Ocean Thermal Energy Conversion (OTEC)

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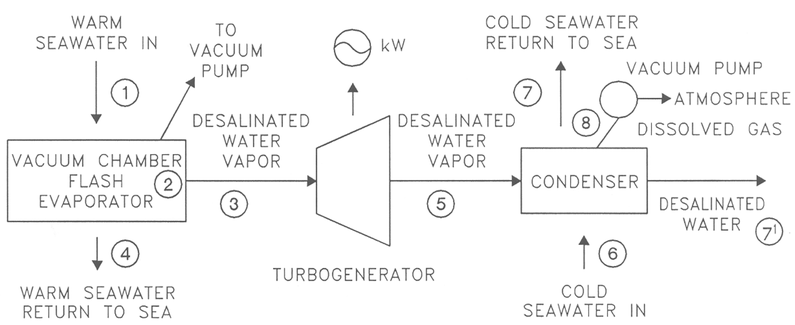
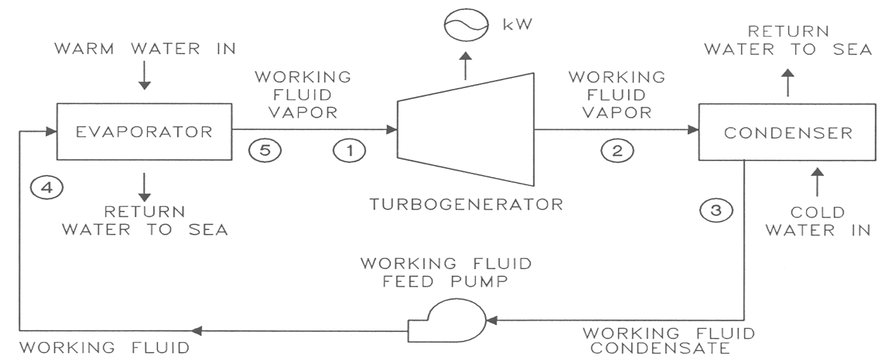
Open-Cycle OTEC (OC-OTEC)



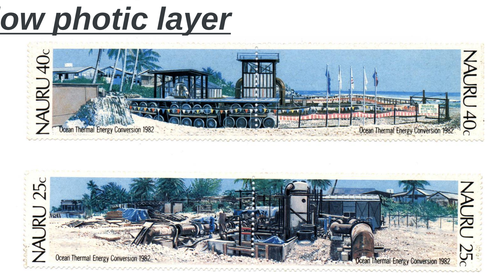
- Surface (Warm) seawater is flash-evaporated in a vacuum chamber → resulting low-pressure steam drives turbine-generator (*electricity*);
- Cold seawater condenses steam (*desalinated water*) downstream of turbine;
- Mixed seawater returned below photic layer

Closed-Cycle OTEC (CC-OTEC)



- Warm (surface) seawater and Cold (deep) seawater used to vaporize and condense a working fluid, such as anhydrous ammonia, which drives a turbine-generator in a closed loop producing kWh (*electricity*)
- Mixed seawater returned below photic layer

50 kW Hawaii (1979)



100 kW Nauru (1982)

100 kW (Hawaii)

100 kW (Okinawa)

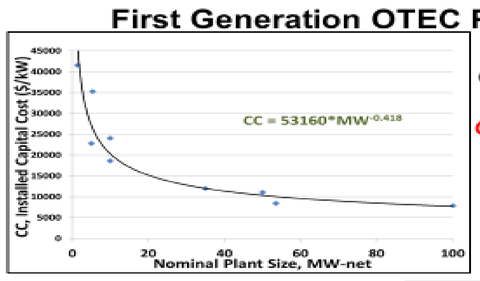
Ongoing

20 kW (S. Korea)

What we learned:

- **365/24 production of electricity & desalinated water determined**
- **Because Ocean is a great "battery" → Baseload/Dispatchable Electricity (unlike all other renewables)**
- **Cost-Competitive scenarios identified → Economy of Scale such that ≥ 100 MW plant in USA & ≥ 10 MW in SIDS**
- **To proceed MUST build/operate a pre-commercial plant ~ 5 MW**
- ***Potential environmental impact: return of spent seawater below the photic zone. Numerical models → return plume equilibrium is below photic layer (1% surface light intensity ~ 120m in Hawaii)***

First Generation OTEC Plants (2009 estimates)

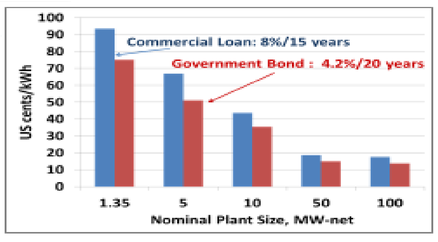


Capital Cost (CC) Estimates ($/kW)

CC strong function of plant size

LCOE ($/kWh) =
CC Amortization + Levelized OMR&R
Annual Inflation @ 3%

No environmental credits included



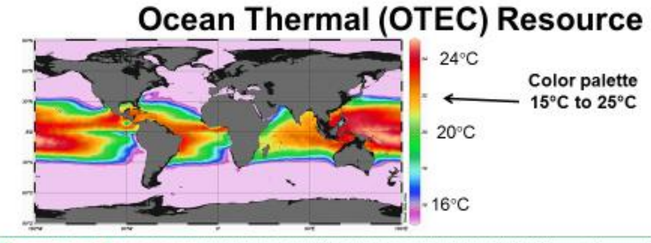
Past, Present & Future:
OTEC Challenges

- **Financing relatively high capital investments that must be balanced by the expected but yet to be demonstrated low operational costs;**
- **We lack operational & environmental records required to proceed into commercialization →**
  Need pre-commercial plant adequately sized (~ 5 MW) and operated in situ > 1⁺ year;

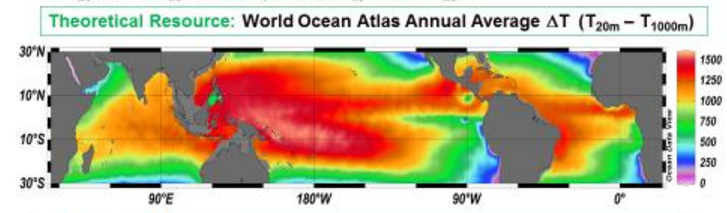
OTEC Resource:

- **Technical resource, expressed as electricity generated with OTEC plant, can be estimated from the Theoretical thermal resource: *ΔT between surface waters and water from 1000 m depth*;**
- **98 Nations with adequate OTEC resource within their EEZ (200 nautical miles);**
- **Annual production (GWh) with 100 MW OTEC plants located in the OTEC-Region estimated (*Nihous, University of Hawai'i*)**

Ocean Thermal (OTEC) Resource



Theoretical Resource: World Ocean Atlas Annual Average ΔT ($T_{20m} - T_{1000m}$)



Technical Resource: 100 MW OTEC Plant Annual Electricity Generation (GWh)
Baseline: 877 GWh/year @ ΔT = 20 °C

Future:
Potential World-Wide Market

How do we prepare for the *post-fossil-fuels era*?

Petroleum Fuels	< 50 Years
Natural Gas	< 120 years
Coal	< 100 years

- **Will need "Patient-Financing" for commercialization of Renewable Energy Technologies**
- **$300M - $750M funding for OTEC Industry over 5 - 15 years → potential world market in Trillions by end of Century (*1,000 plants at 100 MW each ~ $1,000 Billion investment vs. 250,000 Plants sustainable*)**

http://hinmrec.hnei.hawaii.edu/