Ocean Energy Technology

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Outline

- Types of Ocean Energy
- Ocean Energy Potential
- Energy from Tides
- Energy from Waves
- Energy from Temperature Differences
- Energy from Salinity Gradient

Types of Ocean Energy

Ocean energy resources are contained in:

1. Tidal & Currents
2. Waves
3. Temperature Gradients
4. Salinity Gradients

https://www.ocean-energy-systems.org/ocean-energy/what-is-ocean-energy/

Ocean Energy Potential

Approximate Worldwide Ocean Energy Available

Phenomenon	Maximum Potential (in gigawatts)	Practicable to Exploit (in gigawatts)
Tides	2,500 (total dissipation)	20
Temperature difference (OTEC)	2×10^5 (based on total absorbed insolation in equatorial waters)	Near or onshore: 40 Offshore: 10,000
Waves	2,700 (on all the world's coastlines) 10,000 (open sea renewal rate)	500
Salinity gradients (pressure-retarded osmosis, PRO)	2,600	In early test phase
Marine currents	5,000	50
Offshore near-surface winds	20,000	1,000
For comparison:		
Total installed capacity/production of electric energy in 2008		World: 5,000/2,500[a] US: 1,050/500[a]
World freshwater hydroelectric capacity in 2005	4,000	715[a]

Note: All values are gigawatts, annual average. The powers quoted are annual-average useful mechanical (electrical) values, converted from thermal, where applicable, by a representative thermodynamic efficiency: e.g., 2.7% for OTEC.

Tidal & Currents

- **Tidal range**

The rise and fall of the tide (range) offers the opportunity to trap a high tide, delay its fall behind a barrage or fence, and then exhaust the potential energy before the next tidal cycle. The worldwide theoretical power of tidal power (including tidal currents) has been estimated at around 7,800 TWh / year.

- **Tidal current**

The movement of ocean water volumes, caused by the changing tides, creates tidal current energy. Kinetic energy can be harnessed, usually nearshore and particularly where there are constrictions, such as straits, islands and passes.

- **Ocean current**

Open ocean surface currents are driven by latitudinal distributions of winds (clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere).

Energy from Tides

- The tides are cyclic variations in the level of seas and oceans
- The tides represent the planetary manifestation of the potential and kinetic energy fluxes present in the Earth–Moon–Sun system.
- This results in some regions of the world possessing substantially higher local tidal variation than others.
- There are two different means to harness tidal energy. The first is to exploit the cyclic rise and fall of the sea level using barrages. The second is to harness local tidal currents.

Meisen, P. Ocean Energy Technologies for Renewable Energy Generation.

Tidal Bulges (cont’d)

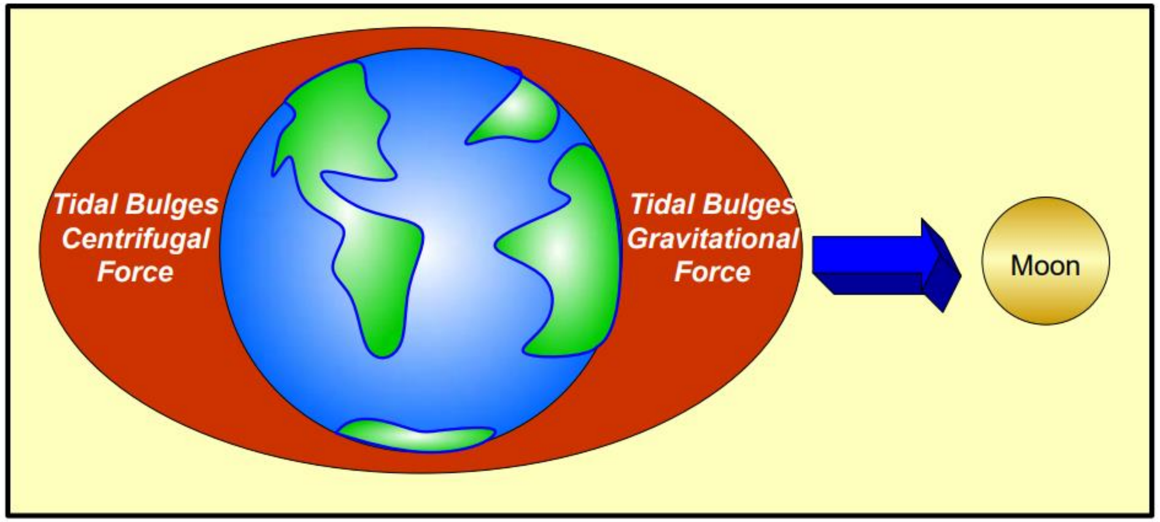


Figure 3.1 Tidal Bulges due to the Gravity and Centrifugal Forces

- The moon maintains its position with respect to the earth due to the gravitational force that pulls the earth and the moon together.
- The sun also plays a role on the balance of the entire system.
- Gravitational force is proportional to the square of the distance between two bodies.
- Tidal force is proportional to the cube of the distance.
- The moon is closer to the earth, therefore the effects of the moon on the generation of tides is $2^{1}/_{4}$ greater than that of the sun.

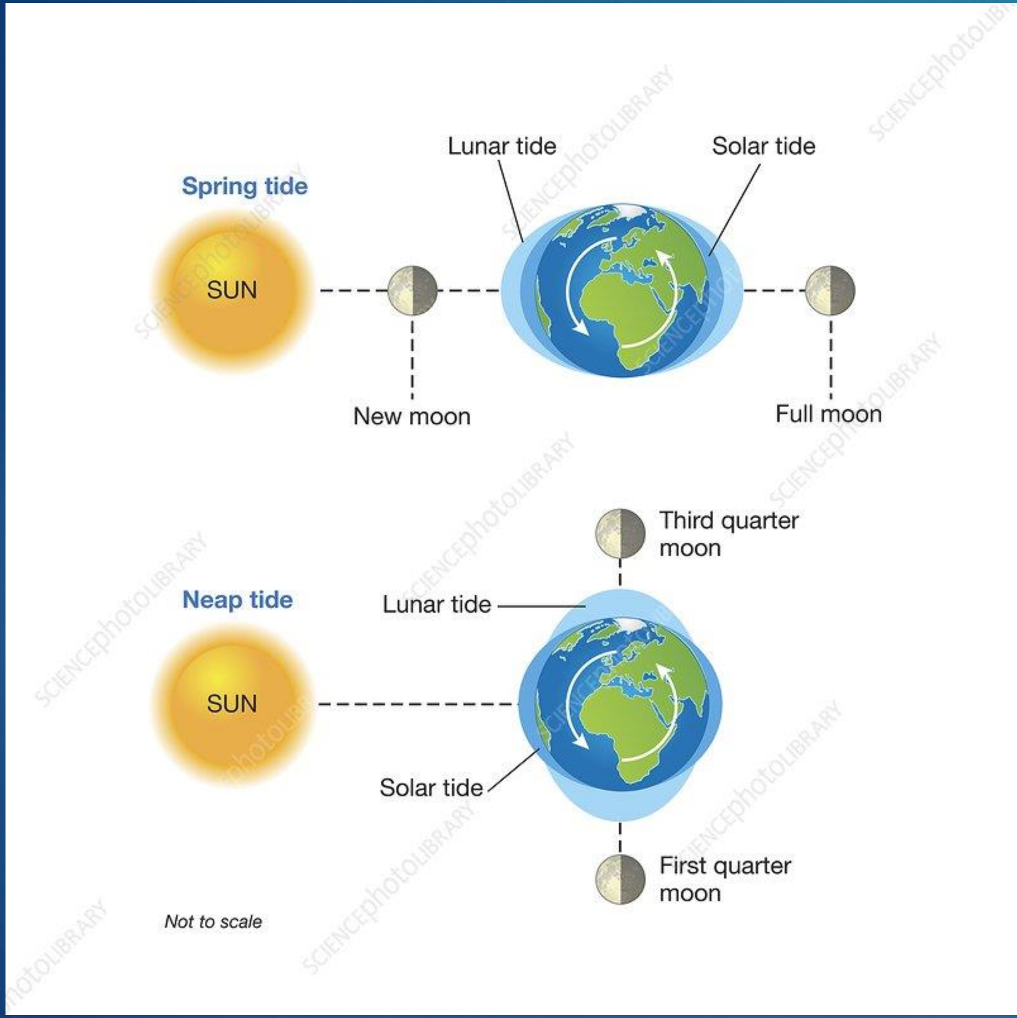
https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf

Tidal Bulges

- The gravitational force of attraction of the moon causes that the oceans waters bulge on the side of the earth that faces the moon.
- The centrifugal force produce the same effect but in the opposite side of the earth.
- On these two sides we can observe the maximum amplitudes of the tides (high tides) and on the midways of it occur the minimum amplitudes of the tides (low tides).
- As the earth rotates these two bulges travel at the same rate as the earth's rotation. The moon rotates around the earth with respect to the sun approximately 29.5 days (lunar month) in the same direction that the earth rotates every 24 hours.
- The rotation of the earth with respect to the moon is approximately 24.84 hours (24 hours and 50 minutes) and is called lunar day. This is the reason of why the tides advance approximately 50 minutes each day.

https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf

Tidal Bulges



- The gravitational force of the sun causes that the ocean waters bulges too but in a lesser degree.
- Twice a month, when the earth, the moon and the sun are aligned (full and new moon) the tide generating forces of the sun and the moon are combined to produce tide ranges that are greater than average knowing as the spring tides.

https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf
What are spring and neap tides? (noaa.gov)

Tidal Bulges

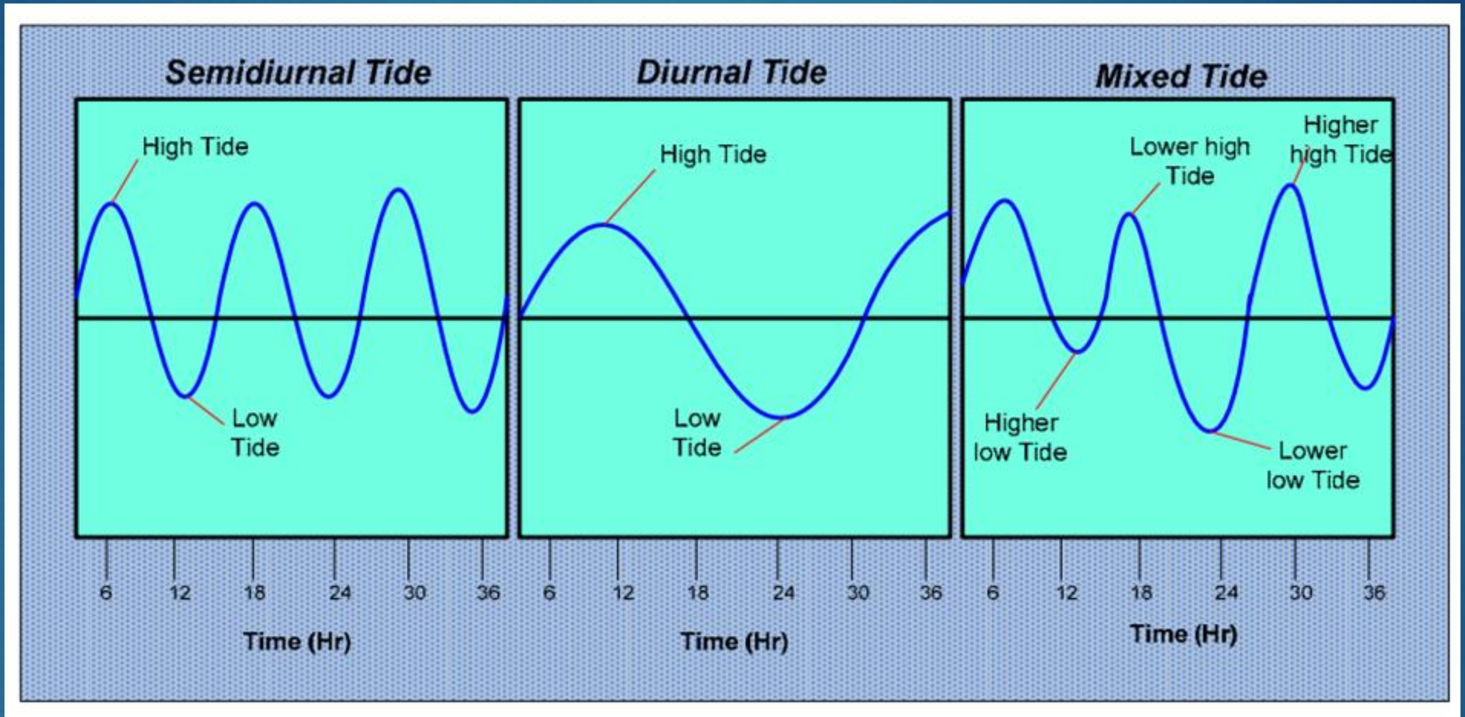
- At half moon (first and third quarters) the sun and the moon are 90° with respect to the earth and the tide generating forces tend to produce tidal ranges that are less than the averages knowing as the neap tides.
- Typically the spring tides ranges tend to be twice of the neap tides ranges.

https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf

Type of Tides

- The tidal movements can be reflected and restricted by the interruption of masses of land, the bottom friction can reduce its velocity and the depth, size and shape of the ocean basins, bays and estuaries altered the movements of the tidal bulges and generate different types of tides.
- There are three types of tides: diurnal, semidiurnal and mixed.
- Diurnal tides (daily) present one single high and low water during a period of a lunar day of 24 hours and 50 minutes and occur in the Gulf of Mexico, Southeast Asia and the coast of Korea.

https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf



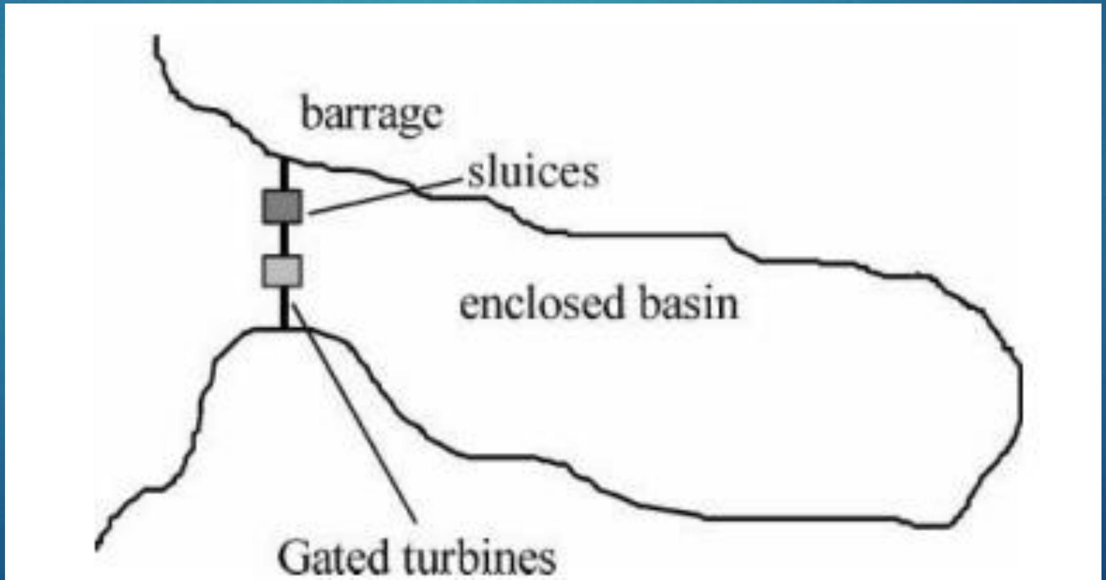
- Semidiurnal tides (twice a day) present two high and two low waters during a lunar day with periods of 12 hours and 25 minutes and is common along the Atlantic coast of North America
- The mixed tides that presents two unequal high and two unequal lows waters and generally have periods of 12 hours and 25 minutes.

Tidal Energy to Electric Energy Conversion

- The technology that is used to produce electricity using the difference between the low and high tides is very similar to the one use on the generation of electricity on the traditional hydroelectric power plants.
- The use of the tidal energy requires a dam or barrage across a shallow area preferably an estuary, bay or gulf of high tidal range where the difference on the low and high tide have to be at least 5 meters.
- The tide basins are filled and empty every day with the flood tides when the water level rises and with the ebb tides when the water level falls.
- On the barrage there are low-head turbines and sluices gates that allow the water to flow from one side of the barrage to inside the tidal basin.

Tidal Barrages (cont'd)

- Single Basin Barrage
- It requires a single barrage across the estuary. That involves a combination of sluices which when open can allow water to flow relatively freely through the barrage and gated turbines.
- These gates can be opened to allow water to flow through the turbines to generate electricity.



http://www.seabreath.it/images/PDF/Ocean-Energy-Technologies.pdf

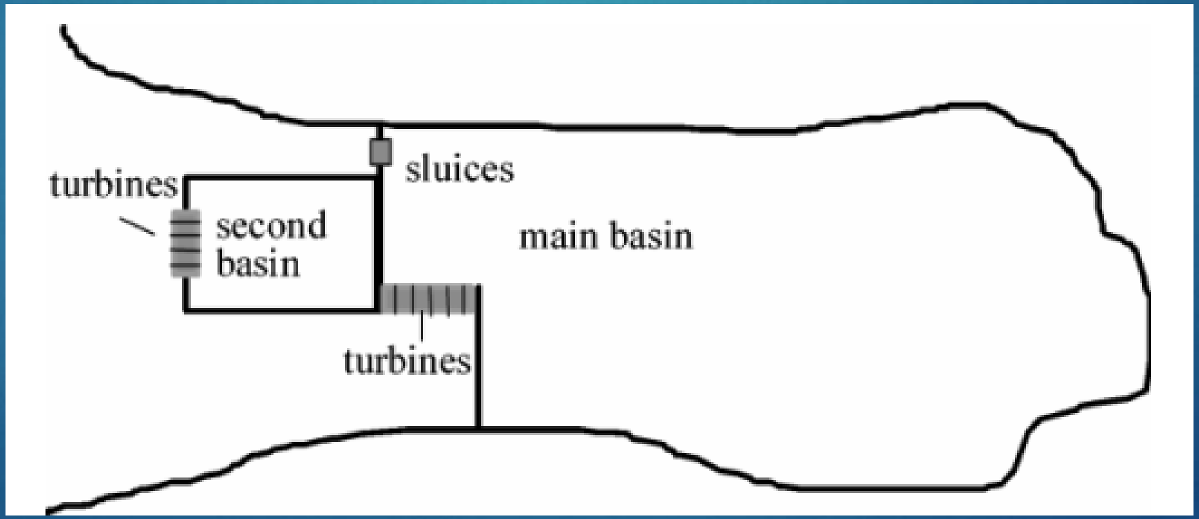
Tidal Barrages

- Ebb Generation Mode
- Incoming water (flood tide) is allowed to flow freely to fill the basin until high tide, then the sluices are close and water are retained on one side of the barrage.
- When the level of the water outside of the barrage decreased (ebb tide) sufficiently to create a hydrostatic head between the open waters and the tide basin, the sluices are open and water flows through the turbines and generate electricity.
- Once the head is low the sluices gates are open and the basin is filled again.

http://www.seabreath.it/images/PDF/Ocean-Energy-Technologies.pdf

Tidal Barrages

- Double Basin System
- Using two basins, the turbines are placed between the basins. The main basin will use the ebb generation mode to operate and pump water with part of the energy that is generated to and from the second basin to generated electricity continuously.
- Double basin systems allow for storage (adjusting the power output to demand of consumers).
- This mode has the disadvantage that is very expensive.



http://www.seabreath.it/images/PDF/Ocean-Energy-Technologies.pdf

Tidal Power (cont'd)

- The energy available from barrage is dependent on the volume of water. The potential energy contained in a volume of water is:

$$E = {}^{1}/_{2}\, A \times \rho \times g \times h^2$$

where:

- *h* is the vertical tidal range,
- *A* is the horizontal area (m^2) of the barrage basin,
- *ρ* is the density of water = 1025 $\mathrm{kg/m^3}$ (seawater varies between 1021 and 1030 $\mathrm{kg/m^3}$) and
- *g* is the acceleration due to the Earth's gravity = 9.81 ${}^{\mathrm{m}}/_{\mathrm{s}^2}$.

http://hydropower-tidalpower.blogspot.com/2009/07/energy-calculations_07.html?m=1

Tidal Power

- Let us assume that the tidal range of tide at a particular place is 32 feet = 10 m (approximation)
- The surface of the tidal energy harnessing plant is 9 km^2 (3 km × 3 km)= 3000 m × 3000 m = 9×10^6 m^2
- Specific density of sea water = 1025.18 kg/m^3

- Mass of the water = volume of water × density
  = (area × tidal range) of water × mass density
  = $(9 \times 10^6\ m^2 \times 10\ m) \times 1025.18\ kg/m^3$
  = 92×10^9 kg (approximation)

- Potential energy content of the water in the basin at high tide = ½ × area × density × gravitational acceleration × tidal range squared
  = $\frac{1}{2} \times 9 \times 10^6\ m^2 \times 1025\ kg/m^3 \times 9.81\ m/s^2 \times (10\ m)^2$
  = 4.5×10^{12} J (approximation)

Tidal Power

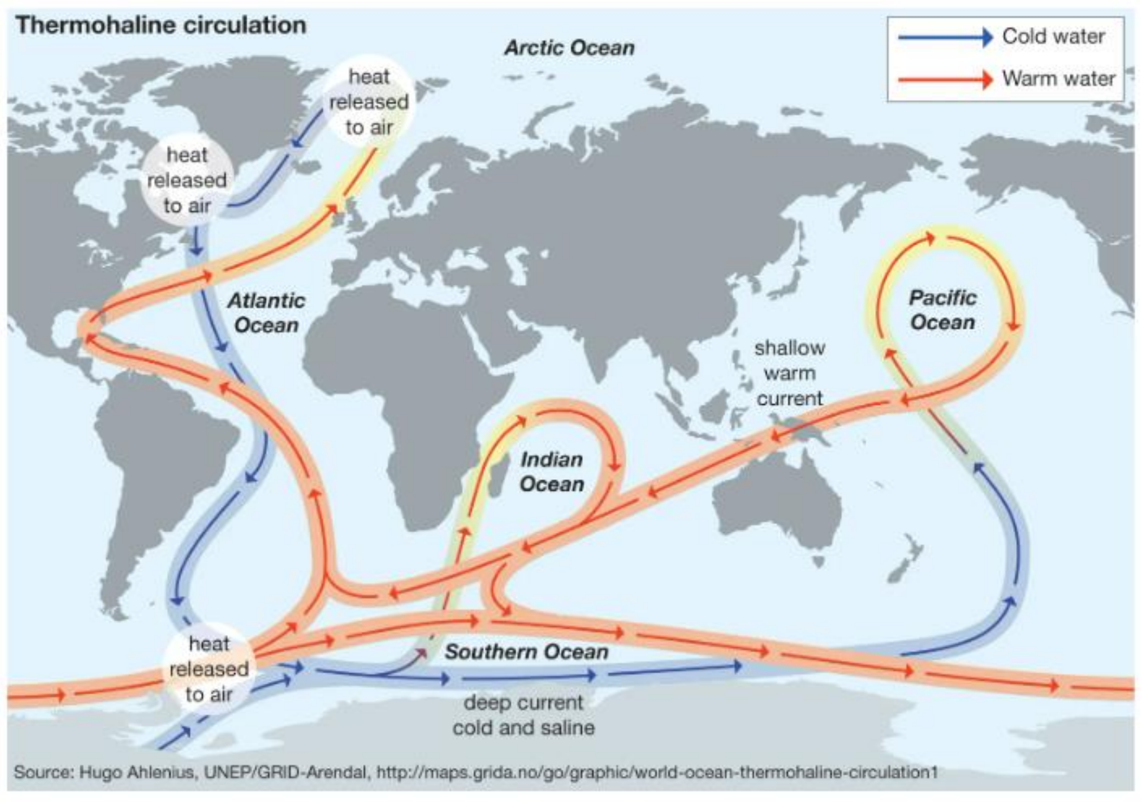
- Now we have 2 high tides and 2 low tides every day. At low tide the potential energy is zero.
- Therefore the total energy potential per day = Energy for a single high tide × 2
  $= 4.5 \times 10^{12}$ J × 2
  $= 9 \times 10^{12}$ J

- Therefore, the mean power generation potential = Energy generation potential / time in 1 day
  $= 9 \times 10^{12}$ J / 86400 s
  = 104 MW

- Assuming the power conversion efficiency to be 30%: The daily-average power generated = 104 MW * 30% = 31 MW (approximation)

Ocean Current

- Ocean currents are driven by solar heating and wind in the waters near the equator, also by tides, salinity and density of the water.
- Current can be divided in two types: marine currents and tidal currents.
- Marine currents are relatively constant and flow in one direction. Tidal currents occurred close to the shore due to gravitational forces.



Energy from Ocean Current (cont'd)

- Currents are flowing bodies like wind.
- Current energy can be calculated using the formula of kinetic energy of flowing bodies: $E_k = {}^{1}/_{2}\, mV^2$.
- The speed of ocean currents is lower when compared to wind speeds but the water is 832 times denser than air.
- Ocean currents can be predicted with years in advanced as they depend of the movements of the sun and moon.

Energy from Ocean Current

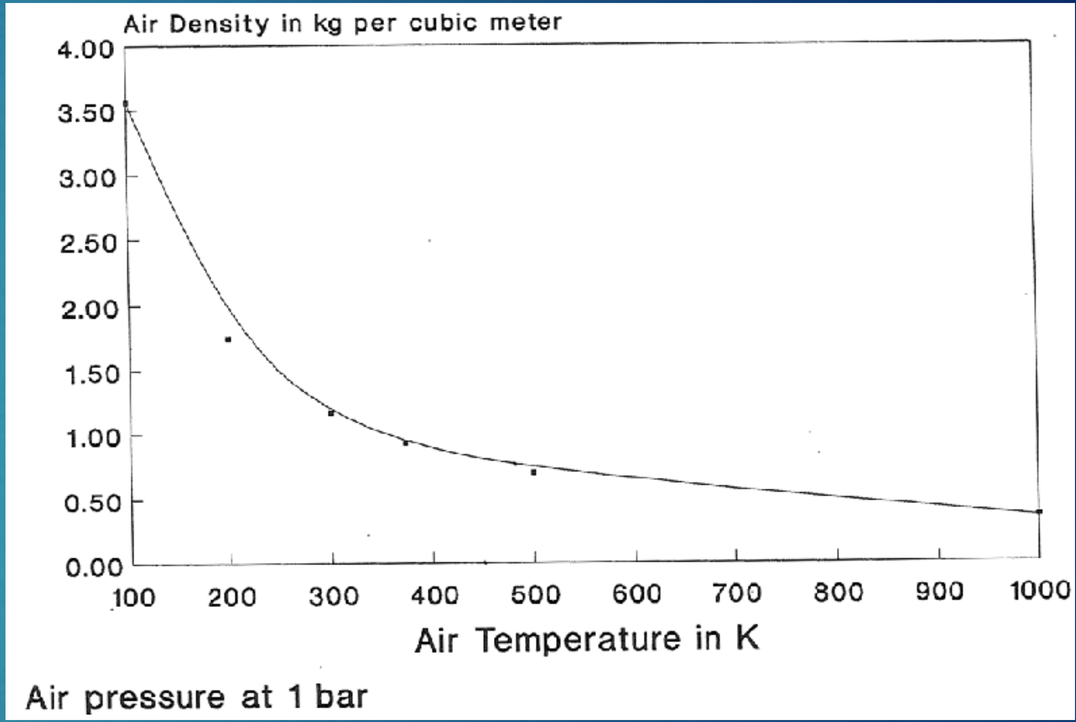
- $EK = \frac{1}{2} mV^2$
- $P = \frac{Ek}{t} = \frac{1}{2} \dot{m} V^2$
- $\dot{m} = \rho A V$
- $A = \pi \left(\frac{D}{2}\right)^2$
- $P_{turbine} = \frac{1}{2} \rho A V^3 C_p$
- The difference between the power of wind and water turbine is in the density of the liquid. The density of ocean water is approximately 800x that of air.

Energy from Ocean Current

- $D = 20\ m$
- $A = \pi\left(\frac{D}{2}\right)^2 = 314.2\ m^2$
- $V = 2\frac{m}{s}$
- $P_{turbine} = \frac{1}{2}\rho A V^3 C_p = \frac{1}{2} \times 1027\frac{kg}{m^3} \times 314.2m^2 \times \left(2\frac{m}{s}\right)^3 \times 0.3 = 387{,}220\ W = 0.387\ MW$
- This number seems small compared to wind turbine, however ocean current is continuous.

Waves

- The energy from surface waves is the most conspicuous form of ocean energy, possibly because of the, often spectacular, wave destructive effects. The waves are produced by wind action and are therefore an indirect form of solar energy.
- The sun creates wind by heating the ground, which heats the air above it, which then causes the heated air to rise. The rising heated air creates a vacuum underneath it as it rises, so that air from the surrounding side rushes in to fill the hole - this is wind.
- Then, when the warm air cools off at high altitude, it sinks or is carried down along with rain by gravity, pushing the air down at the ground out of the way, creating more wind.



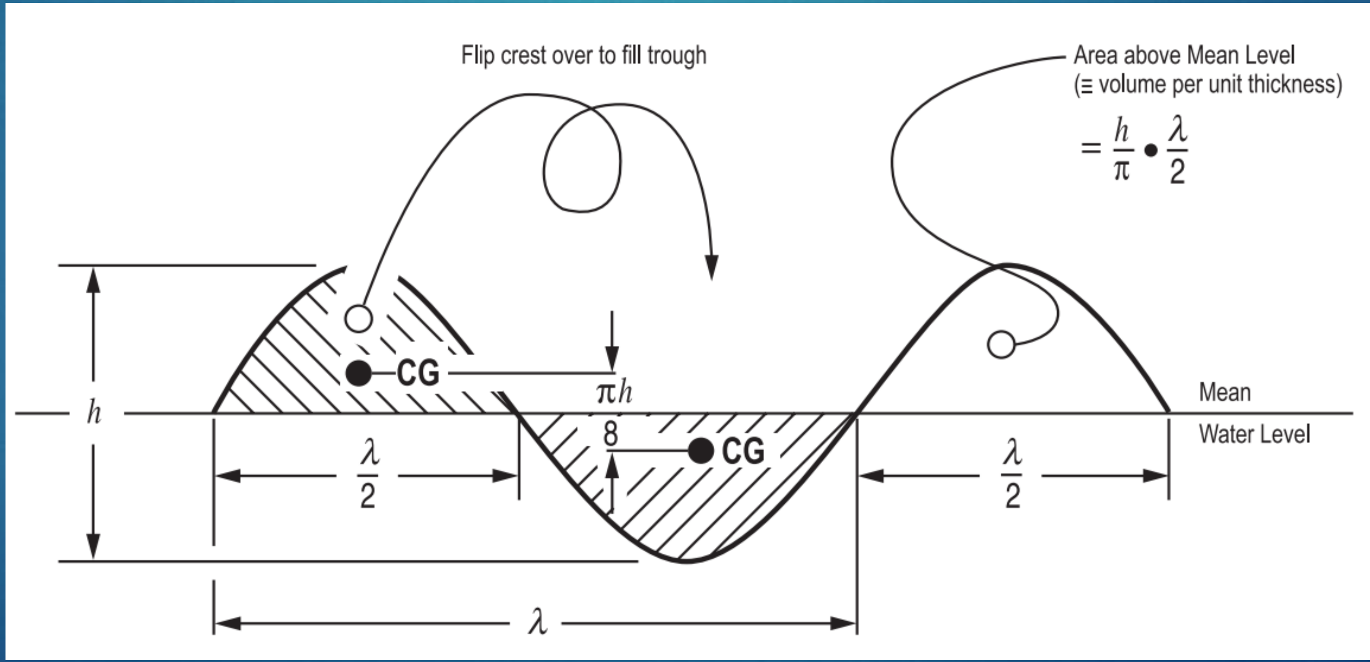
http://scienceline.ucsb.edu/getkey.php?key=5549#:~:text=The%20sun%20creates%20wind%20by,the%20hole%20%2D%20this%20is%20wind.
https://www.researchgate.net/figure/Air-density-at-different-temperatures_fig4_332045398 (CC license)

Ocean Wave (cont’d)

- Waves are created by the interaction of the prevailing winds with long reaches of open water.
- Strong storm-force winds create a disorganized, chaotic, local wave fi eld, which, through a process of interactive reinforcement and interference, leads to a more regular sequence of swells propagating away from the storm zone.
- As waves approach shallow water (depth approximately the same as wavelength), significant changes take place: wavelength shortens, speed is reduced, and the profile steepens — to produce the surfer’s delight and breakers on the beach.

Ocean Wave (cont'd)

- Penner and Icerman (1984) and Twidell and Weir (2006), consider a sinusoidal wave with crest-to-trough height *h* (thus, the height from mean sea level to crest is *h*/2).
- Then the average height above the levelized sea is $2/\pi$ times this value, or h/π ; the center of gravity of the wave mass above sea level is $\pi h/16$.



Tester, J. W., et.al. Sustainable Energy. Choosing Among Options.

Ocean Wave

- Thus, if the mass above sea level is (inverted and) dropped to fill in the below-level trough (which is its mirror image), potential energy is made available for extraction due to a total drop of *πh/8*. One has, per unit width of wavefront, and for wavelength, *λ*.

$$\Delta PE = mg\Delta h = \left[\rho\left(\frac{h}{\pi}\right)\left(\frac{\lambda}{2}\right)\right]g\left(\frac{\pi h}{8}\right)$$

or

$$\Delta PE = \frac{1}{16}\rho\lambda g h^2$$

Energy from Ocean Wave

- Power is energy per unit time (here, wave period, *T*), and wavelength is given by

$$\lambda = \frac{gT^2}{2\pi}$$

- which all combine to yield $P_{pe} = \frac{1}{32\pi}\rho g^2 h^2 T = 0.98 h^2 T \text{ , kW}_e\text{/m}$

- where

  ρ = density of seawater (1,025 kg/m^3)

  g = acceleration of gravity (9.807 m/s^2)

  h = crest-to-trough wave height (e.g., 2 m)

  T = wave period: time for successive crests to pass a fixed observer (e.g., 10 s).

- Kinetic energy equals potential energy, and hence total energy is double that of equation P_{pe}.

Tester, J. W., et.al. Sustainable Energy. Choosing Among Options.

Energy from Ocean Wave

- Kinetic energy equals potential energy, and hence total energy is double that of P_{pe} equation.
- To estimate power, however, we should use the group velocity, which is half the phase (i.e., crest) velocity (MacKay, 2009), and therefore:

$$P = 0.98 h^2 T, \ \mathrm{kW_e/m}$$

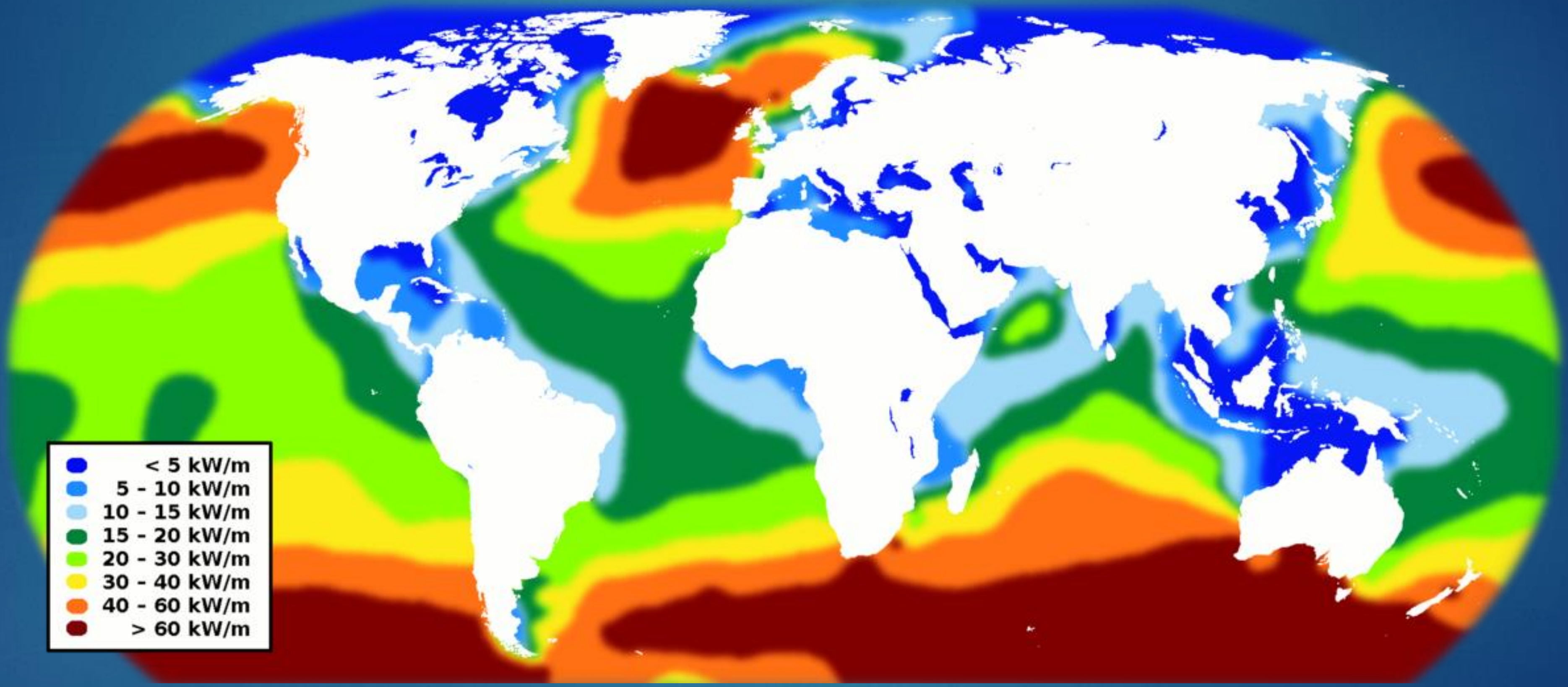
- Based on our input parameters:

$$P = 0.98 \times (2\mathrm{m})^2 \times 10\mathrm{s} = 39.2 \ \mathrm{kWe/m}$$

- The dependence on wave height squared (h^2) in equation also highlights the vulnerability of wave machines to storm damage. Doubling wave height to 4 m would unleash power on the order of 156.8 kWe/m.

Tester, J. W., et.al. Sustainable Energy. Choosing Among Options.

Wave Energy Map

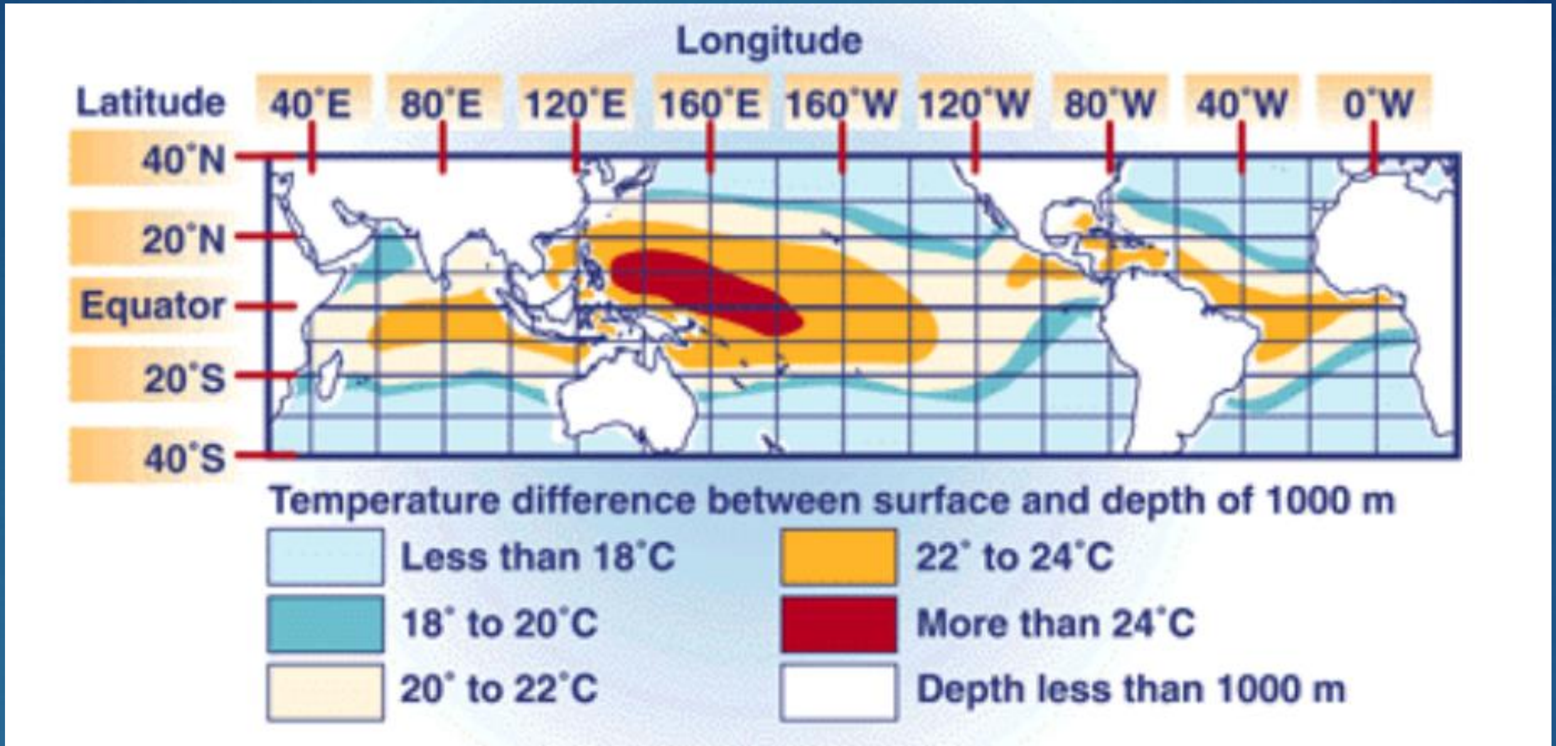


https://commons.wikimedia.org/wiki/File:World_wave_energy_resource_map.png

Ocean Thermal Energy

- The large difference between the temperatures of the ocean surface waters and the deep seawaters stimulate the presence of thermal gradients.
- Based on this concept, the Ocean Thermal Energy Conversion (OTEC) has been proposed and is currently under development.
- OTEC converts the difference between warm surface waters and cold deeper waters (approximately 1000 m below the surface) into energy.
- The minimum water temperature difference must be 20° C (36° F) to operate the OTEC power cycle on a satisfactory way.

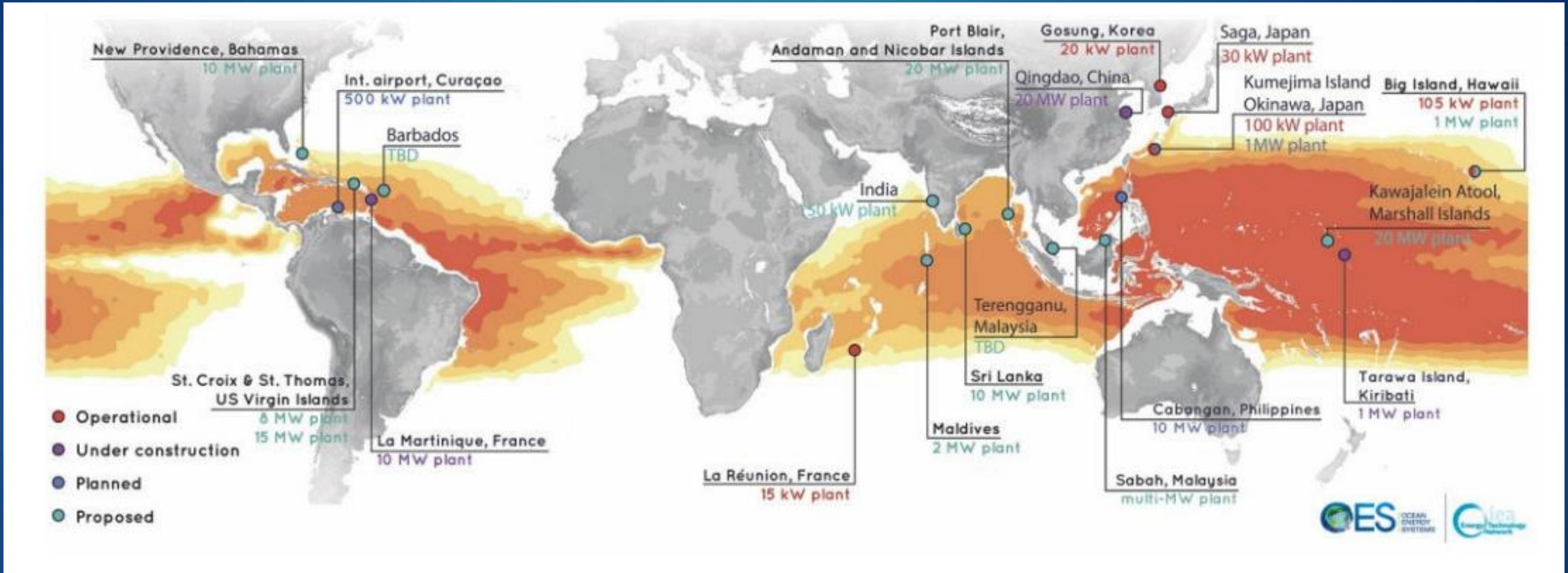
https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf



- Map of temperature difference between surface and depth of 1000 m.
- Compared with technologies such as wave energy, the energy available from OTEC is one or two orders of magnitude higher. But the thermal efficiency is very low; the theoretical maximum efficiency is 6 or 7%. Furthermore, the extraction of energy is difficult and thus expensive (pumping material).

http://www.seabreath.it/images/PDF/Ocean-Energy-Technologies.pdf

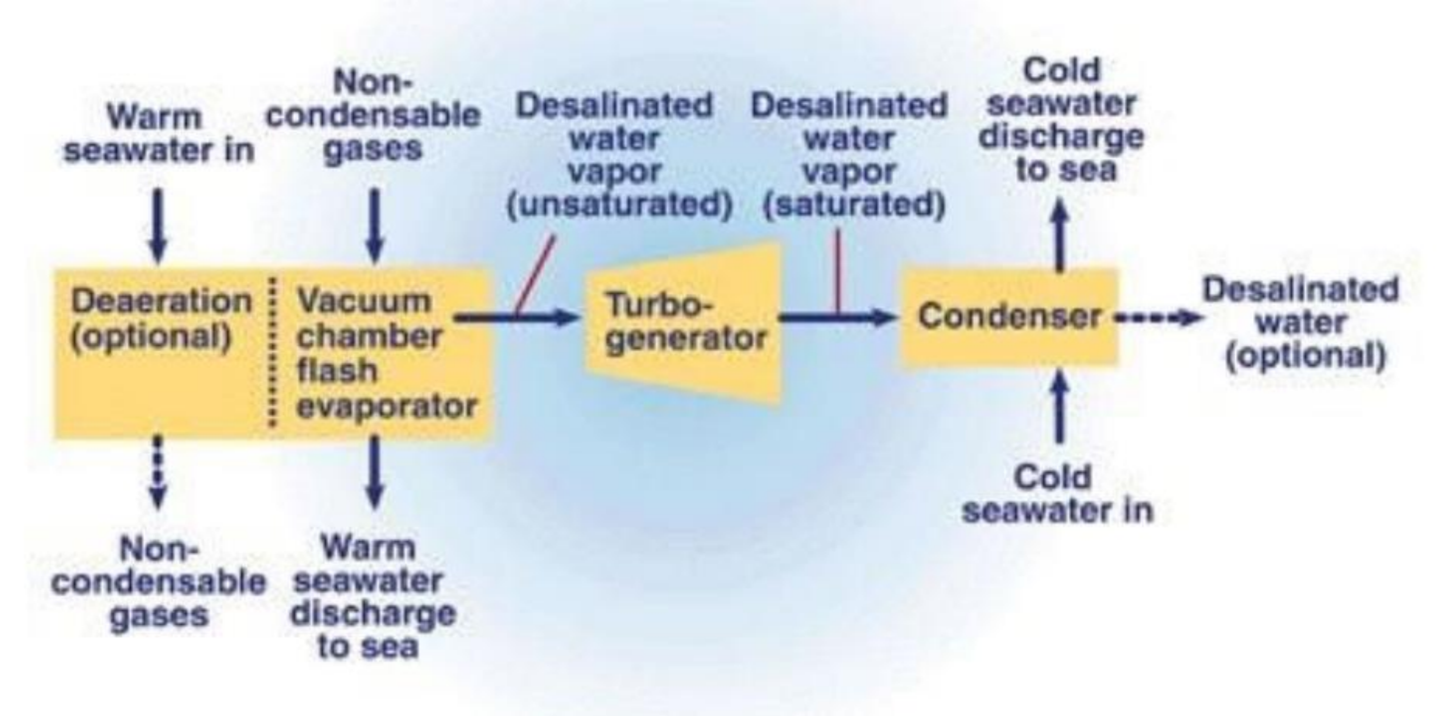
OTEC Projects around The World



Types of OTEC Technology

- Three kinds of cycles are used: the open cycle, the closed cycle and the hybrid cycle.
- The main concept is the same for all systems. There is a heat engine placed between a high temperature and low temperature reservoir.
- As in a steam turbine, the engine converts heat energy into kinetic energy. To operate, the cold sea water is either pumped directly (can be more than one kilometer) or desalinated near the sea bed to then float up through a pipe to the surface.

Open Cycle (cont'd)

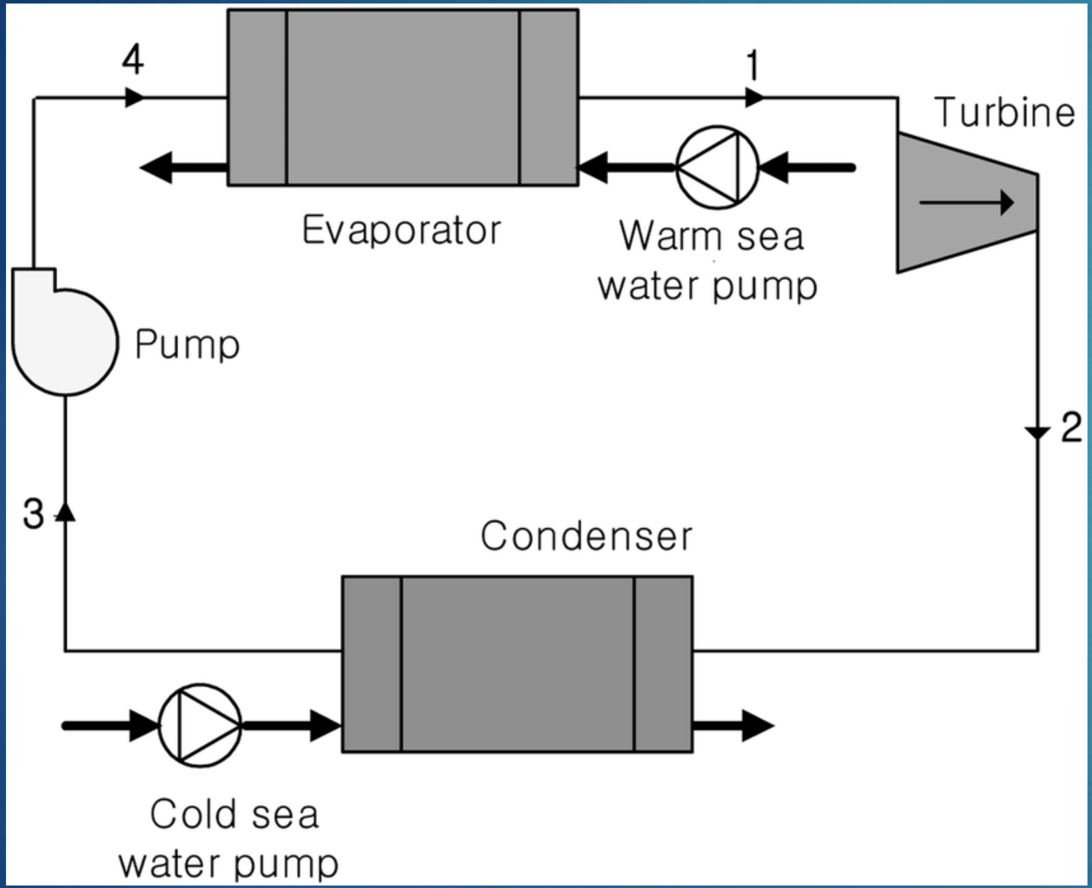


- In the open cycle warm seawater can be use as the working fluid. When the surface seawater is flashed evaporated it is pumped into a vacuum chamber to produce a spray of the liquid. Making the pressure of the chamber less than the saturation pressure of the spray of the water, it starts to boil.

Open Cycle

- The steam that is produce passes through the turbine to generate electricity. The steam later condensates using the cold seawater and is not returned to the evaporator.
- This condensation process can be done using two methods: spray cold seawater over the steam or in a surface condenser in which the steam and the cold water do not enter in contact with each other, producing desalinated water. If the condensation is done using the spray method the mixed of steam and cold water is discharged back to the ocean.

Closed Cycle (cont'd)



- In the OTEC closed cycle two working fluids work to complete the cycle. First, it is necessary to use warm seawater to vaporize a second working fluid such as ammonia, propane or a freon-type refrigerant. This second working fluid will flow through an evaporator (heat exchanger).

https://www.researchgate.net/figure/Diagram-of-Closed-OTEC-cycle_fig2_263636909

Closed Cycle

- The high pressure steam that is produced moves a turbine that is connected to a generator that produces electricity. After the steam moves the turbine, it is condensate using the cold seawater that is pumped from the depths and is pumped back to the evaporator to start the cycle.
- The turbines that are use in the closed cycle are usually smaller than the ones use in the open cycle because the density and operating pressure of the second working fluid are higher.

Power from OTEC

- In a closed cycle OTEC power generation system, water flow rate to evaporator = 1000 tons/hr. Ocean temperature at 1000 m depth = 5 °C. Density of sea water = 1000 kg/m^3, specific heat of sea water = 4200 J/kg-K. Calculate the power output of an ideal (based on the Carnot cycle efficiency) OTEC plant in such conditions. Show all the parameters on a suitable diagram.

Power from OTEC

- Water flow rate to evaporator:

$$\dot{m}_s = 1000\,\frac{tons}{hr} = 277.778\,\frac{kg}{s}$$

- Ocean surface temperature T1 = 25 °C = 298 K
- Ocean temperature at 1000 m depth T2 = 5 °C = 278 K
- Cp = 4200 J/kg °C
- Rate of heat supplied by sea water in evaporator

$$\dot{Q}_s = \dot{m}_s \times C_p \times (T_1 - T_2)$$

$$\dot{Q}_s = 277.778\,\frac{kg}{s} \times 4200\,\frac{J}{kg.K} \times (298 - 278)\mathrm{K} = 23333.33\,\frac{\mathrm{kJ}}{\mathrm{s}}$$

Power from OTEC

- Assuming the evaporator and boiler to be 100% efficient, the same heat rate is supplied to the fluid in the boiler/evaporator.
- Carnot efficiency

$$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{278\ K}{298\ K} = 0.0671 = 6.71\%$$

- Despite the low efficiency, the energy stored in the ocean in enormous. Its overall throughput that always matters in energy calculations.
- Power output

$$P = \eta \times \dot{Q}_S = 0.0671 \times 23333.33 \frac{\text{kJ}}{\text{s}} = 1566\ \text{kW} = 1.566\ \text{MW}$$

Salinity Gradient

- Where rivers meet the ocean, there is a large gradient in salinity, and it is possible to exploit this salinity gradient to produce electricity.
- Salinity gradient power is the energy that is available for conversion due to the difference in salt concentration between two fluids, generally fresh and salt water, i.e. where a river flows into the sea.
- River discharge varies vastly, depending on catchment size, soil type, weather conditions, the amount of rainfall, land use and slope.
- The largest river discharge in the world is the Amazon in South America, which has a mean discharge of 209,000 m^3/s. The second globally ranked river, the Congo, has an annual mean discharge of 41,200 m^3/s.

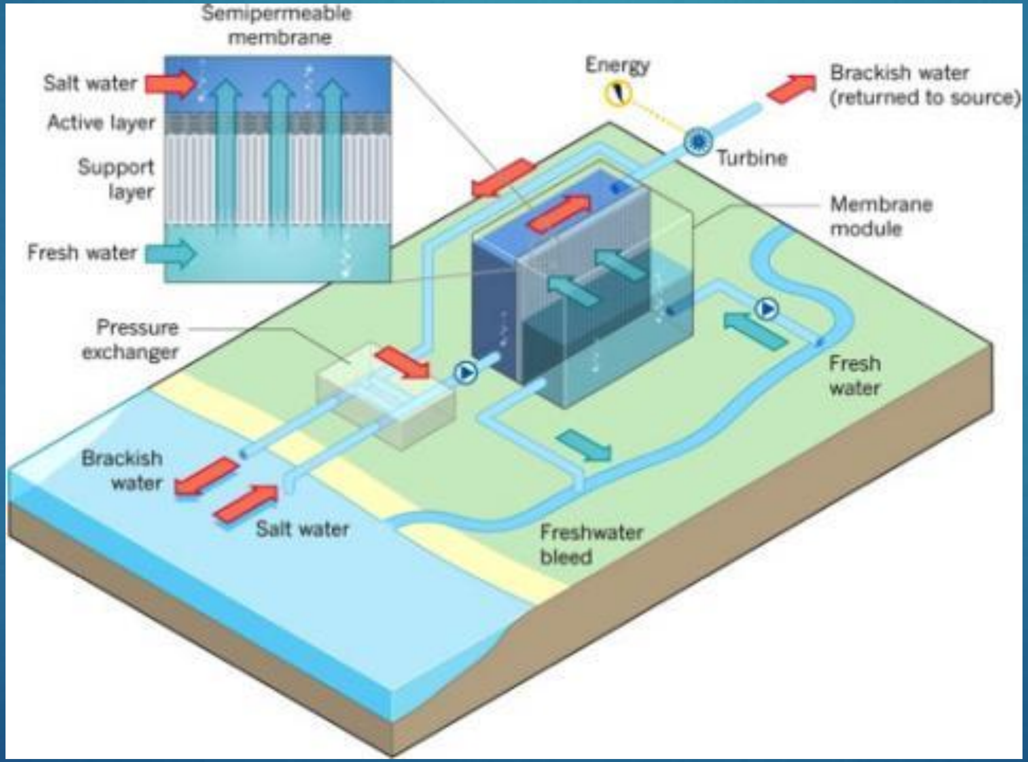
https://research.bangor.ac.uk/portal/files/38945670/CH0000_UN_163_Neill_v2.pdf

Energy from Salinity Gradient (cont’d)

- River water has a salinity close to zero, whereas the mean salinity of seawater is around 35% (parts per thousand).
- There are two main salinity energy conversion technologies – pressure retarded osmosis (PRO) and reversed electro dialysis (RED).
- Both are based on separating the river and sea water by a semi-permeable membrane.
- By placing water of differing salt content either side of this membrane, the water (solvent) will flow through the membrane from the region of high water potential (region of lower salt concentration) to a region of low water potential (region of higher salt concentration) – a process known as osmosis.

Pressure Retarded Osmosis (PRO)

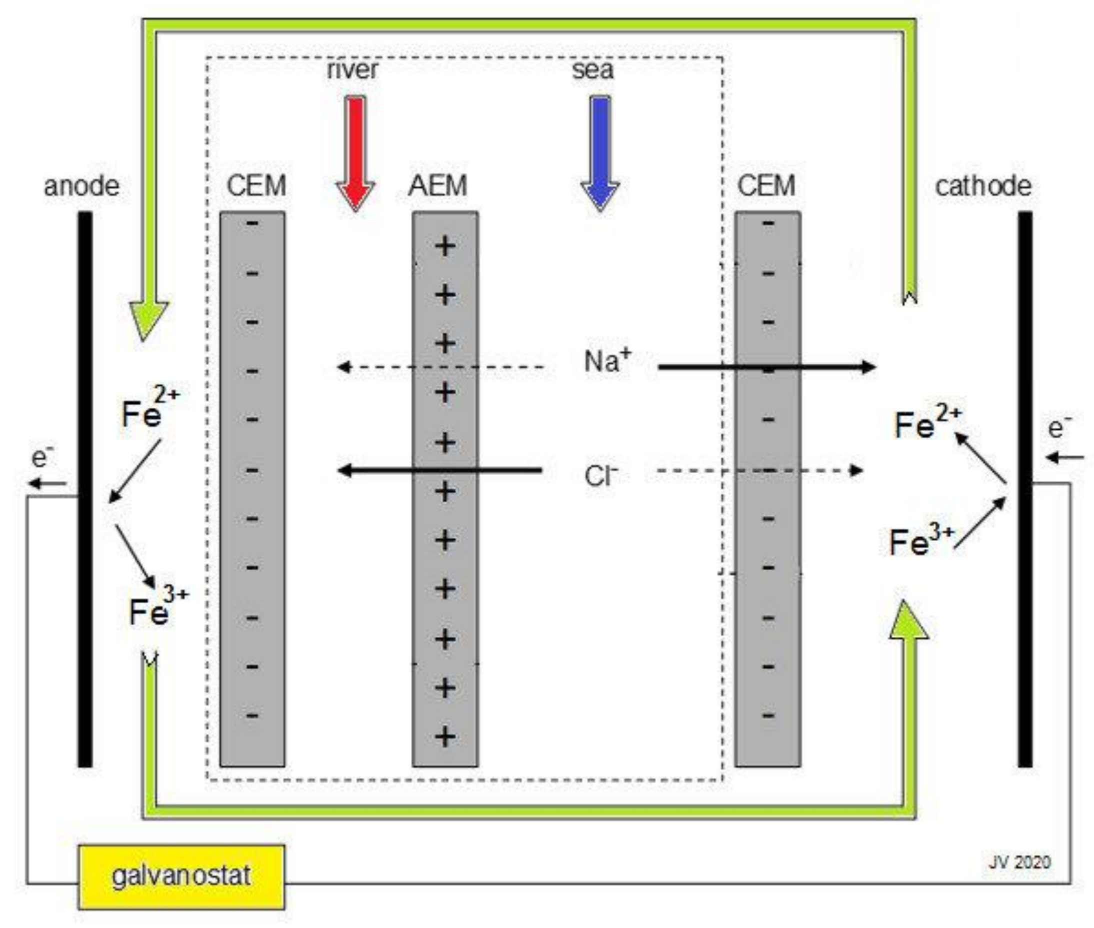
- In PRO – the simplest of the two technologies – the flux of fresh water through the membrane towards the sea water increases the pressure inside the sea water chamber. The pressure is then used to spin a turbine and turn a generator.



https://tethys-engineering.pnnl.gov/technology/pressure-retarded-osmosis

Reversed Electro Dialysis (RED)

- In RED, energy is harvested from the difference in the salt concentration between seawater and fresh water. RED uses stacks of alternating anion and cation exchange membranes to generate electricity.
- In RED, ions in the concentrated solution flow into the solution of low salt concentration through ion exchange (IX) membrane. The ion flows are transformed to electron flows by the electrode. The advantages of RED over PRO are that there is no moving part involved and hence more process reliability is expected. The fouling is also less serious since it is not water but ions that flow through the IX membrane.



https://www.sciencedirect.com/topics/engineering/salinity-gradient
https://www.researchgate.net/figure/Reverse-electrodialysis-RED-stack-with-only-one-cell-pair-the-part-within-the-dashed_fig1_343955264

Potential Site for Salinity Gradient Energy (SGE)

Table 1: Estimations of potential SGE from different studies

Authors	Combination of aqueous solutions (Concentrated vs. dilute)	Study site
(Wick, 1978)	Seawater vs. river water	Amazon river, Brazil La Plata-Parana River, Argentina Congo River, Congo Yangtze River, China Ganges River, Bangladesh
(Loeb, 2002)		Mississippi river, United States
(Helfer & Lemckert, 2015)		Brisbane river, Australia
(Jahromi et al., 2015)		Bahmanshir River, Iran
(Alvarez-Silva & Osorio, 2015)		Magdalena river, Colombia
(Khodadadian Elikaiy et al., 2021)		Arvand River, Iran
(Zachopoulos et al., 2022)		Strymon river, Greece
(Helfer et al., 2014) (Wick, 1978)	Brine from hypersaline systems vs. river water	Great Salt Lake, United States
(Loeb, 2001)		Dead sea, Israel Great Salt Lake, United States
(Helfer & Lemckert, 2015)		Lake Eyre and Lake Torren, Australia
(Emdadi et al., 2016)		Lake Urmia, Iran

Nishita Gajendragadkar (2022)

Online Resources

- https://www.uprm.edu/aret/docs/Ch_3_Ocean.pdf
- https://x-engineer.org/wave-energy/
- https://www.thermodynamicsheatengines.com/downloads.html
- http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/watwav2.html
- http://hyperphysics.phy-astr.gsu.edu/hbase/watwav.html#c3
- http://hydropower-tidalpower.blogspot.com/2009/07/energy-calculations_07.html?m=1

- https://www.youtube.com/watch?v=JOP33yCKmNw
- https://www.youtube.com/watch?v=_LRc6k-clzE
- https://www.youtube.com/watch?v=bacwP-9osVE
- https://www.youtube.com/watch?v=Nai-dcyogb8
- https://www.youtube.com/watch?v=sLIHQ-2TbvA
- https://www.youtube.com/watch?v=59XkpnXpqtw
- https://www.youtube.com/watch?v=B1vzxhiqOXQ
- https://www.youtube.com/watch?v=5UxCUuk4CEs

- How batteries work - Adam Jacobson - YouTube
- https://www.youtube.com/watch?v=7uIlq_Ofzgw
- How do ocean currents work? - Jennifer Verduin - YouTube
- How Ocean Currents Work (and How We Are Breaking Them) - YouTube
- TU Delft - OTEC - YouTube
- Closed Cycle OTEC Plant - YouTube
- Open Cycle OTEC Plant - YouTube
- RANKINE CYCLE (Simple and Basic) - YouTube

- P7 - Solar, Sidereal & Lunar day - YouTube
- What Causes Tides? - YouTube
- Ocean's Tides Explained - YouTube
- Ocean Thermal Energy Conversion (OTEC) - Turning water into watts..!! – YouTube
- https://www.youtube.com/watch?v=zjzgcHngQFM
- https://www.youtube.com/watch?v=LJV4d4XtHuo
- Moon Phases: Crash Course Astronomy #4 - YouTube