Assessing Power Generation Potential of Mid-Scale OTEC system in the Southeastern United States

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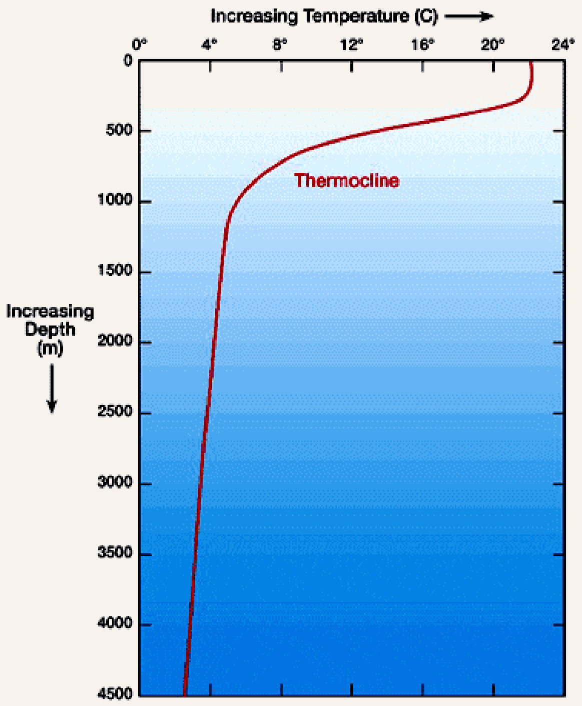
Outline

- Overview
- Mid-Scale OTEC Specifications and Mathematical Modeling
- Methodology
- Results
- Conclusions and Future Works

Overview

- OTEC concept was proposed by D'Arsonval in 1881.
- OTEC generates electricity via a thermodynamic cycle using the temperature difference between the warm sea surface and cold deep water
- Three main type of OTEC cycles: Closed-cycle, Open-Cycle, Hybrid-cycle



Temperature profile of ocean water[1]

[1] https://www.marinebio.org/oceans/temperature/
[2] https://www.makai.com/renewable-energy/otec/

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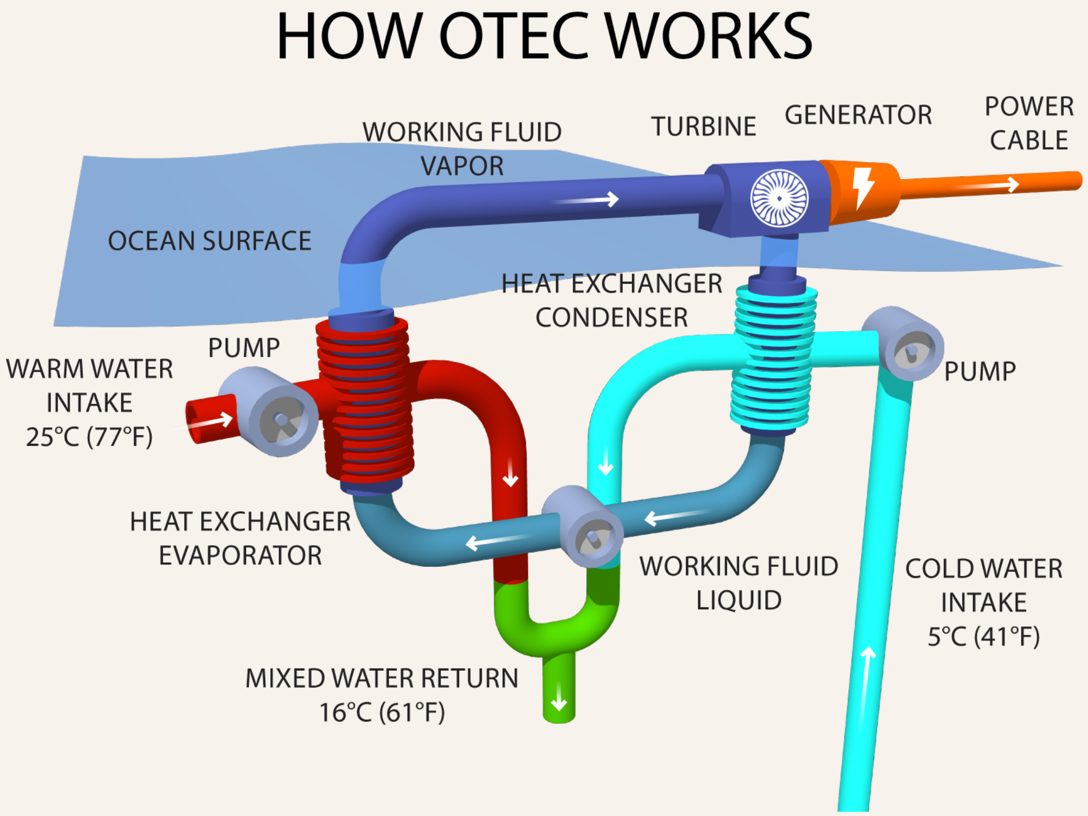

OTEC diagram[2]

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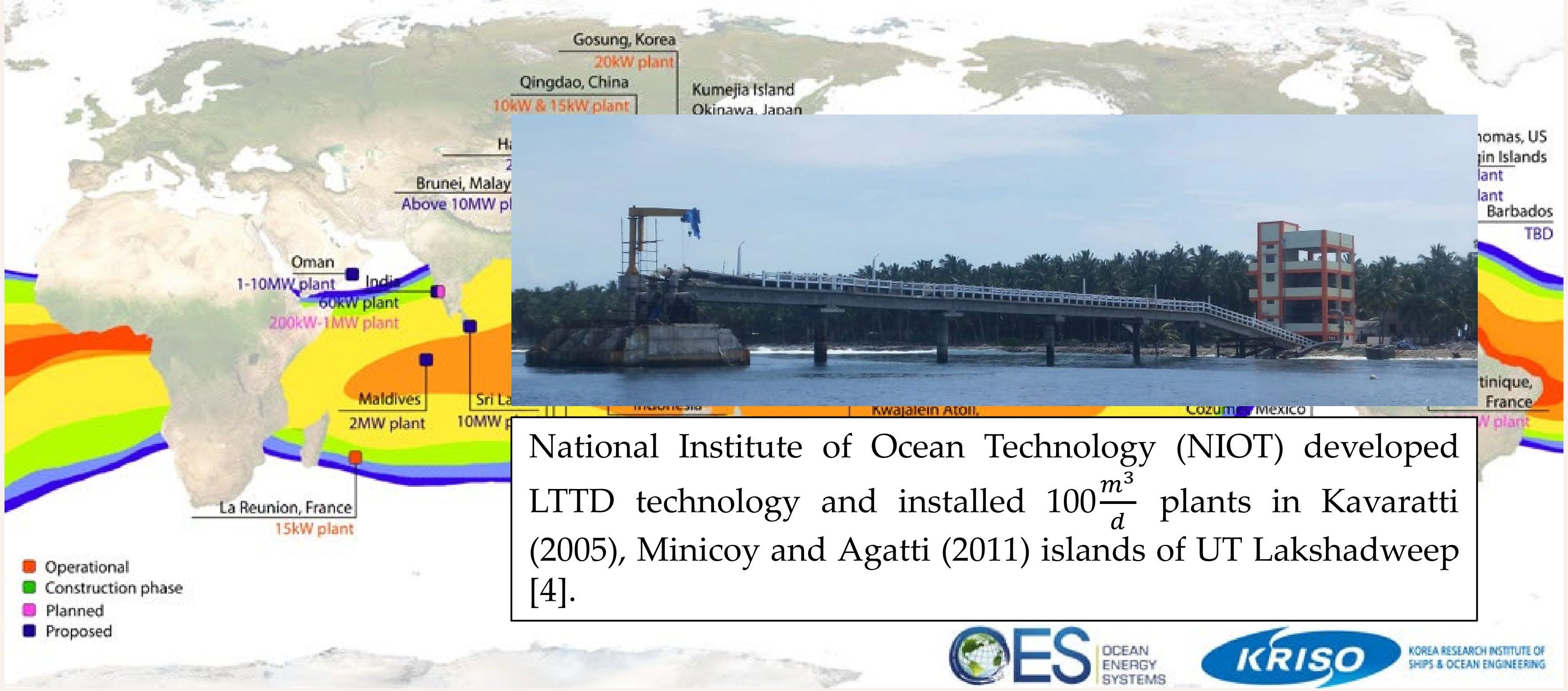
Overview



National Institute of Ocean Technology (NIOT) developed LTTD technology and installed $100\frac{m^3}{d}$ plants in Kavaratti (2005), Minicoy and Agatti (2011) islands of UT Lakshadweep [4].

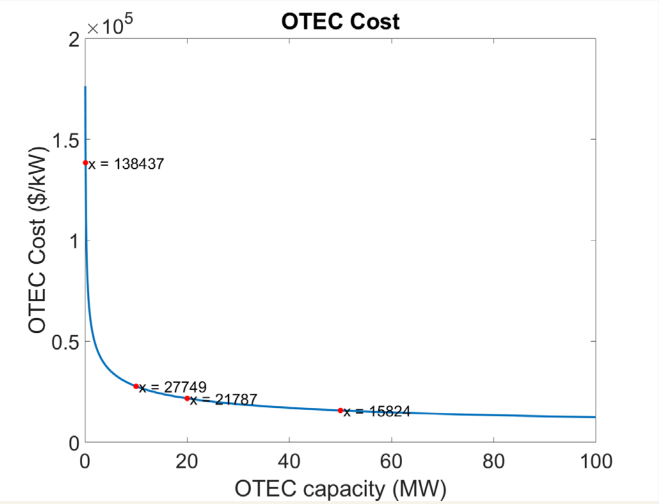
Present and future planned OTEC/SWAC projects around the world (2021)[3]

Main challenges: Cold Water Pipe, High Capital Costs

[3] https://www.ocean-energy-systems.org/news/iea-oes-released-a-white-paper-on-ocean-thermal-energy-conversion-otec-for-policymakers-and-developers.-/
[4] Gujjula, D., Alluri, S. K. R., Dhinesh, G., Kumar, S. P., & Murthy, M. R. (2022). Scaling of low-temperature thermal desalination plants–design space exploration. Desalination and Water Treatment, 256, 18-25.

Overview

- Increased plant sizes can significantly reduce the unit cost of electricity.
- **HDPE Pipe:** Seafloor-mounted HDPE cold-water conduits remain the industry benchmark, most notably the 1.4 m-diameter, 2.8 km-long pipeline installed off Hawaii in 2001 to 900 m depth [6].
- Commercial HDPE risers up to 3.5 m ID [7] (with adequate wall thickness) can serve as a single cold-water intake for a 5 MW plant and be bundled for higher capacities
- Using three bundled cold-water intake pipes in parallel has been common practice in previous studies.



OTEC diagram[5]

OTEC Size	LCOE ($/kWh)
10MW	0.356 < LCOE <0.615
100 MW	0.201 < LCOE <0.297

[5] Vega, Luis, and Benjamin Martin. "Ocean Thermal Energy Conversion (OTEC) Economics: Updates and Strategies.".Ocean Energy Systems (OES) (2024).
[6] Daniel T.H., (2001). 55" seawater system CIP project update. NELHA Pipeline, 10, October 2001. http://www.nelha.org/pdf/PLiss10.pdf
[7] https://agruamerica.com/worlds-largest-hdpe-pipe/

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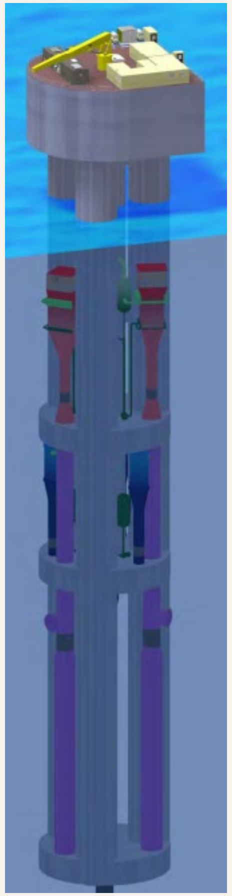


OTEC mini-spar power plant[5]

[5] Vega, Luis, and Benjamin Martin. "Ocean Thermal Energy Conversion (OTEC) Economics: Updates and Strategies.".Ocean Energy Systems (OES) (2024).
[6] Daniel T.H., (2001). 55" seawater system CIP project update. NELHA Pipeline, 10, October 2001. http://www.nelha.org/pdf/PLiss10.pdf
[7] https://agruamerica.com/worlds-largest-hdpe-pipe/

Mid-Scale OTEC Specifications

- Cold water intake pipe : 3-pipe bundle of 3.5-meter diameter
- Warm Water intake pipe: 7-meter pipe split into two 3-meter diameter pipe
- $T_{ww} = 25.7℃, T_{cw} = 4.1℃$
- Working fluid: R134a
- Net output power = 19 MW

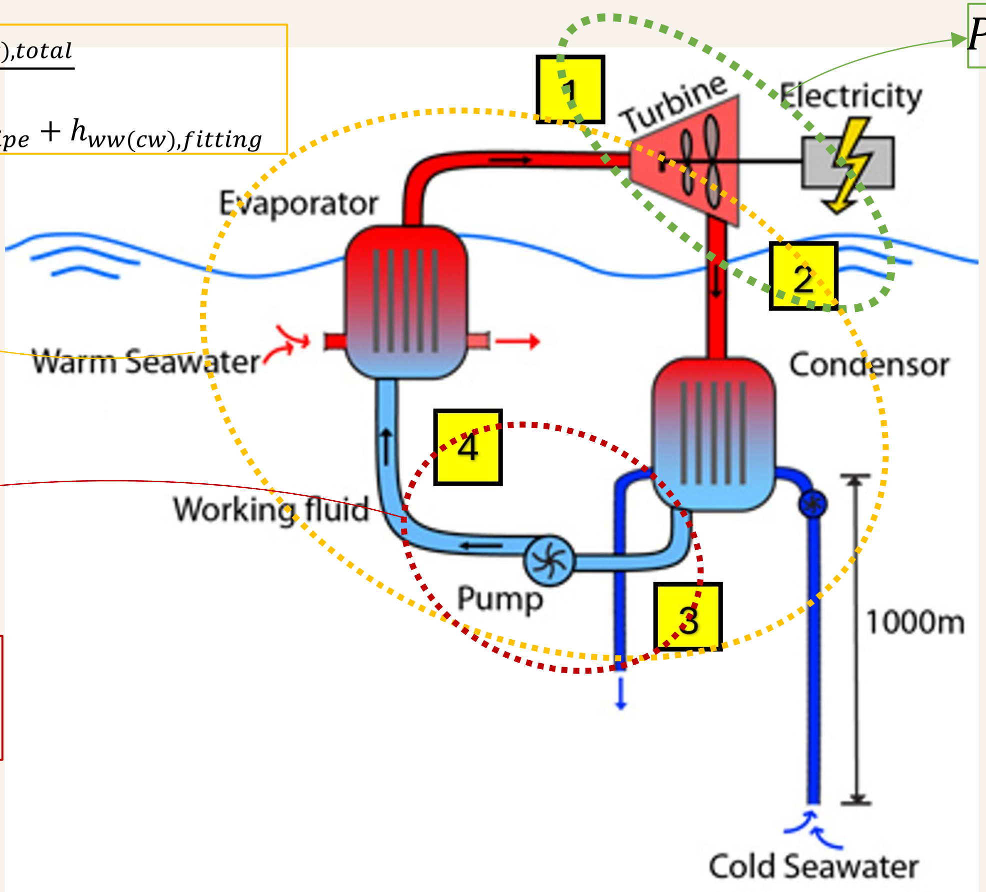
OTEC Plant Model

$$P_{Net}(kW) = P_{Gross} \times \eta_G \times \eta_{throttle} \times \eta_{wiring} \times \eta_{inverter} - P_{ww,p} - P_{cw,p} - P_{wf,p}$$

$$P_{ww(cw),p}(kW) = \frac{\dot{m}_{ww(cw)} \times g \times h_{ww(cw),total}}{1000 \times \eta_{sw,p}}$$

$$h_{ww(cw),total}(m) = h_{cw,static} + h_{evap\ (cond)} + h_{ww(wc),pipe} + h_{ww(cw),fitting}$$

$$P_{Gross}(kW) = \dot{m}_{wf} \times (H_1 - H_2)$$



$$P_{wf,p} = \frac{\dot{m}_{wf} \times (P_{Evap} - P_{Cond})}{1000 \times \rho_{wf} \times \eta_{wf,p}}$$

OTEC Plant Model

$$h_{evap(cond)}(m) = \frac{\Delta P_{@Evap(@cond)}}{\rho_{sw} \times g}$$

$$h_{ww(cw),fitting} = \sum_n h_{fitting,n}$$

$$h_{fitting,n} = K_n \left(\frac{V_n^2}{2g}\right)$$

$$h_{ww(cw),total}(m) = h_{cw,static} + h_{evap\ (cond)} + h_{ww(wc),pipe} + h_{ww(cw),fitting}$$

$$h_{cw,static} = 1m$$

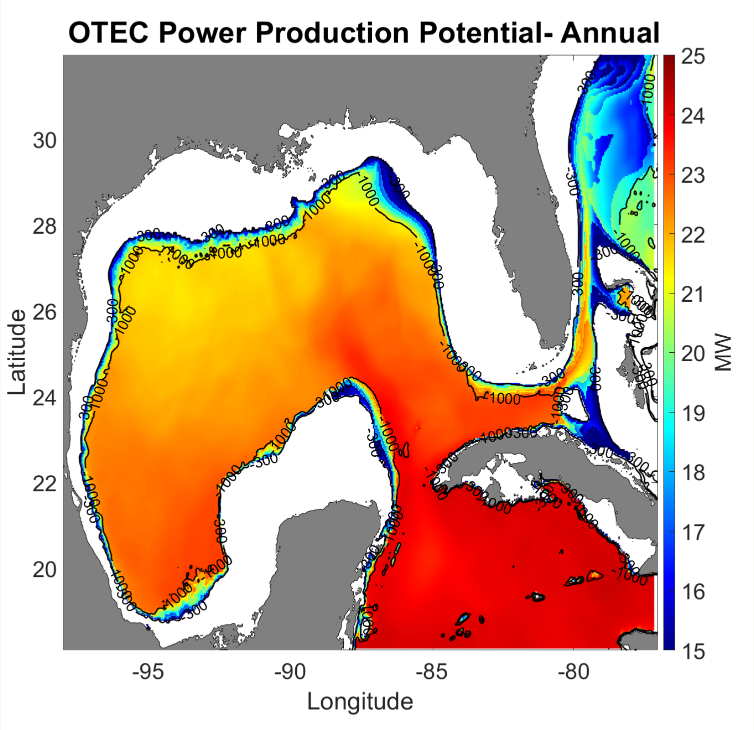
$$h_{ww(cw),pipe} = \sum_n h_{pipe,n}$$

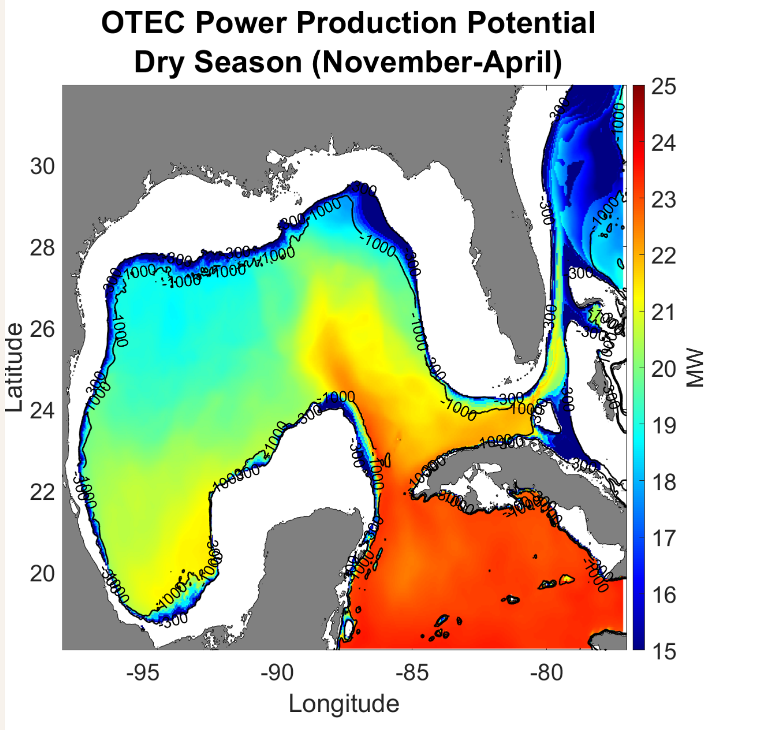
$$h_{pipe,n} = \frac{10.583 \times L_{pipe,n} \times \left(\frac{q}{N_{pipe,n}}\right)^{1.852}}{c^{1.852} \times d_n^{4.8655}}$$

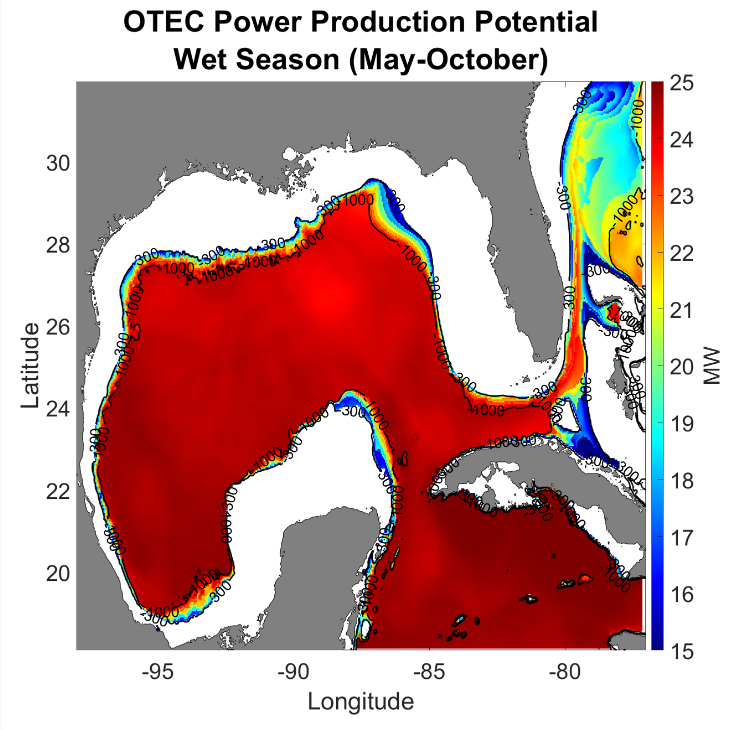
OTEC Power Production Assessment Methodology

- Applied OTEC model across Gulf of America, Florida Straits, Peuro Rico and U.S Virgin Islands
- Retrieved daily 2021 temperature profiles from HYCOM at 300m-1000m (100m increments)
- Used the 20m depth temperature as the warm water intake temperature
- Simulated daily net power for each grid point and intake depth, fixing pipe length by vertical distance
- Calculated annual average net output power at each location
- Split results into wet (May to October) and dry (November to April) seasons
- Mapped spatial distribution of peak OTEC potential Across study region

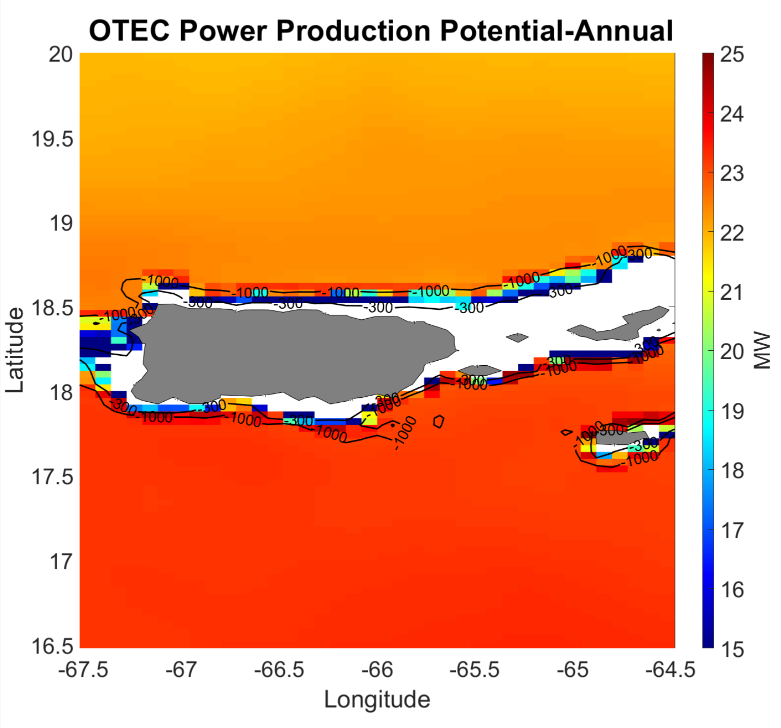
Results


OTEC Power Production Potential- Annual
Latitude
Longitude
MW

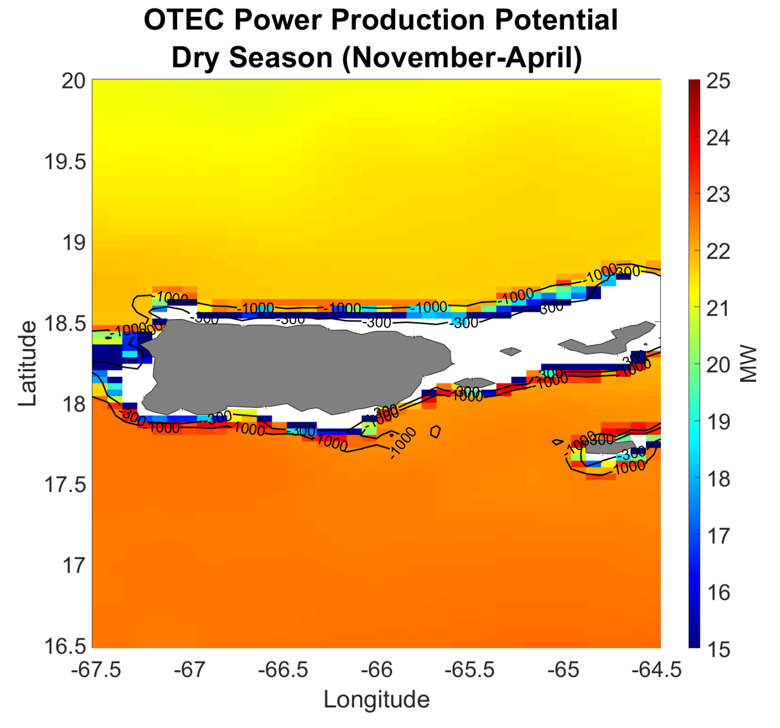

OTEC Power Production Potential
Dry Season (November-April)
Latitude
Longitude
MW


OTEC Power Production Potential
Wet Season (May-October)
Latitude
Longitude
MW

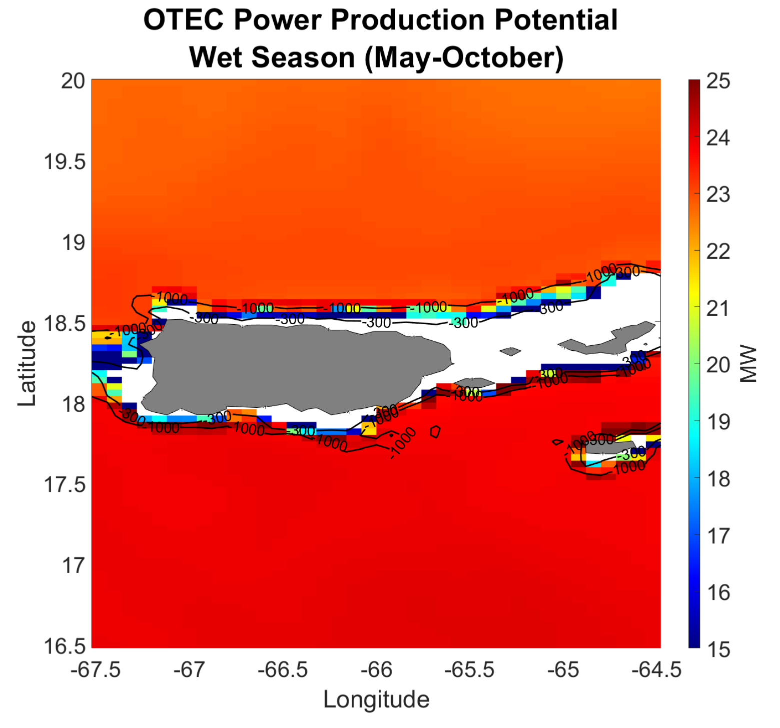
Results



OTEC Power Production Potential-Annual
Latitude
Longitude
MW



OTEC Power Production Potential
Dry Season (November-April)
Latitude
Longitude
MW



OTEC Power Production Potential
Wet Season (May-October)
Latitude
Longitude
MW

Conclusion and Future work

- South of Cuba, Puerto Rico/USVI consistently exceed 23 MW year-round, due to steep bathymetry and strong ΔT.
- Gulf of America Exhibits strong seasonal variability and delivers peak net power only further offshore, where depths exceed 800-1000m.
- **Future Work**: Commercial deployment needs optimization of system components size, as well as in-depth capital-cost modeling and LCOE analysis to confirm economic viability and attract investors.

THANKS FOR YOUR ATTENTION

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