Ocean Thermal Energy Conversion (OTEC): Potential for Multiple Applications at Sea and Onshore

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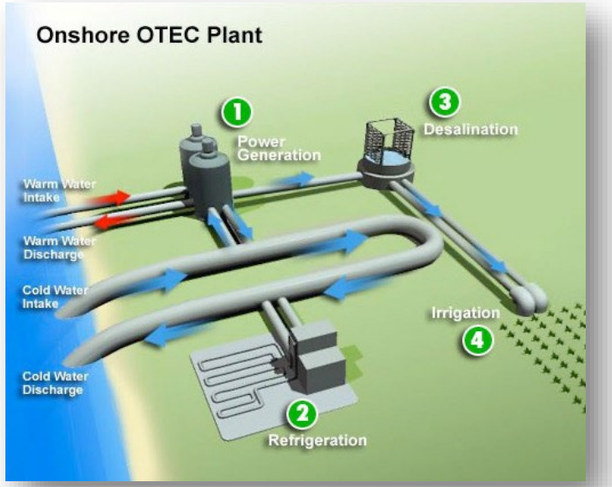
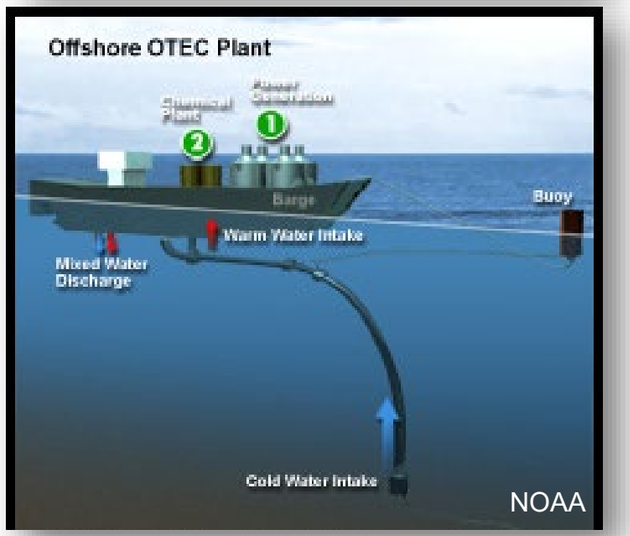
Ocean Thermal Energy Conversion (OTEC)

- Relatively simple technology only viable in tropical regions
- Generates energy from temperature differential between warm surface water in the tropics and the deep cold water below (~20˚C)
- No large-scale OTEC systems have been successfully deployed, but nearshore and onshore plants are under development
  - Small, onshore systems can supply power, desalinated water, and sea water air conditioning (SWAC)
  - Large, floating offshore plants could provide baseload power
- Potential for additional services and products with OTEC
- Seawater air conditioning (SWAC) is related but does not require as large a temperature differential





OTEC in the United States

- Little engagement in OTEC development in US for about a decade
  - Renewed focus and legislation in 2020
  - Funding so far has been small:
    - ✓ SBIRs & STTRs
    - ✓ Small projects at US DOE national laboratories

Examining feasibility of OTEC in US waters

- Reaching out to experts around the world
- Examining barriers to development
- Use cases to examine feasibility (PR, St. Croix, Hawaii, Guam)
- Resource assessment in Puerto Rico
- Coupled with aquaculture and grid stabilization in Guam
- OTEC end uses: power, disaster recovery, freshwater

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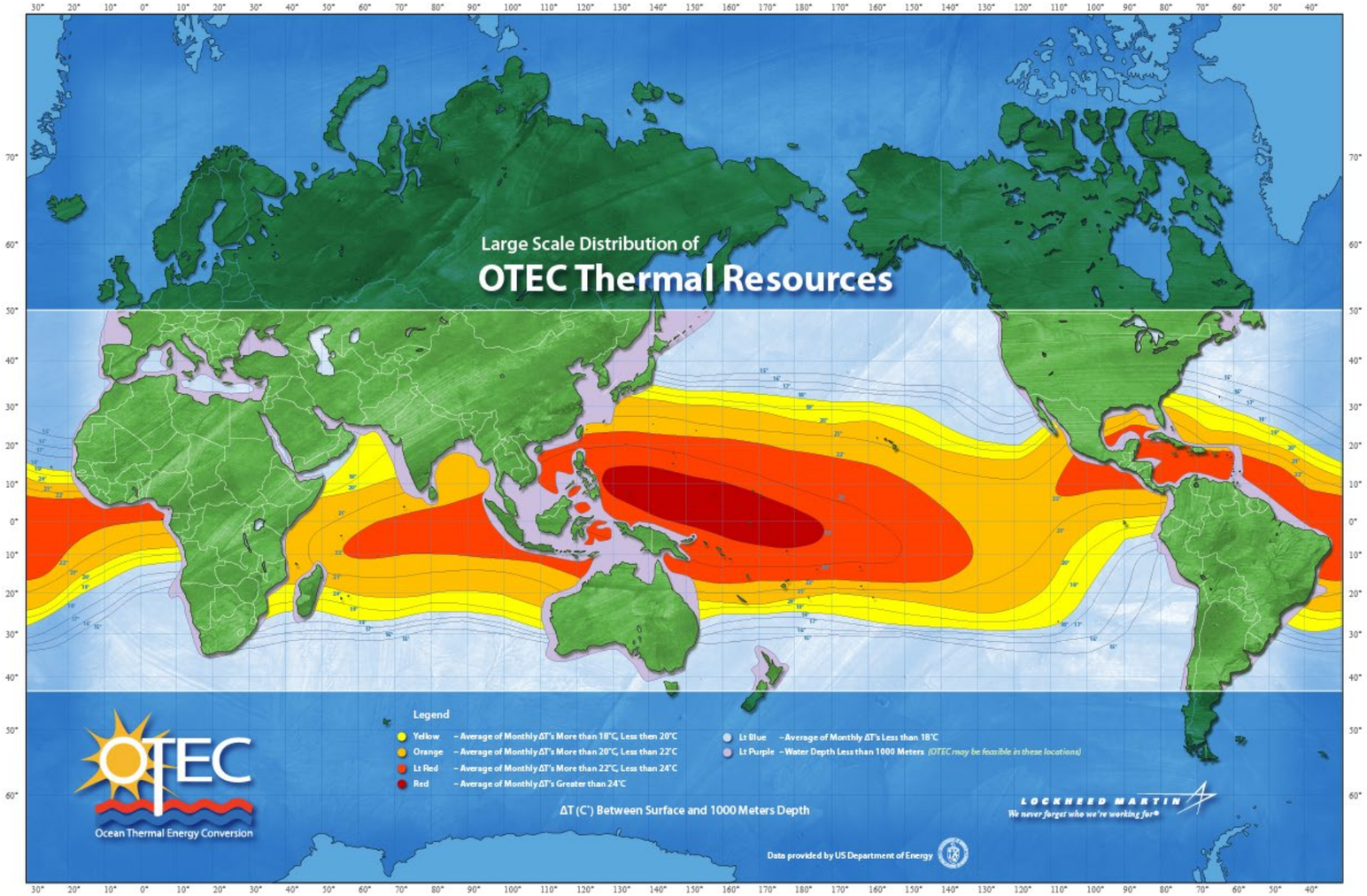
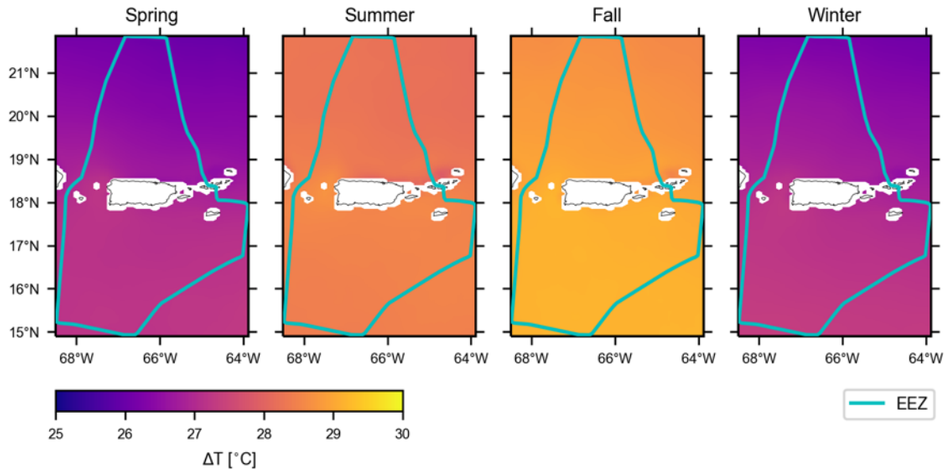
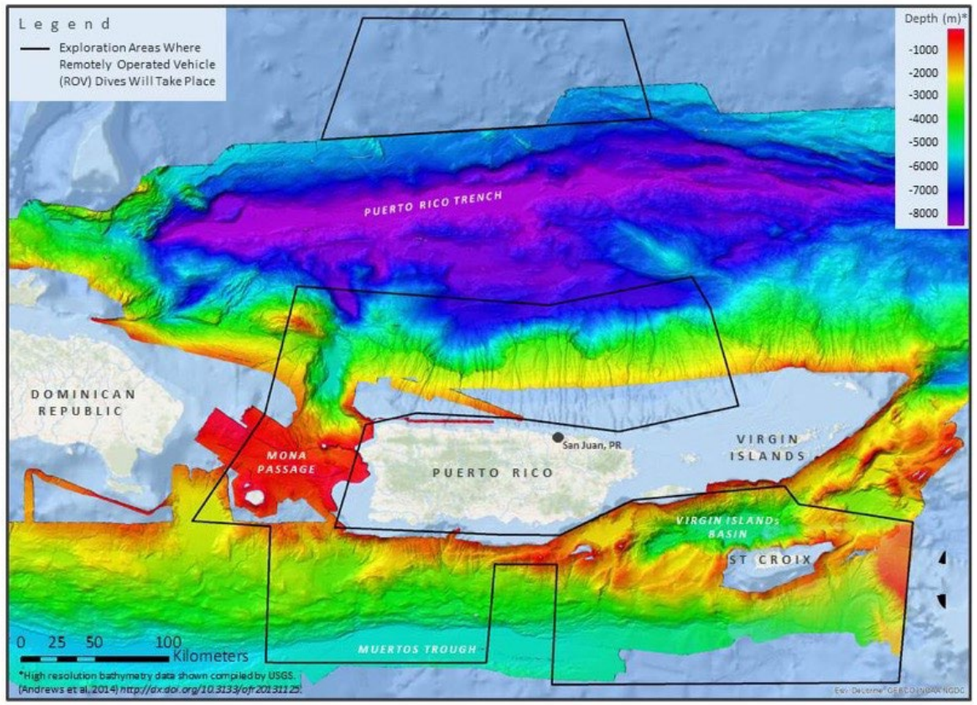
OTEC Resources and Planned Developments



Puerto Rico and US Virgin Islands

- Islands in eastern Caribbean Sea
- Close to Puerto Rico trench = deep ocean water close to islands
- Adequate temperature differential year round



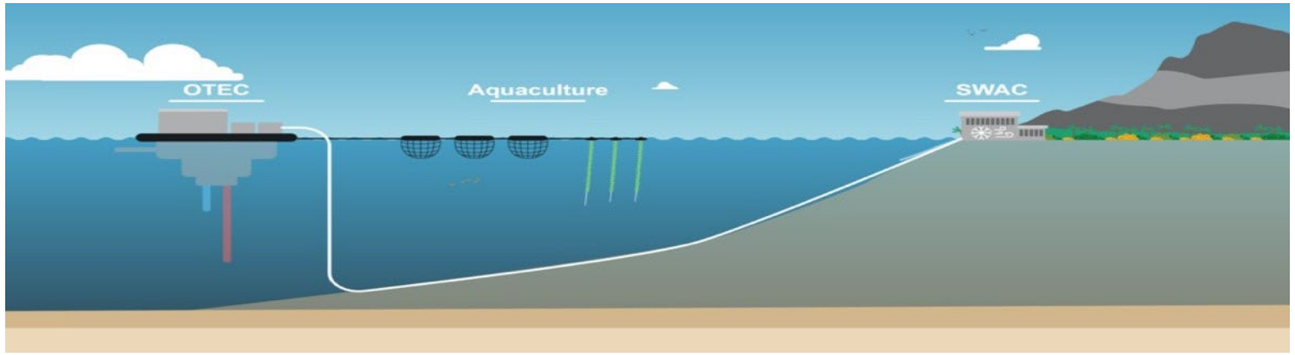


Puerto Rico Case

- 10MW OTEC plant
- Backup power grid, disaster recovery emergency services
- Also aquaculture
- Puerto Yabucoa nearest port
- 4.7km to cold water pipe
- Hazards
- Environmental effects
- Community support

Multi-Use OTEC Platform

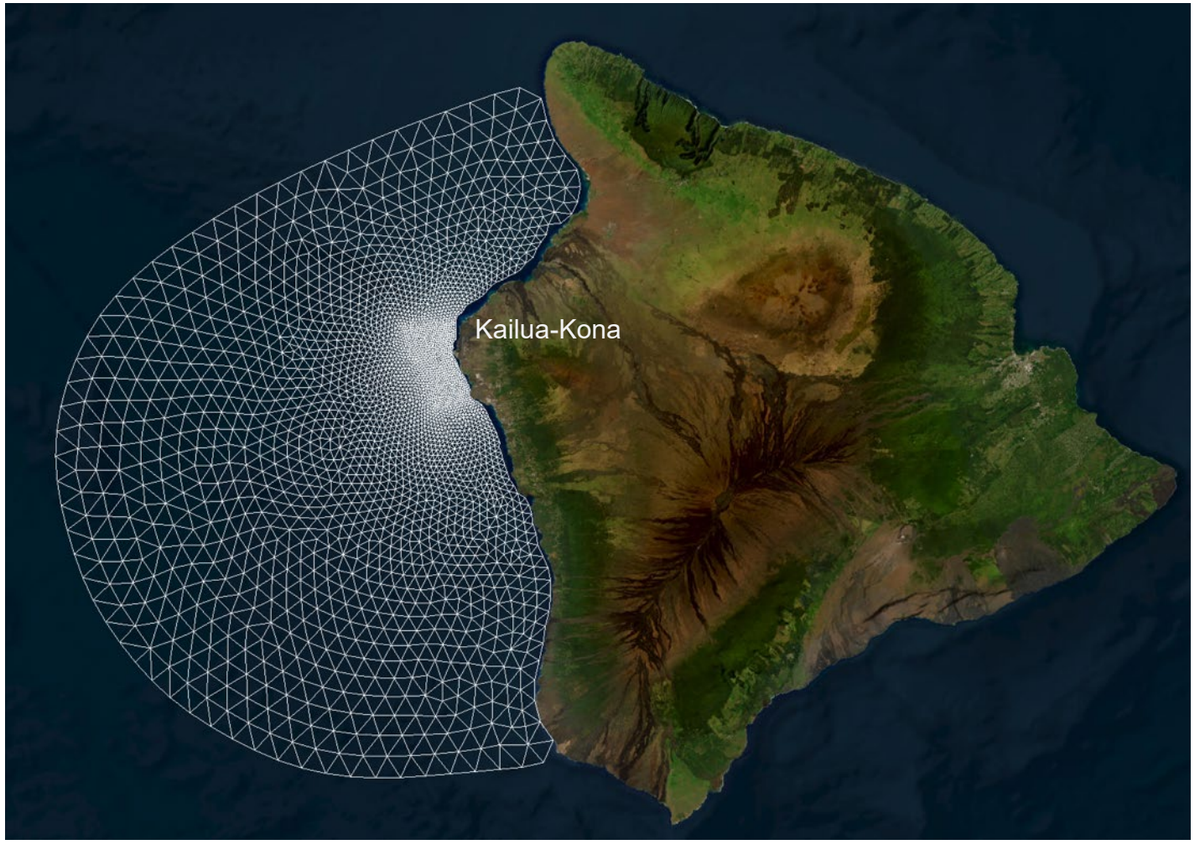
- PNNL, Makai, & Ocean ERA
- Located off Kona, HI at NELHA
- Technical feasibility of OTEC platform to provide:
  - Power
  - SWAC and district cooling
  - Desalination
  - Deep water for aquaculture
  - Critical mineral extraction
  - Efuels (ammonia/hydrogen)
- Tradeoffs for multiple uses
- Specific environmental effects
  - New plume model
- Community needs/values



Location

- Existing plant at NELHA on Hawaii
- 10MW floating OTEC plant
- Power for nearby installations, SWAC
- Port of Kawaihae 37 km north
- Hazards
- Environmental
- Community support

Resource Characterization Model Domain



- **Grid**
  - 360 m ~ 4.5 km horizontal resolution
  - 2 ~ 48 vertical layers
- **Bathymetry**
  - ETOPO 2022
- **Target period**
  - Aug 1 2015 to Dec 31 2019 – 1825 days
- **Forcing**
  - CFS V2
- **Initial and boundary conditions**
  - CMEMS & FES 2014
- **Computational resources**
  - 2 node / 72 cores (Eagle)

Potential environmental effects

- Discharge of cold water at surface
- Entrainment of water with biota
- Discharge of chemicals
- Interference with migration routes
- Entanglement in mooring lines
- Reef effect on fish
- Settling of benthic organisms, potential non-native species introduction
- Changes in nearshore waters due to temperature, circulation changes

Each effect will depend on the scale and location of the OTEC plant

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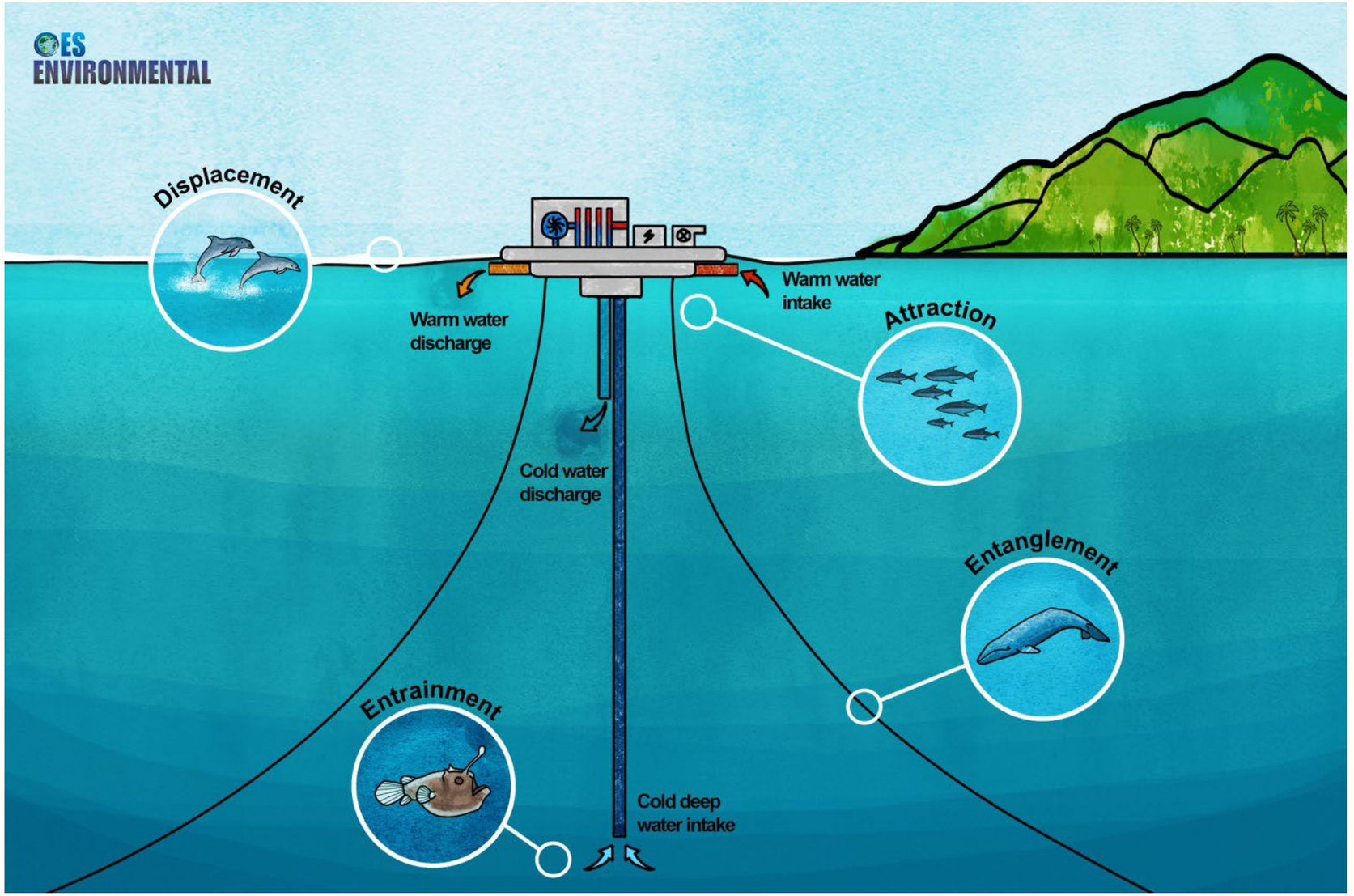
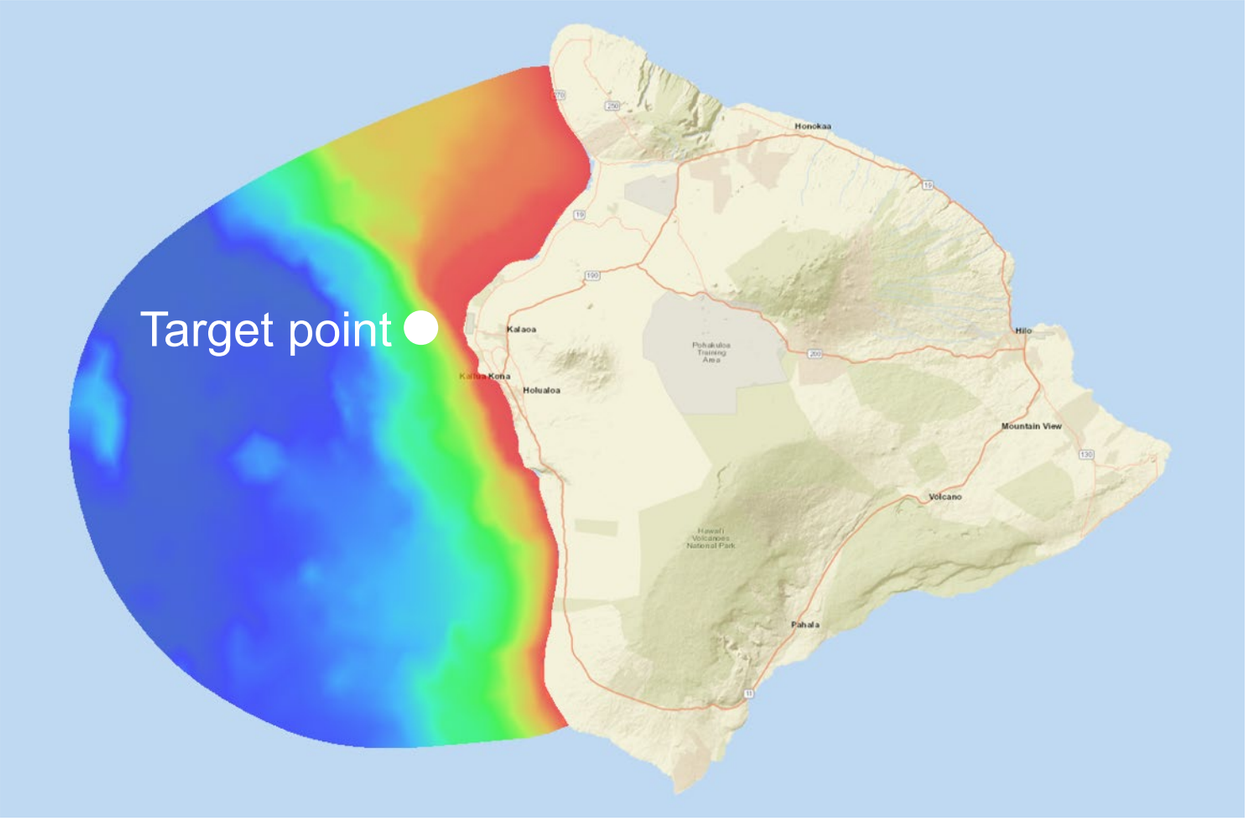
Potential Environmental Effects of OTEC



Cold-water plume model



Discharge location
Longitude: -156.1415423
Latitude: 19.735094

Discharge depth
70m

Discharge temperature
10^{o}C

Discharge rate
Exp.1: 400 m^3/s
Exp.2: 800 m^3/s
Exp.3: 1600 m^3/s
Exp.4: 3200 m^3/s

Target period
Jan 1, 2015 to Jan 1, 2016 (one year)

Cold water plume model at different discharge rates

Discharge rate: 400 m^3/s (Exp. 1 – base case)

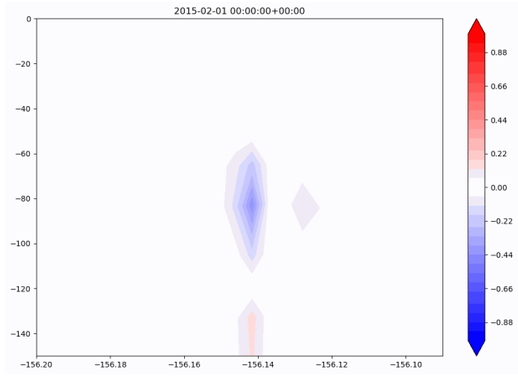
Discharge rate: 800 m^3/s (Exp. 2 – base case)

Discharge rate: 1600 m^3/s (Exp. 3 – base case)

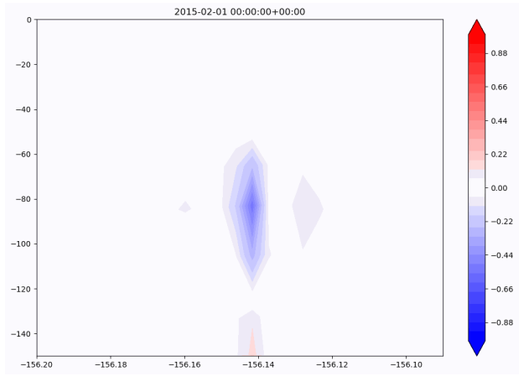
Discharge rate: 3200 m^3/s (Exp. 4 – base case)

C°

Water depth (m)



Longitude (deg)



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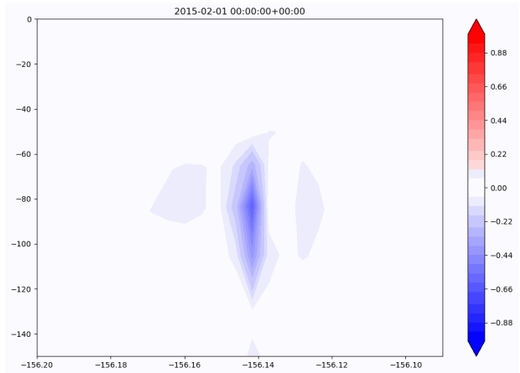
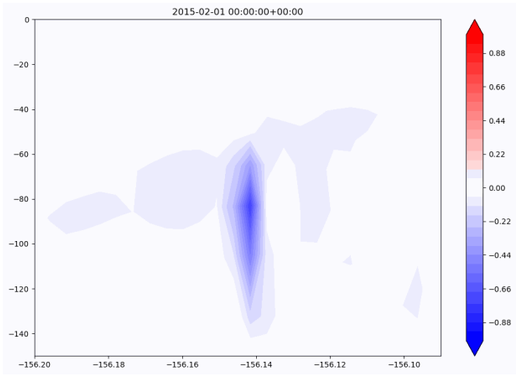


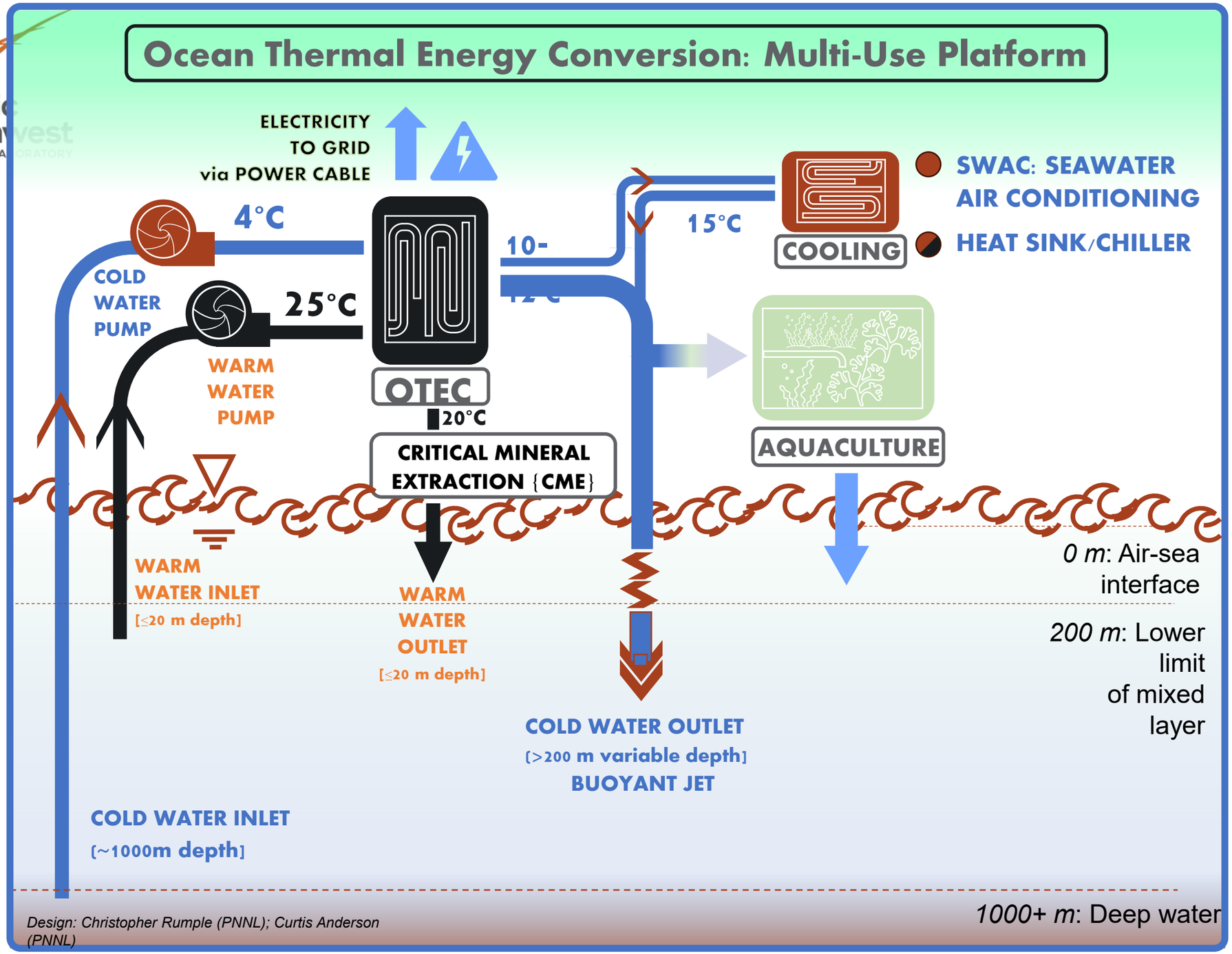
Longitude (deg)

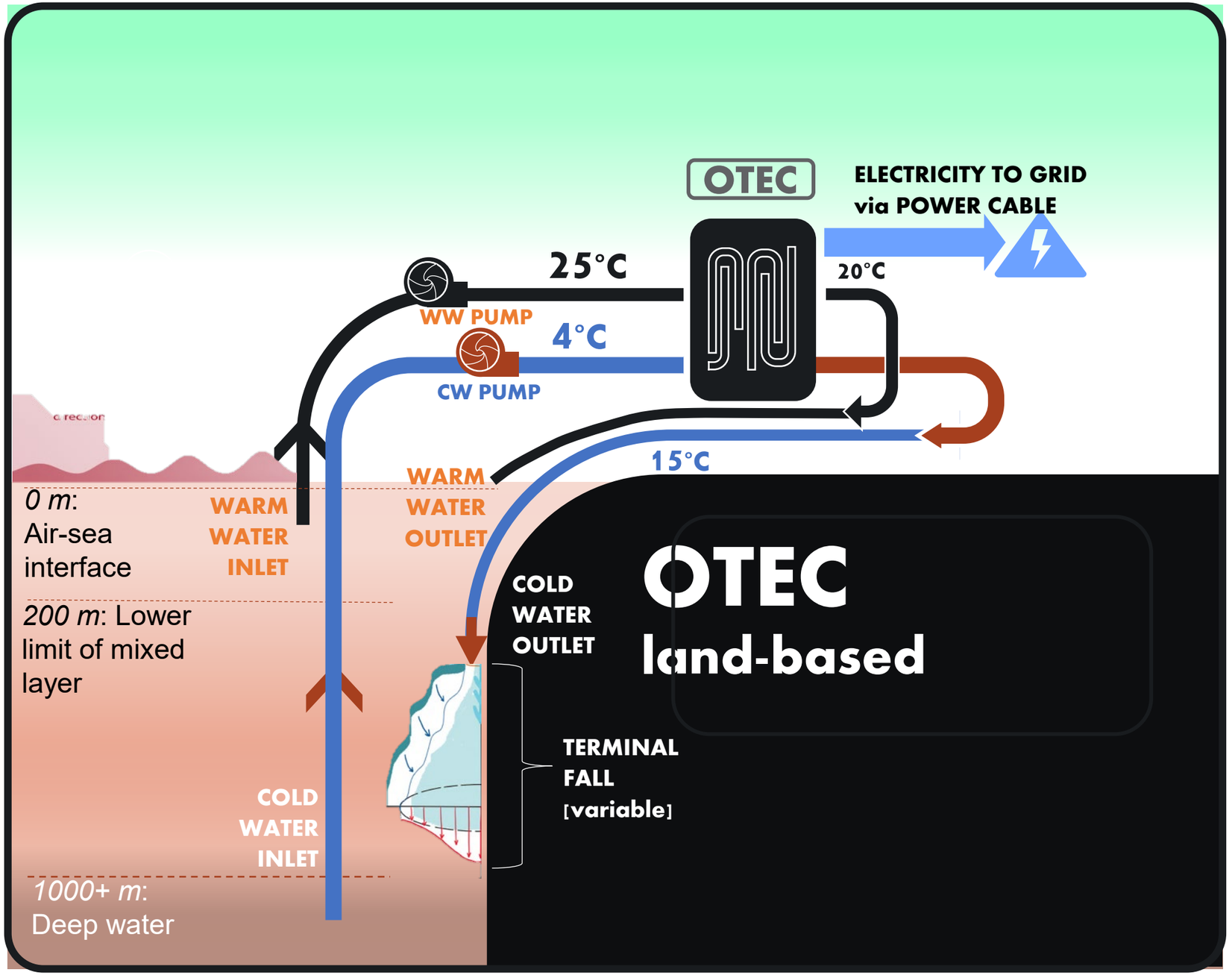


Longitude (deg)

Increased cold-water plumes (e.g., blue area) with the higher discharge rates

2015-02-01


Ocean Thermal Energy Conversion: Multi-Use Platform
ELECTRICITY
TO GRID
via POWER CABLE
4°C
COLD
WATER
PUMP
25°C
WARM
WATER
PUMP
OTEC
20°C
10-
15°C
COOLING
SWAC: SEAWATER
AIR CONDITIONING
HEAT SINK/CHILLER
AQUACULTURE
CRITICAL MINERAL
EXTRACTION {CME}
WARM
WATER INLET
[≤20 m depth]
WARM
WATER
OUTLET
[≤20 m depth]
COLD WATER OUTLET
[>200 m variable depth]
BUOYANT JET
COLD WATER INLET
[~1000m depth]
0 m: Air-sea
interface
200 m: Lower
limit
of mixed
layer
1000+ m: Deep water
Design: Christopher Rumple (PNNL); Curtis Anderson
(PNNL)


OTEC
ELECTRICITY TO GRID
via POWER CABLE
25°C
20°C
WW PUMP
4°C
CW PUMP
15°C
WARM
WATER
OUTLET
0 m:
Air-sea
interface
WARM
WATER
INLET
200 m: Lower
limit of mixed
layer
COLD
WATER
OUTLET
OTEC
land-based
TERMINAL
FALL
[variable]
COLD
WATER
INLET
1000+ m:
Deep water

OTEC Feasibility

- Technology is well tested, baseload power
- Optimization continues for efficiency, survivability
  - Heat exchangers
  - New materials and designs for pipes
  - Hardening for typhoon/hurricane resistance
- Capital costs very high (100s millions USD)
- O&M costs expected to be low (compared to other offshore renewables)
- Potential environmental effects understood, can be mitigated
  - Cold water return
  - Entrainment (minimal)
  - Land-based footprint
- Training community members as operators

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Thank You!

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