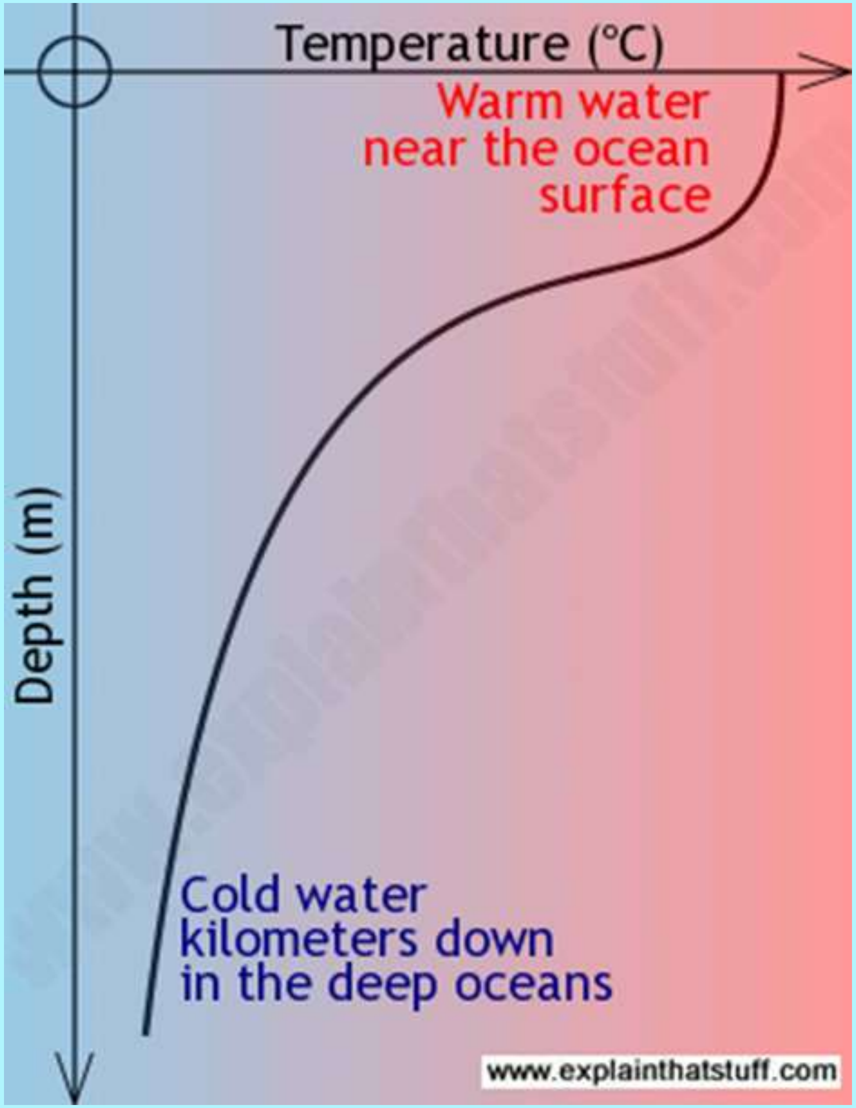
- The oceans cover a around 71 percent of the Earth's surface. Hence, world's largest solar energy collector and energy storage system.
- Ocean thermal energy conversion (OTEC) is a way to generate electricity using the temperature difference of sea water at different depth to run heat engines and produce useful work.
- Since OTEC exploits renewable solar energy, recurring costs to generate electrical power are minimal.
- OTEC utilizes the world’s largest solar radiation collector - The ocean.  The ocean contains enough energy power all of the world’s electrical needs.

# O T E C Characteristics

- It uses the ocean's naturally available temperature gradient (thermocline), or thermal energy.
- It is completely Green Renewable Energy
- Unlike Solar or wind, available continuously as a base load. Thus eliminating the need to store energy.
- Up to 88,000 TWh/yr of power could be generated from OTEC without affecting the ocean's thermal structure.



# Ocean Thermal Temperature




- A heat engine efficiency is greater for large temperature difference.
- In the oceans the temperature difference is greatest in the tropics, although still a modest 20 to 25 °C.
- OTEC has the potential to offer global amounts of energy that are 10 to 100 times greater than other ocean energy options such as wave power

# OTEC History

- In 1881, Jacques Arsene d'Arsonval, a French physicist, proposed tapping the thermal energy of the ocean
- . D'Arsonval's student, Georges Claude, built the first OTEC plant, in Matanzas, Cuba in 1930, The plant was later destroyed in a storm
- In 1935, Claude constructed a plant aboard a 10,000-ton cargo vessel moored off the coast of Brazil.Weather and waves destroyed it before it could generate net power
- In 1962, J. Hilbert Anderson and James H. Anderson, Jr. focused on increasing component efficiency. They patented their new "closed cycle" design in 1967.

# OTEC History

- Japan is a major contributor to the development of OTEC technology. Beginning in 1970 the Tokyo Electric Power Company successfully built and deployed a 100 kW closed-cycle OTEC plant on the island of Nauru

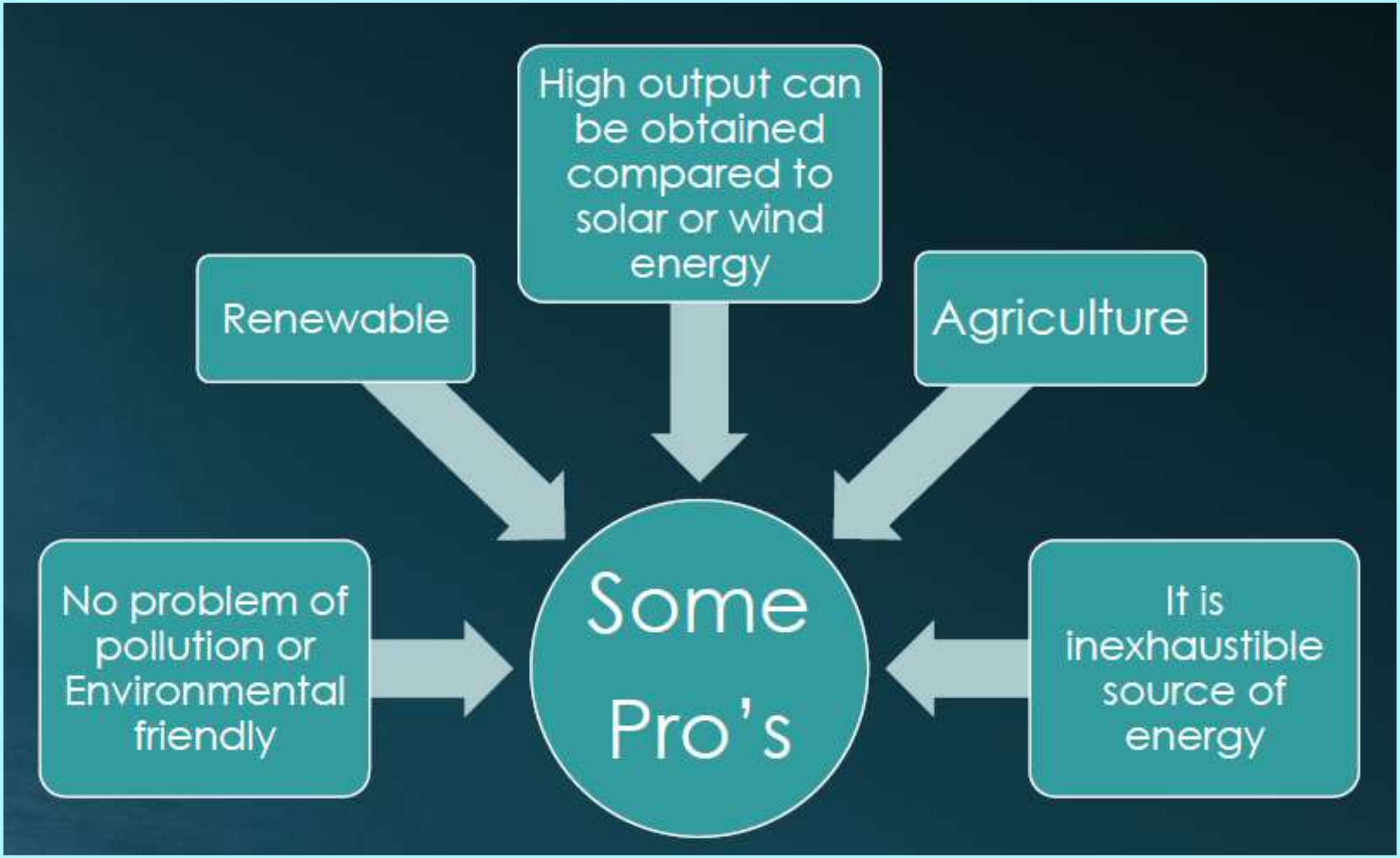
- OTEC test facility at Keahole Point, Kona, Hawaii (estd. 1974)

- In 2002, India tested a 1 MW floating OTEC pilot plant near Tamil Nadu.

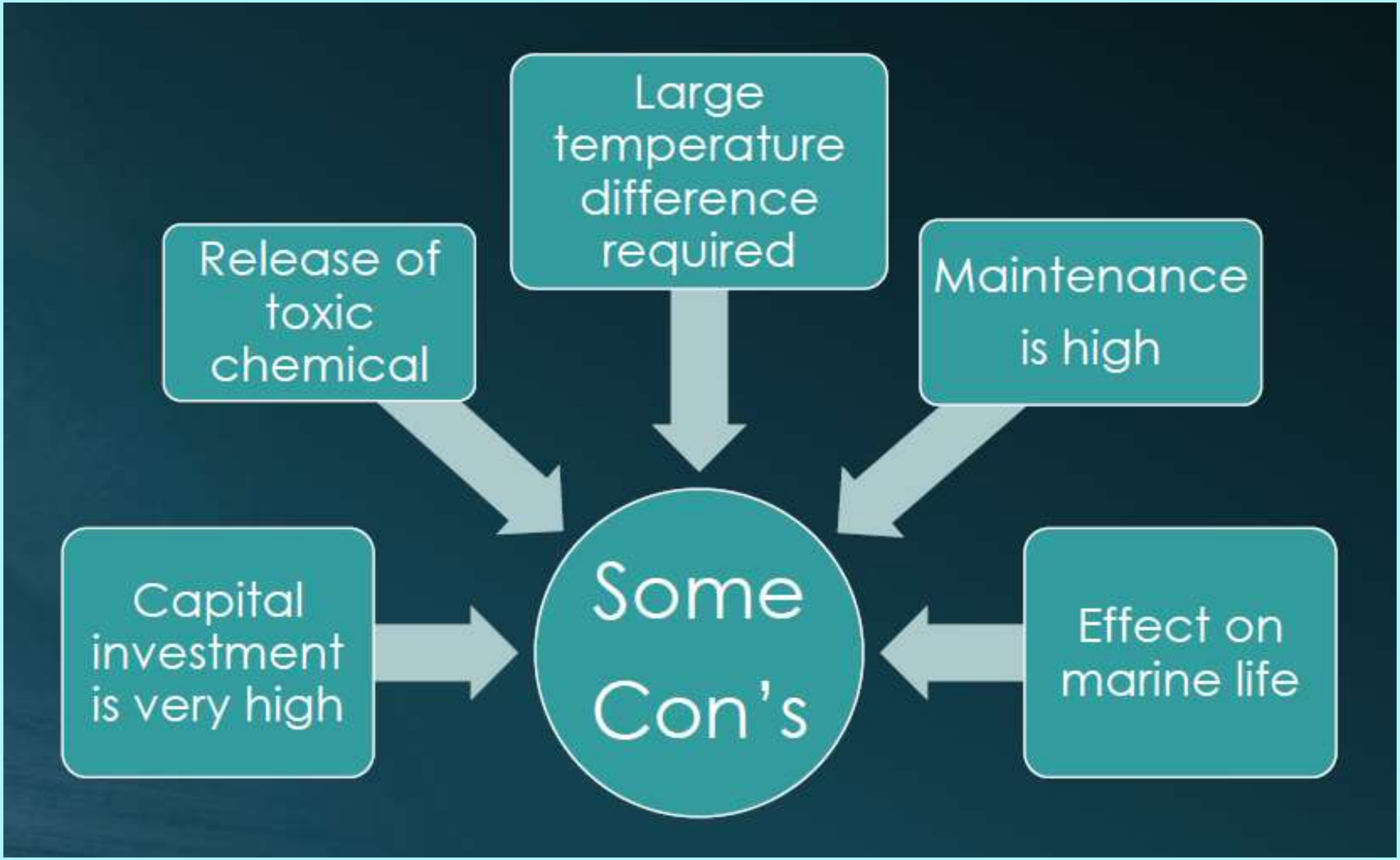
# OTEC Plants

| Country | Power output | Purpose | Year |
| --- | --- | --- | --- |
| Saga, Japan | 30 kW | Research and development | 1980 |
| Gosung, Korea | 20 kW | Research and development | 2012 |
| Reunion Island, France | 15 kW | Research and development | 2012 |
| Kumejima, Japan | 100 kW | Research and development, electricity production | 2013 |
| Hawaii, USA | 105 kW | Electricity production | 2015 |

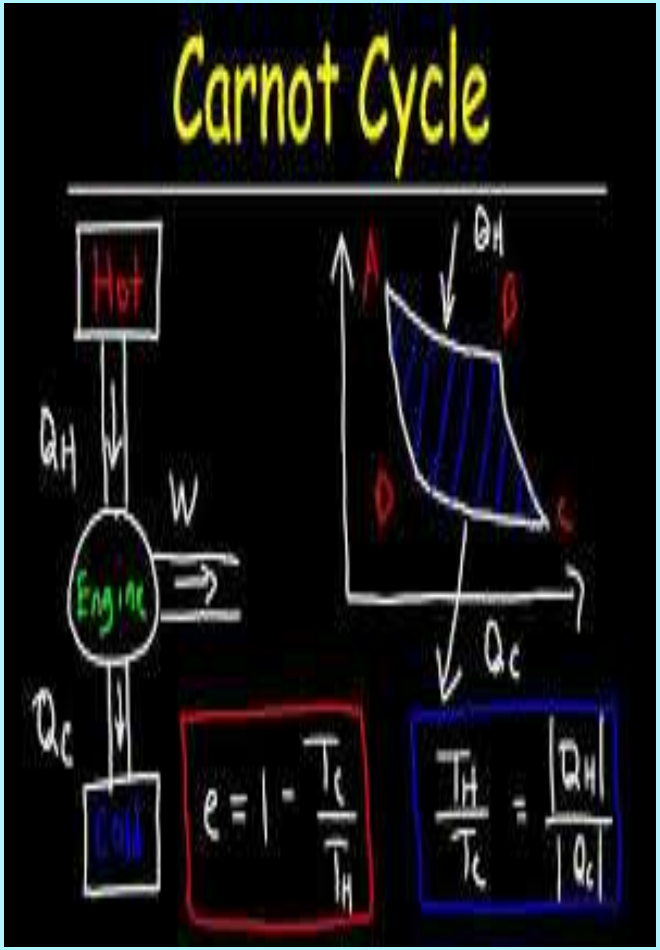
# OTEC Advantages



# OTEC Disadvantages

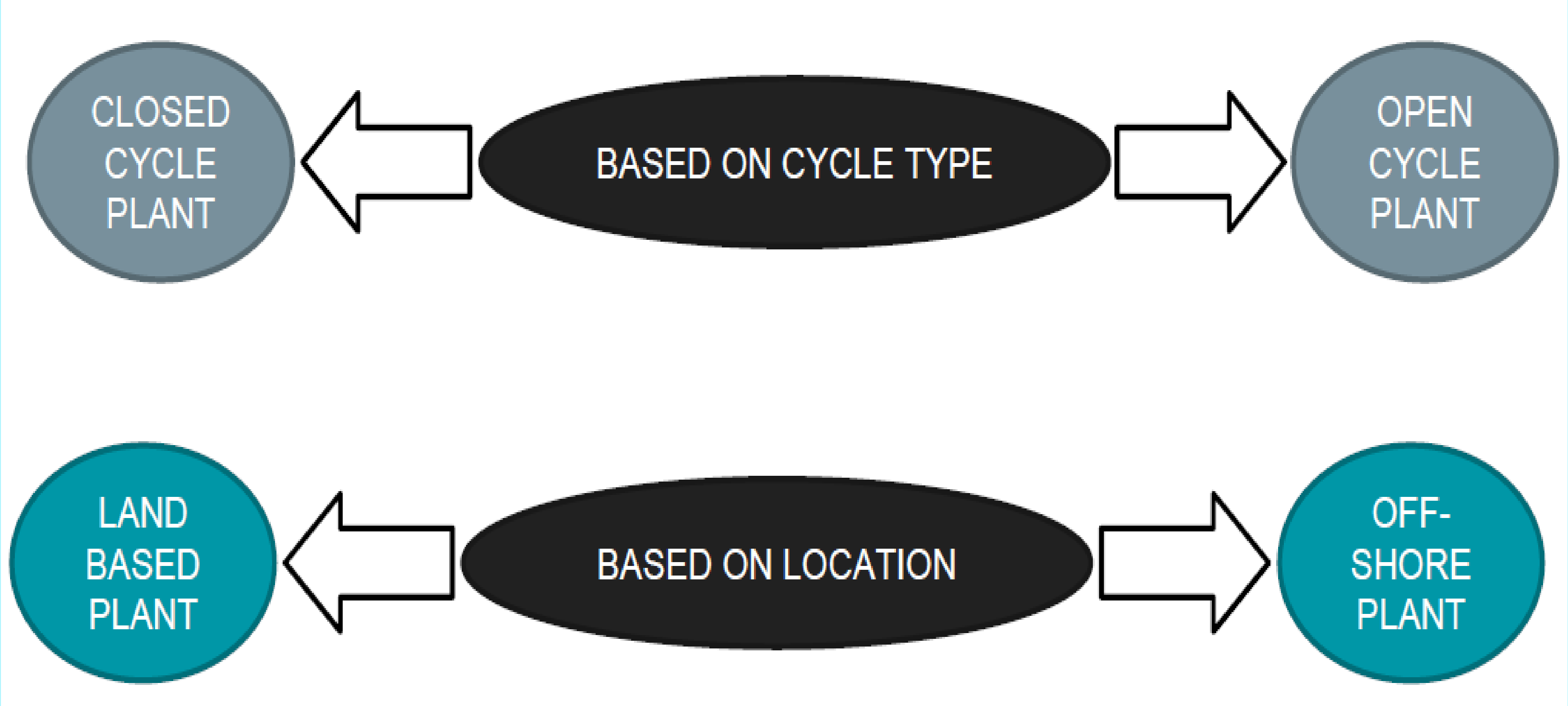


# OTEC Plant Theory

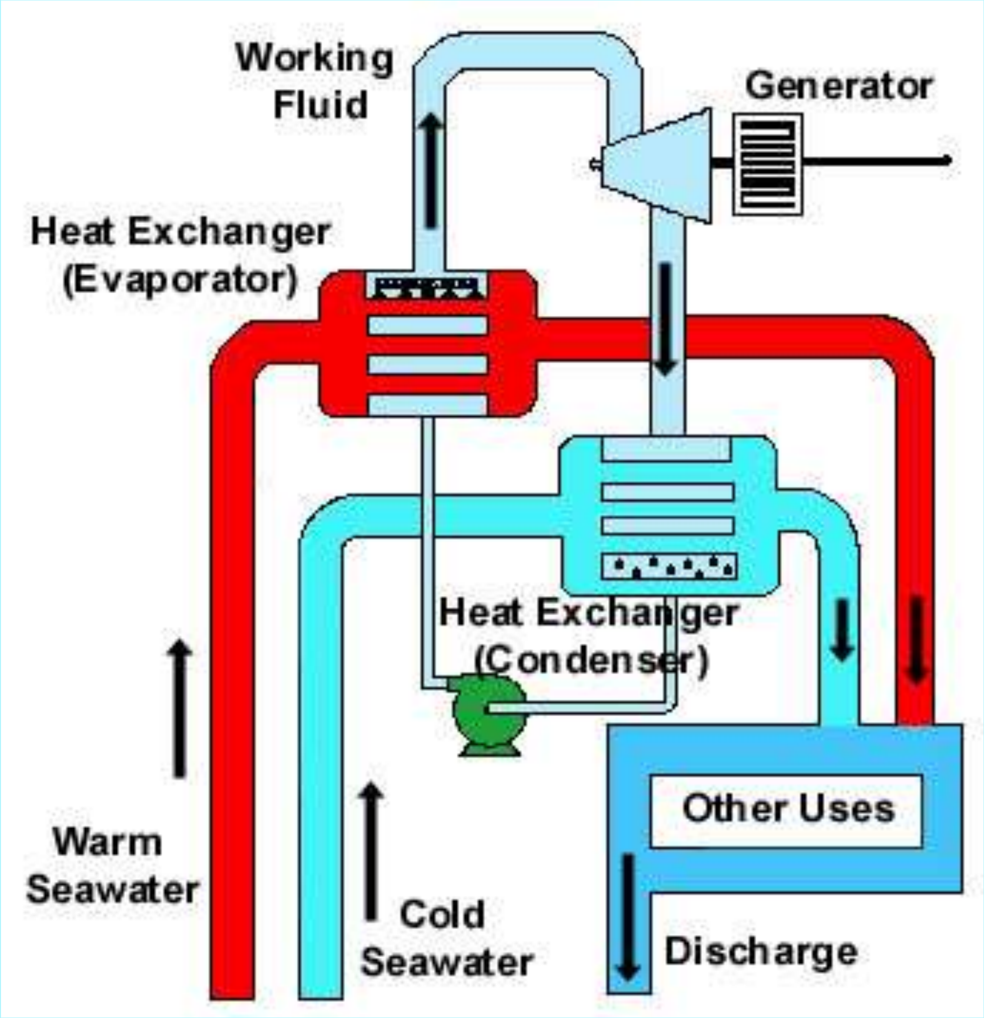



Thermodynamic efficiency:
The main technical challenge of OTEC is to generate significant amounts of power efficiently from small temperature differences. It is still considered an emerging technology. Early OTEC systems were 1 to 3 percent thermally efficient, well below the theoretical maximum 6 and 7 percent for this temperature difference. Modern designs allow performance approaching the theoretical maximum Carnot efficiency.

# OTEC Plant Classification

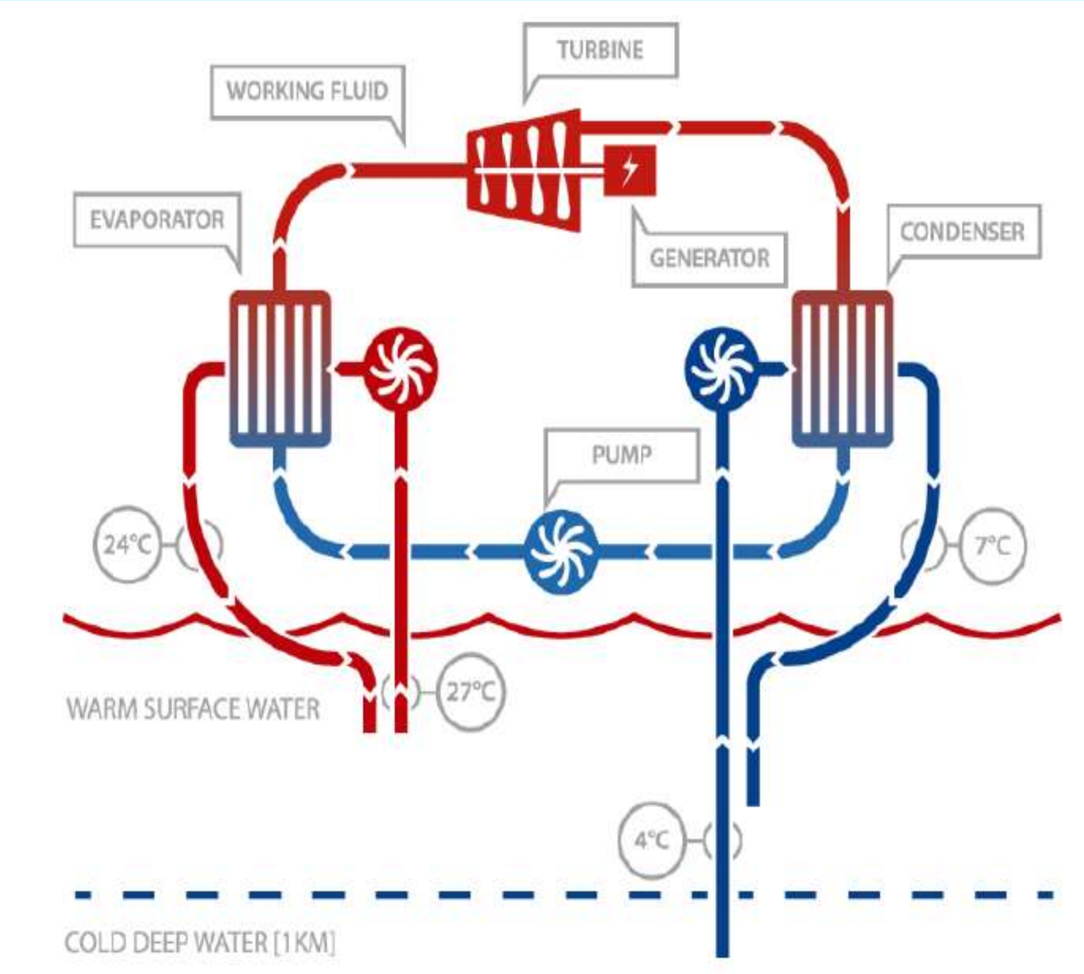


# OTEC Closed Cycle

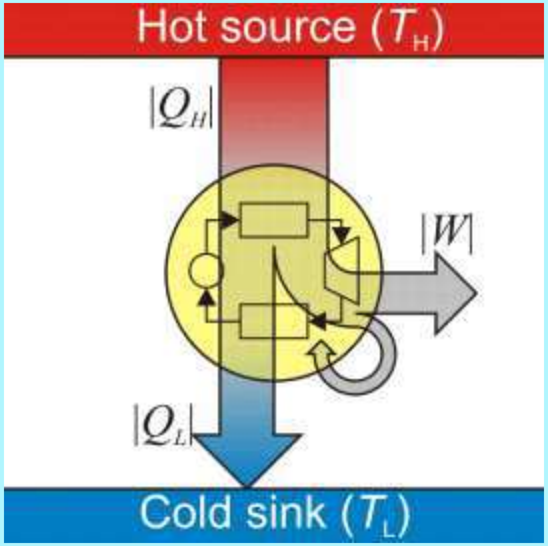



Closed-cycle systems use fluid with a low boiling point, such as ammonia (having a boiling point around -33 °C at atmospheric pressure), to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor turns the turbo-generator.

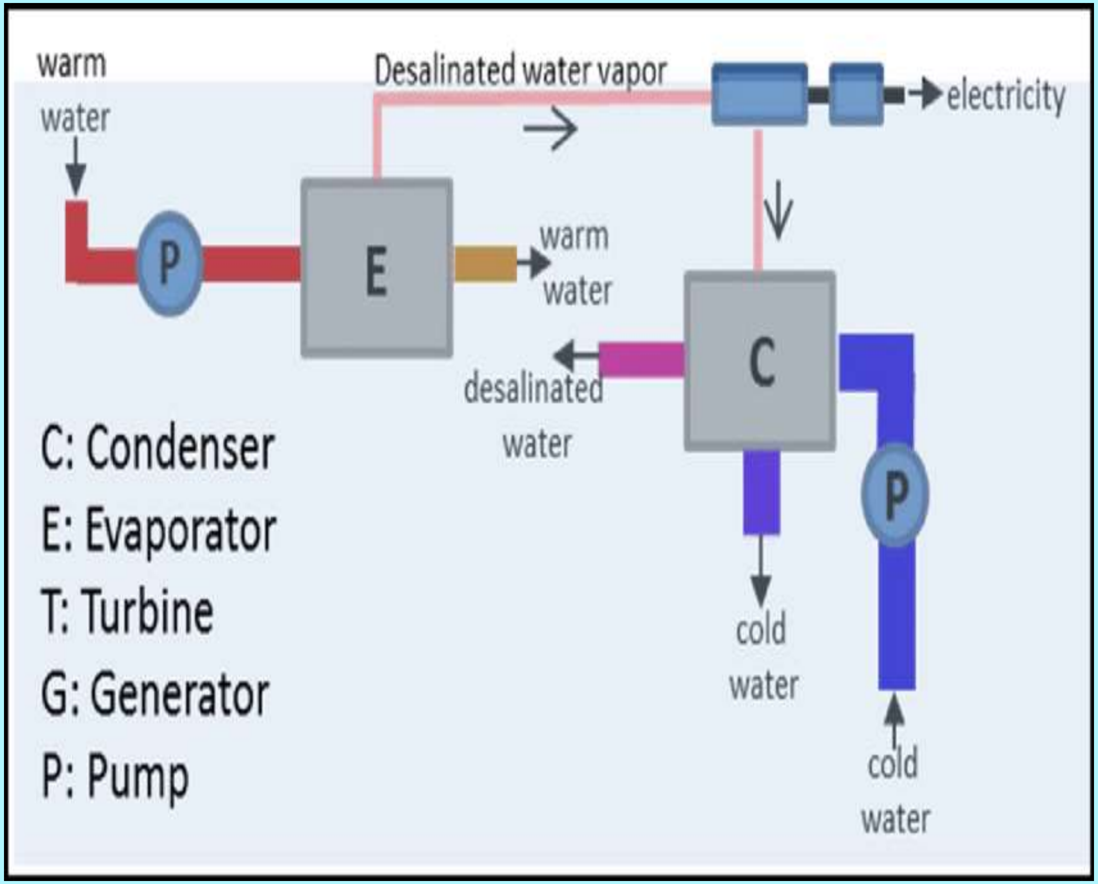
# OTEC Closed Cycle




Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.

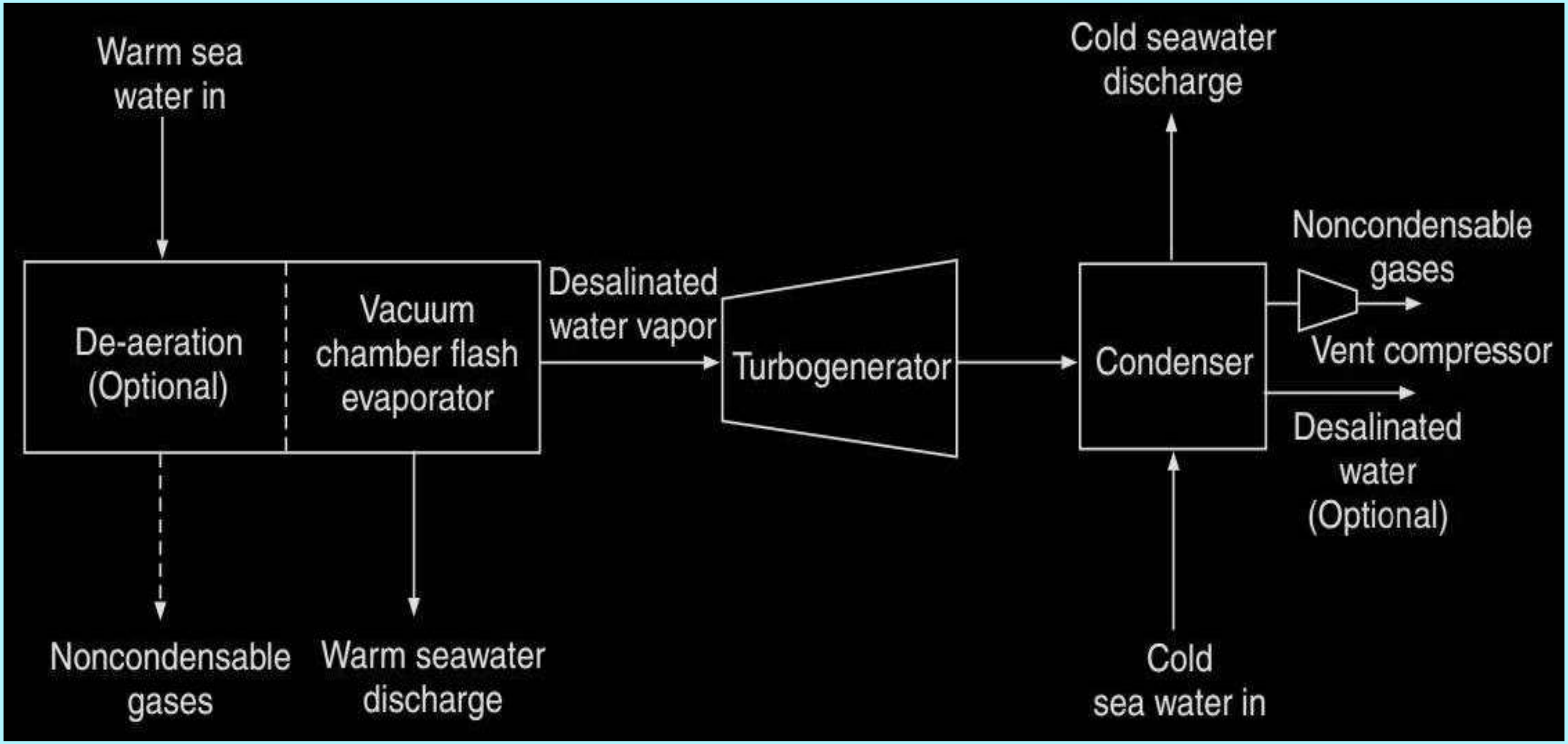


# OTEC Open Cycle



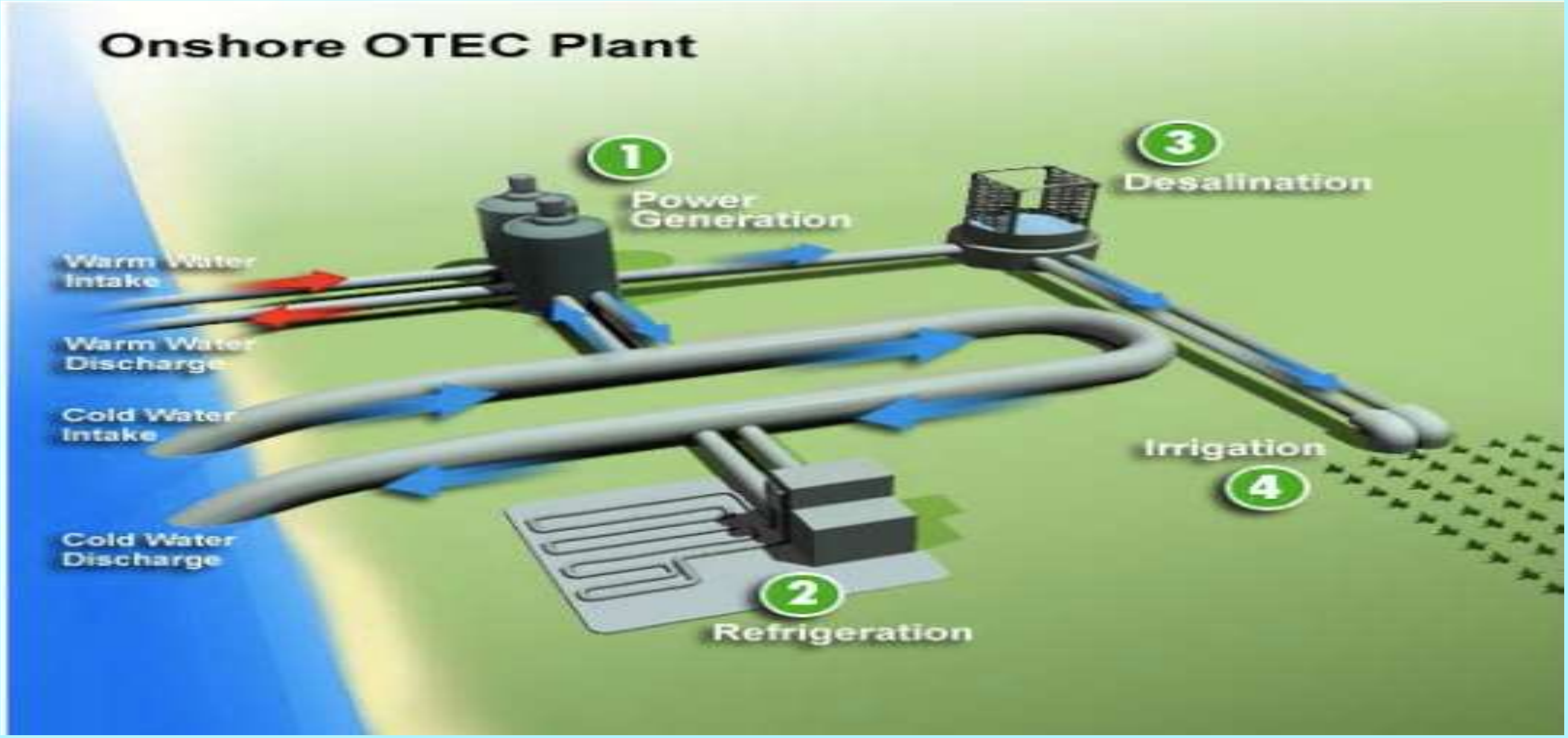

Open-cycle OTEC uses warm surface water directly to make electricity. The warm seawater is first pumped into a low-pressure container, which causes it to boil. In some schemes, the expanding vapor drives a low-pressure turbine attached to an electrical generator.

# OTEC Open Cycle



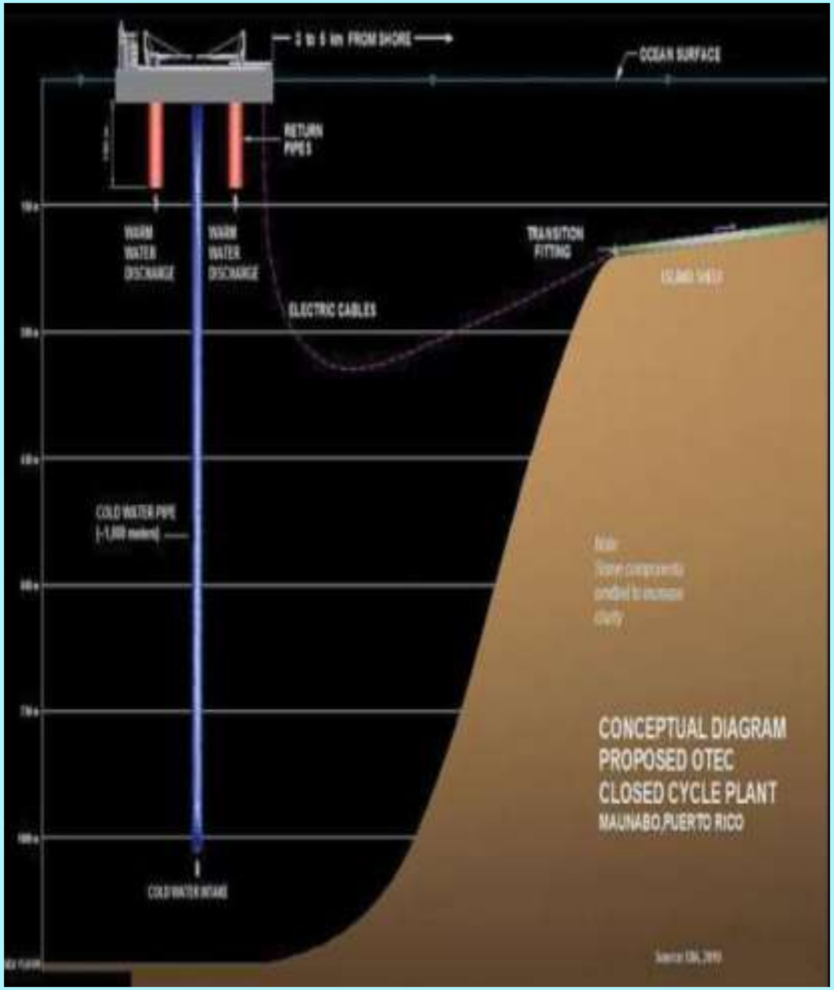

The vapor, which has left its salt and other contaminants in the low-pressure container, is pure fresh water.

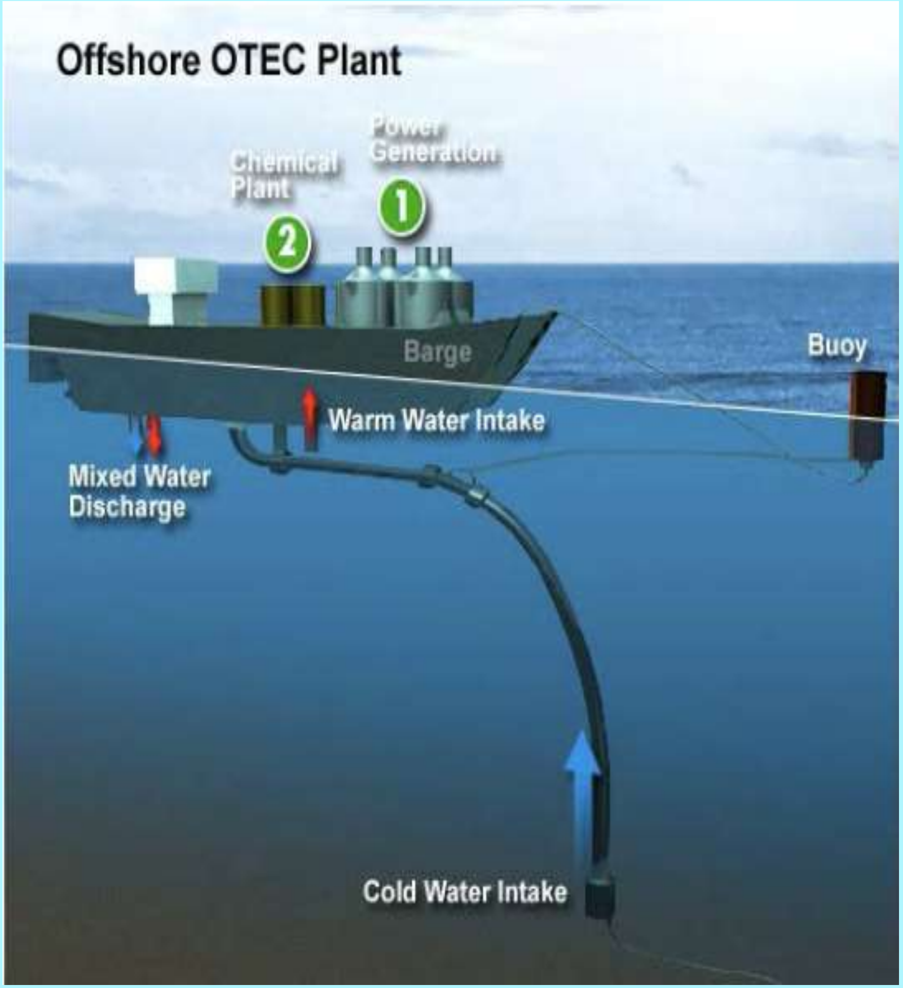
# Land based OTEC Plant



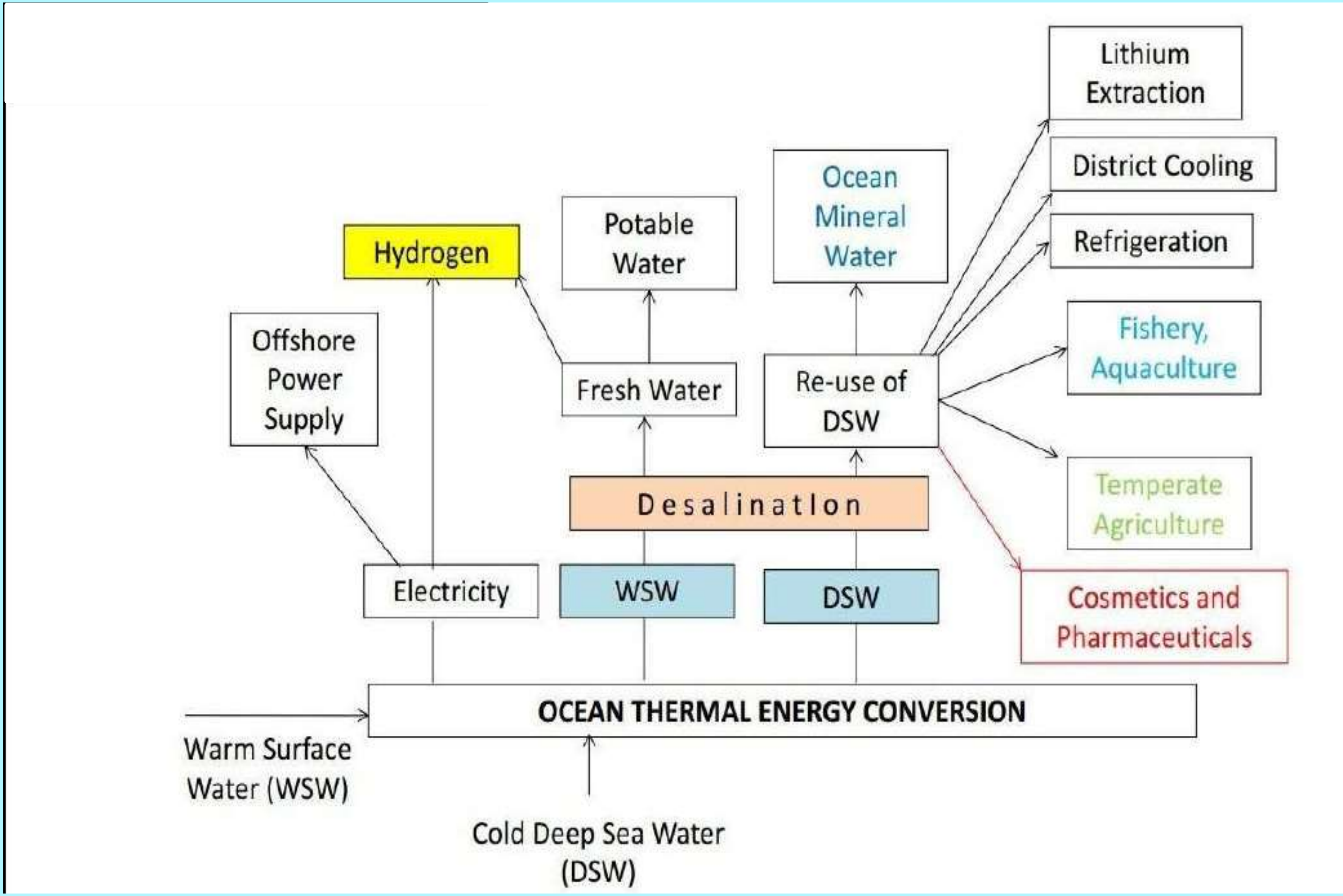

Notice how it can be used for irrigation and refrigeration besides power generation.

# OFFSHORE OTEC Plant



# OTEC Other Uses



# OTEC Benifits

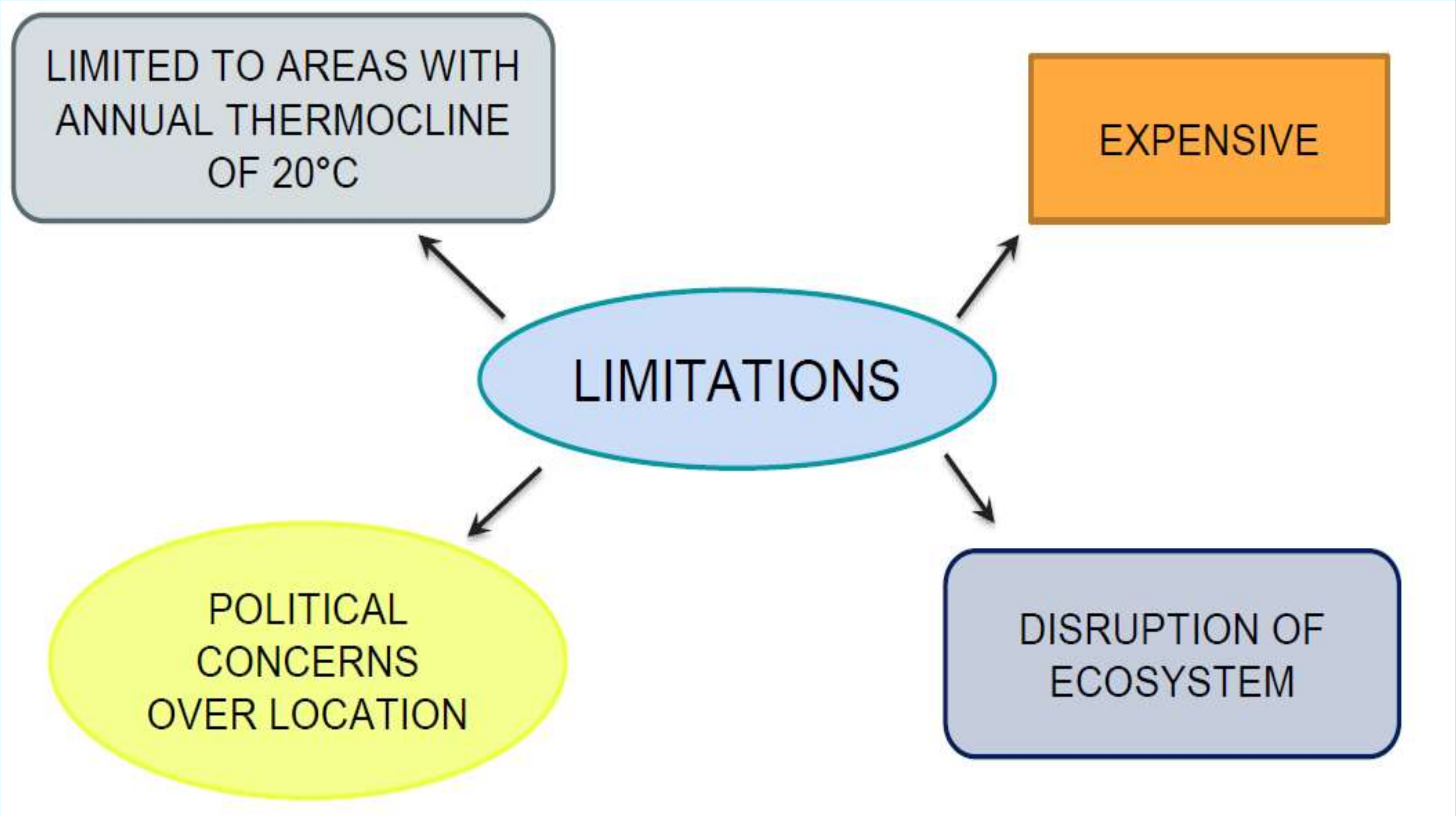
**Direct Benefits**

- No Fuel
- Abundant Supply
- Fresh Water
- Renewable

**Indirect Benefits**

- Predictable Cost
- Agriculture
- Potable Water
- Independence of Fossil Fuels
- Reduced Carbon Footprint

# OTEC Limitations



**Thank You**