Ocean Thermal Energy Conversion

Asia-Pacific Clean Energy Conference 2012

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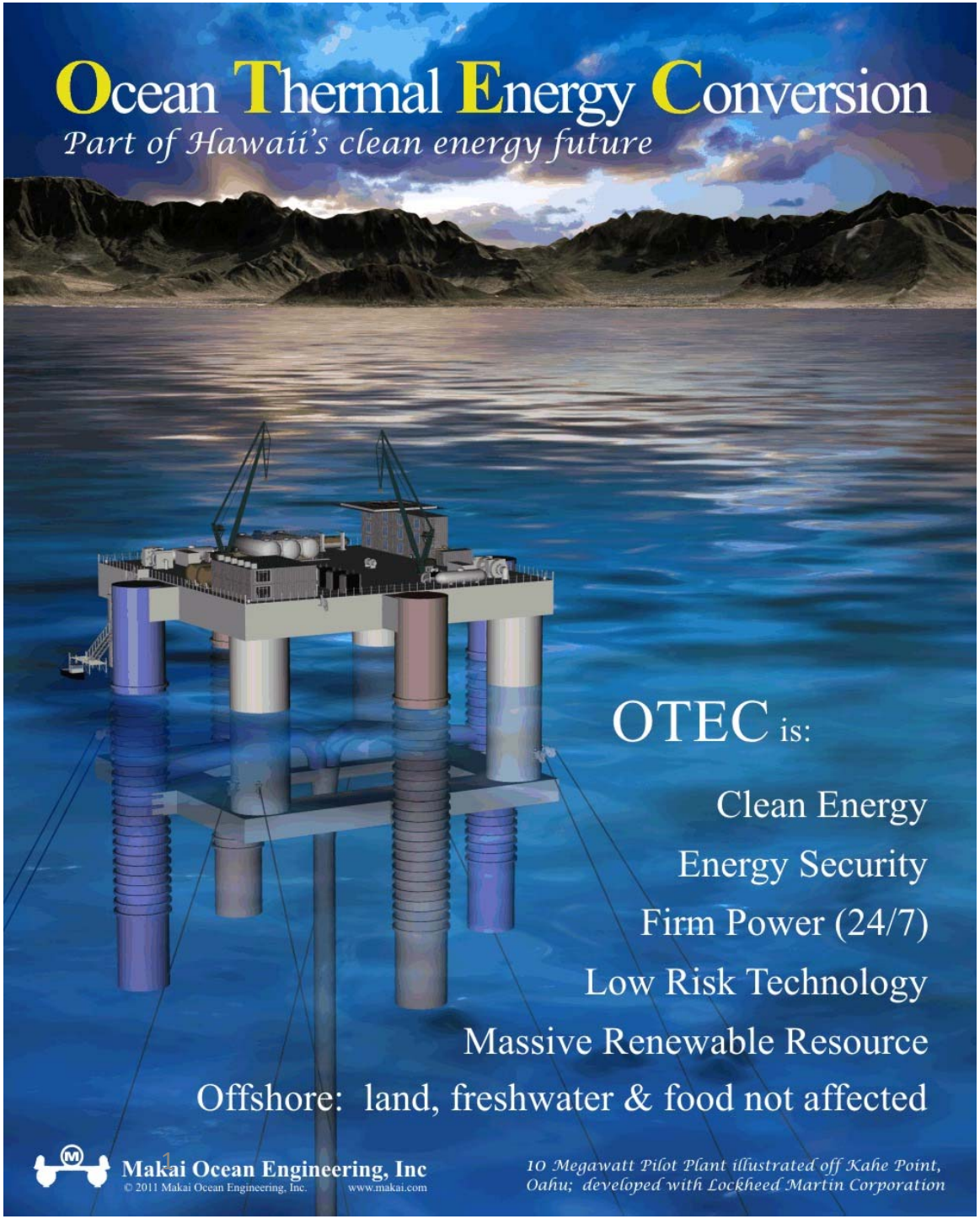
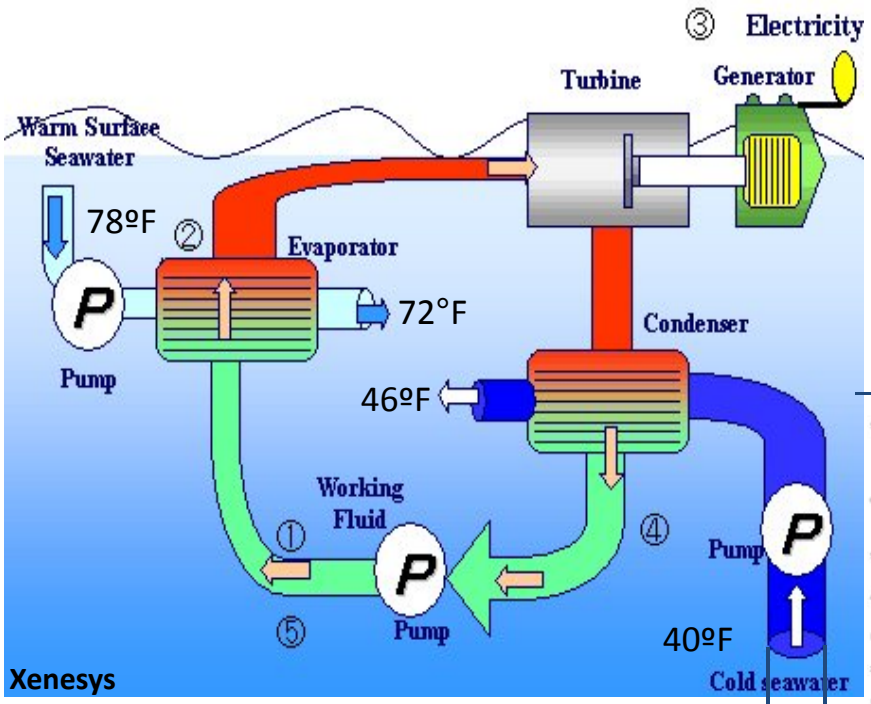
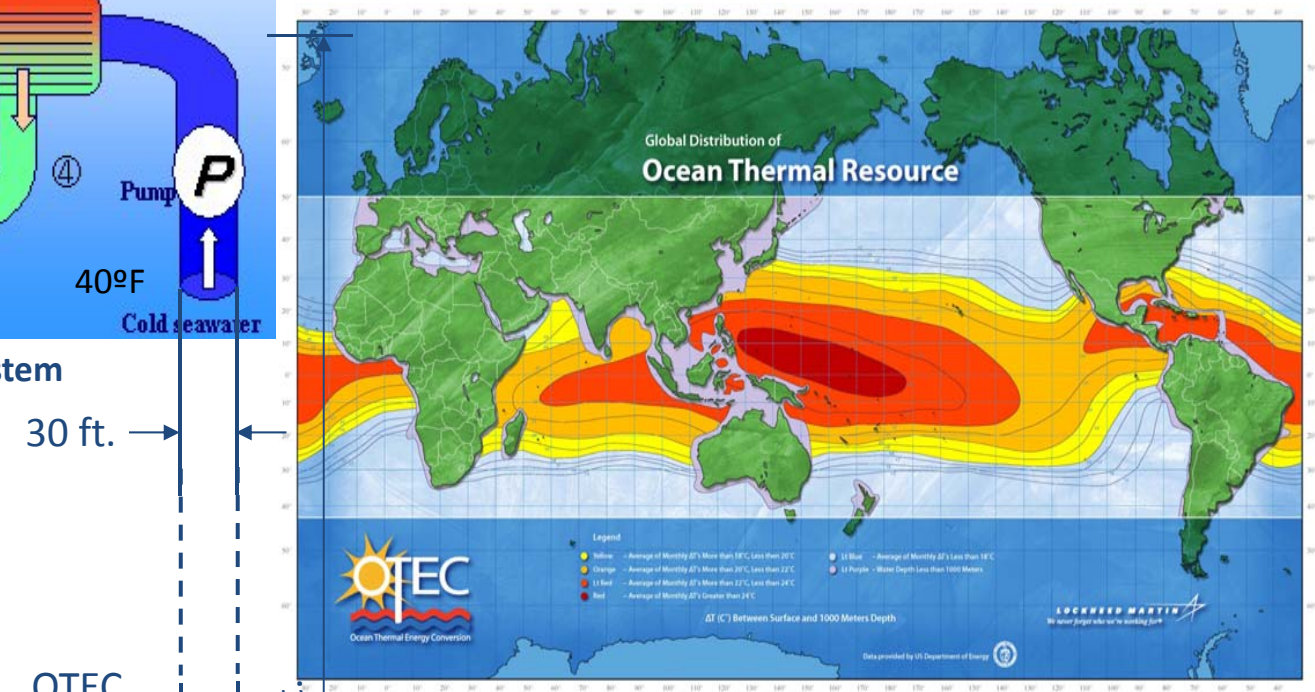


OTEC Fundamentals



Closed Cycle OTEC System

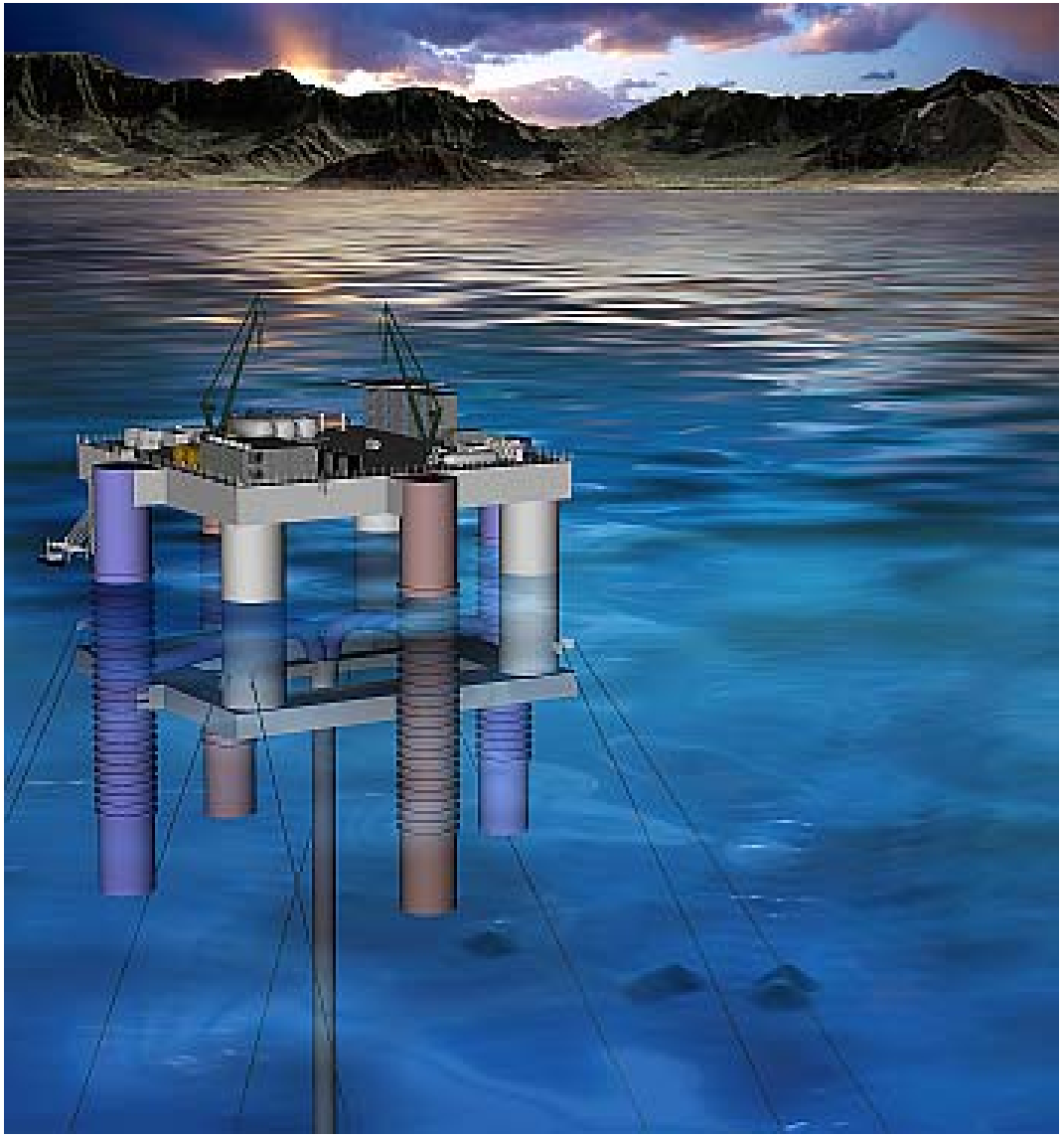
Temperature difference between warm surface water and deep cold water drives a Rankine cycle to turn a turbine to produce power.



Surface vs Deep Water Temperature Delta

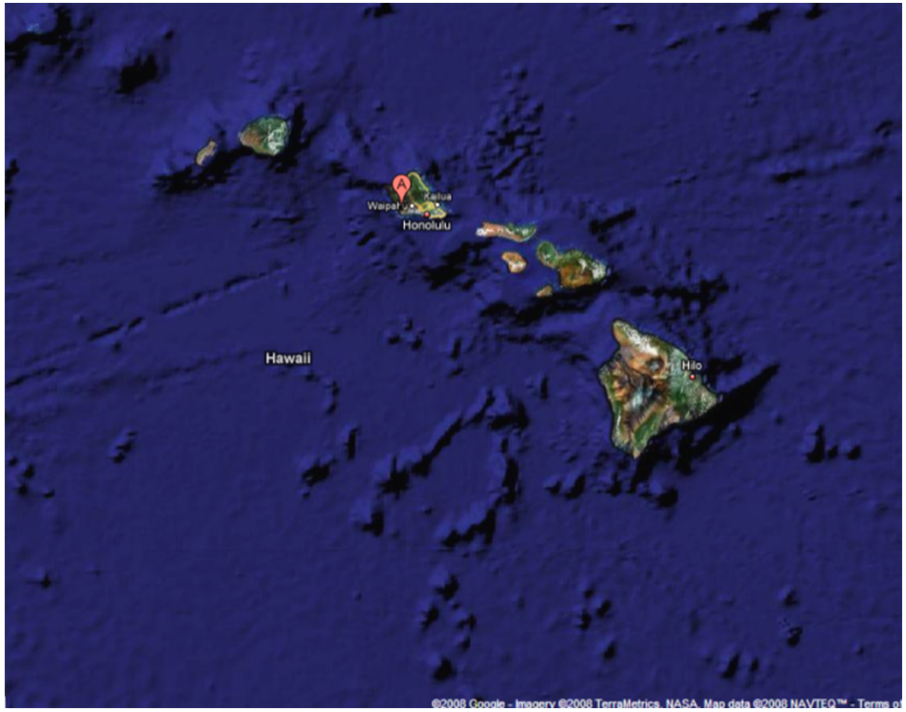
OTEC plants are:

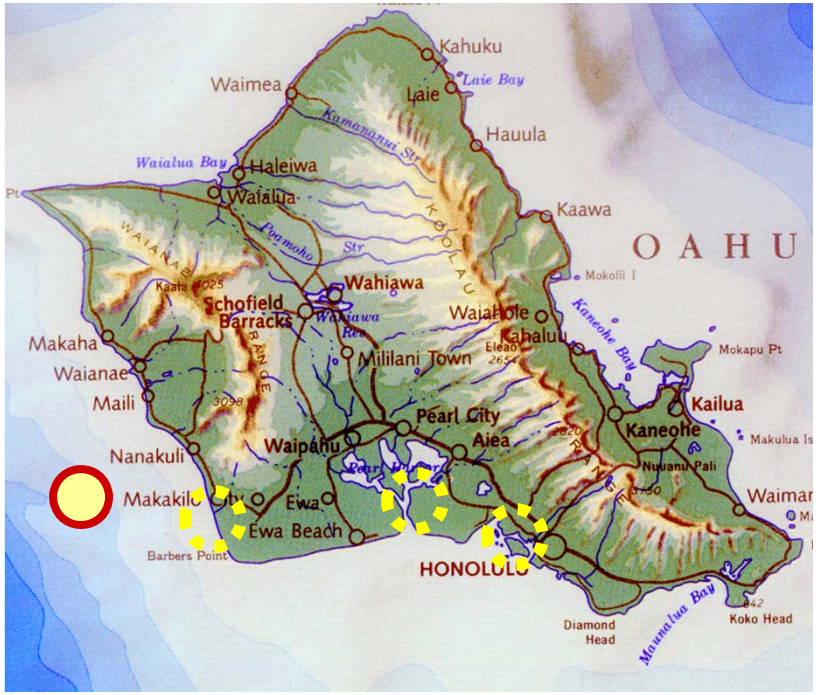
- Located in tropics
  - Access to deep cold water
  - Access to warm surface water
- Floating Offshore most likely
  - Platform: like oil rig
  - Mooring in deep water
- Large Vertical pipeline
- Cable to shore
- Large size
  - Economy of size dictates ~100MW
  - ~10m Pipeline

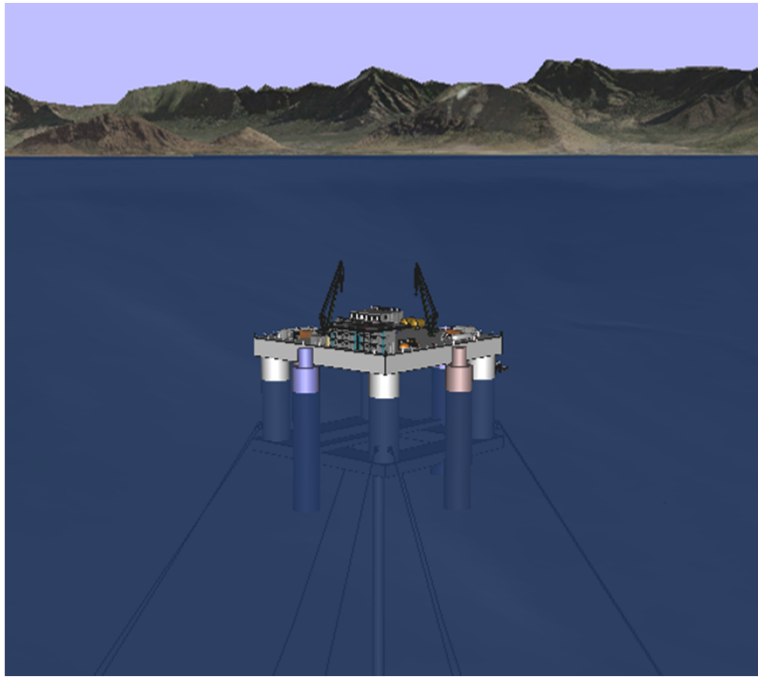


Hawaii OTEC

- 6 km to shore
- 1.2 km deep

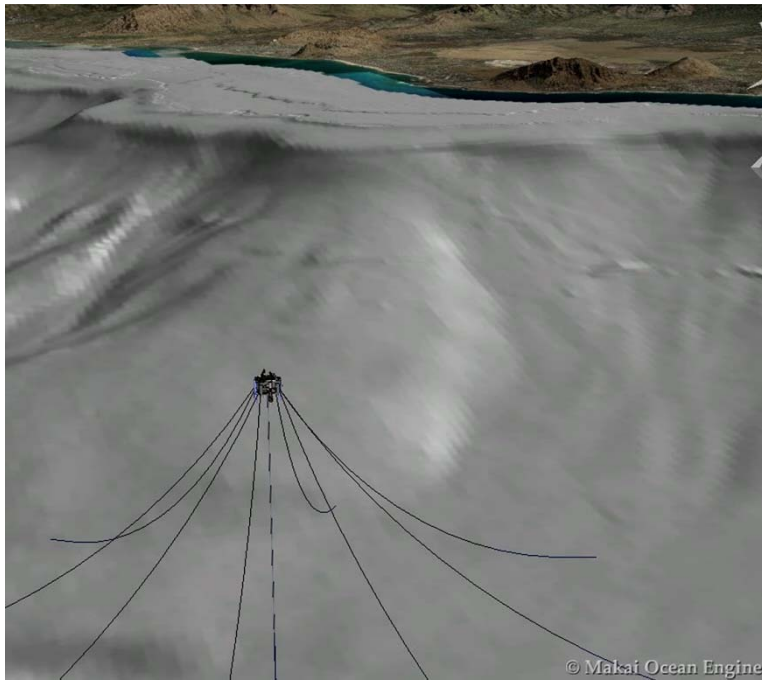


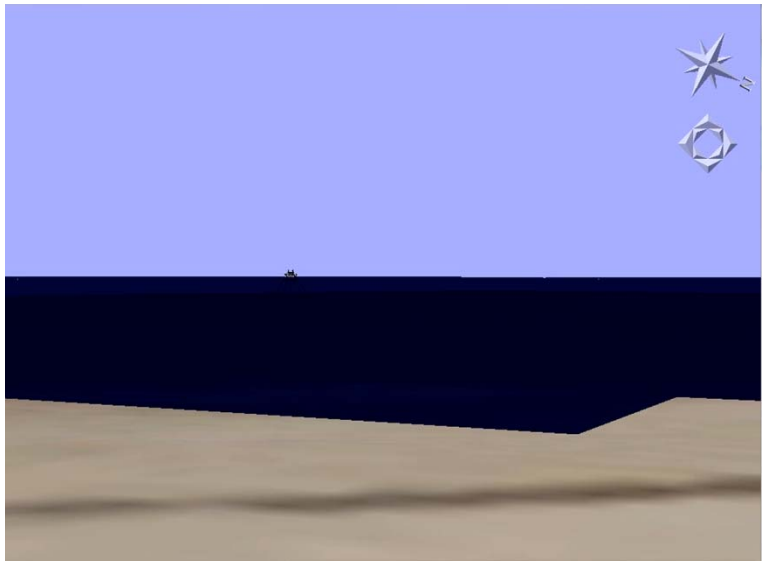




Why OTEC?

- Massive energy source
- Firm renewable power (base load) 24/7
- Non competitive with other vital resources: land, water, food
- Energy Security
- Near zero carbon emissions
- Today – OTEC is economically viable at large sizes (100MW and larger) in island communities such as Hawaii, Guam, Puerto Rico





OTEC: the Alternative Energy Elephant in the Room

Typical Alt Energy numbers:

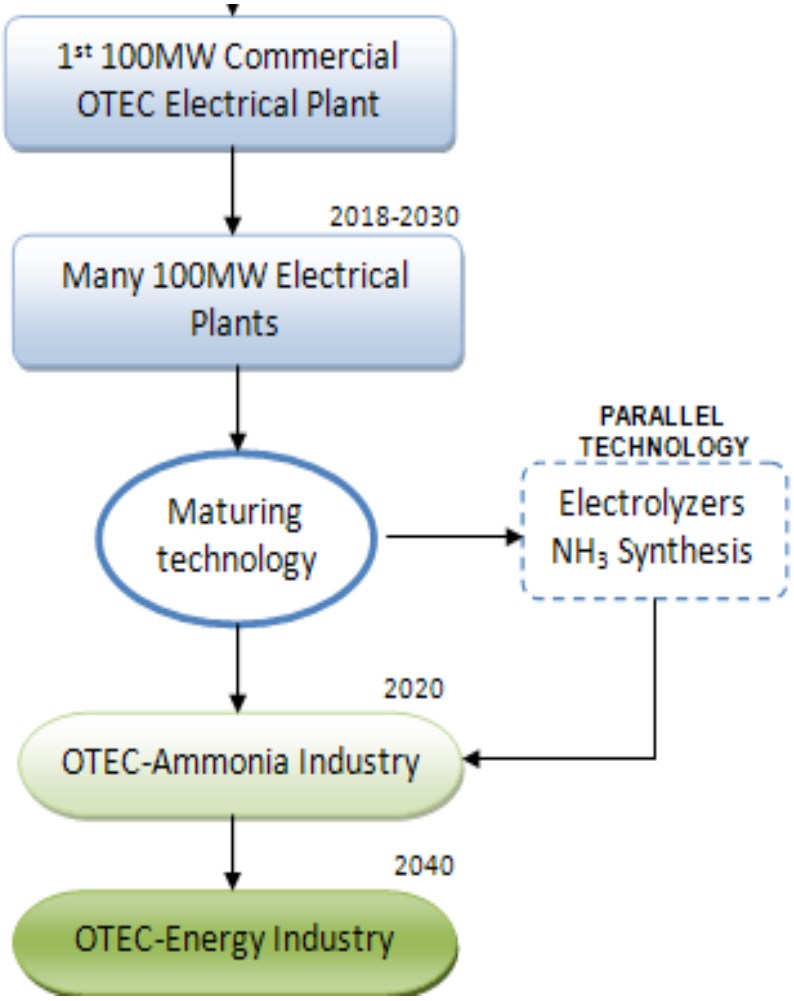
- Number of jobs
- Tons of CO2 saved
- Barrels of oil
- ???????

The numbers that count:

- Potential: 100% Hawaii Energy (or 100% world energy)
- Economically viable in Hawaii at large scale

Our focus on near term, low-lying fruit, & low-budget "solutions" encourages ignoring the elephant. With a 100% goal, the elephant is hard to ignore.

Beyond Hawaii



Immediate

- Ideal base load power for HI, PR, Guam, US Bases

Mid Range

- Development of huge export market; grid connected:
- Alternate Energy solution and Global Warming solution for tropical regions.

Longer Range

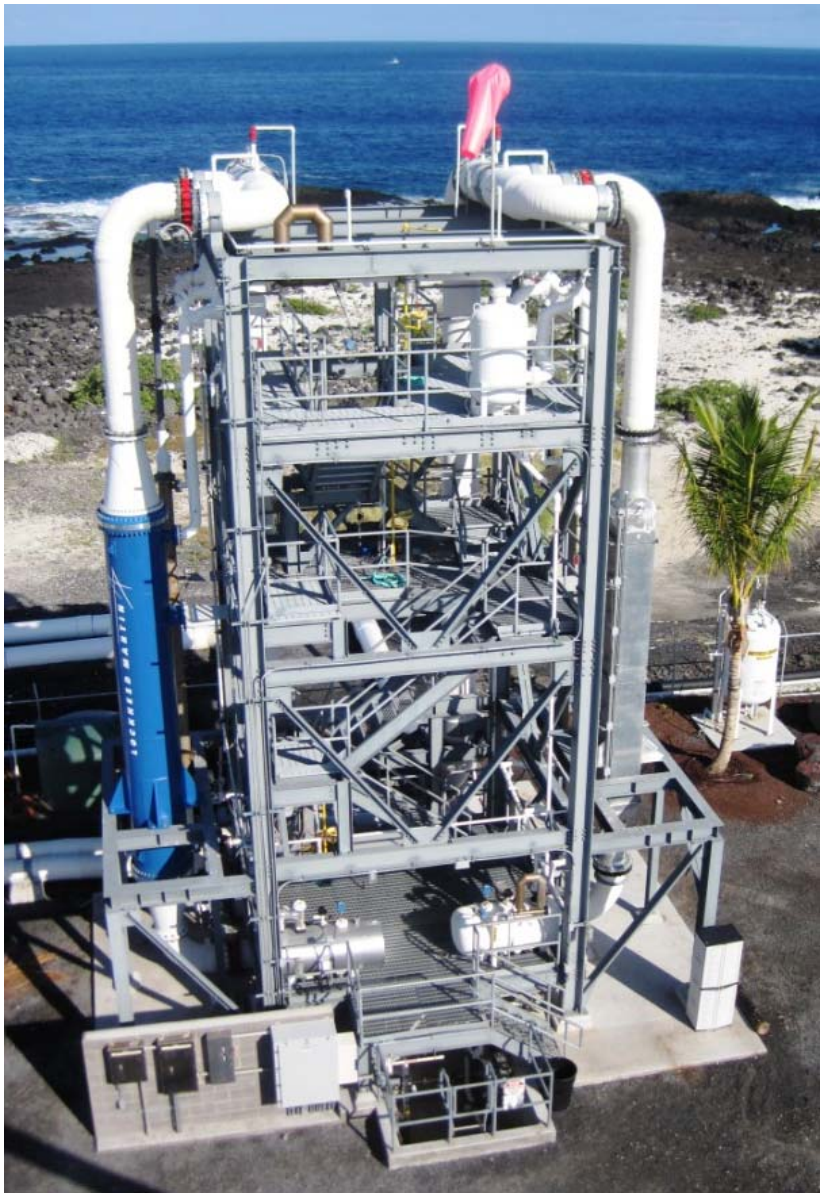
- Ammonia Production
- Development of strategic-size OTEC industry feeding mainland
- low risk backup to potentially higher risk coal, gas, nuclear.
- technology matures based on grid-Connected plants alone.

Programs

- Active and Cooperative/Competitive Programs:
  - OTE Corp – Bahamas land based effort
  - OTEC International, Abel Foundation – NELHA demonstration land based
  - France, DCNS – pilot plant at Reunion Island or Martinique, EU support
  - Lockheed – working toward 5-10MW Pilot Plant
  - EHS – OTEC plans in Pacific
  - Japan – Long term and continuing development, Okinawa small plant
  - US Navy – ONR – support of HX development work
  - DOE – small R&D support
- Financing is always the issue

Makai's OTEC Testing Facility

- Testing Facility to evaluate performance of OTEC HXs (NavFac)
- Continued HX development and testing (ONR)
- Aluminum HX corrosion testing lab.



OTEC Plume Modeling

DARPA/CEROS and DoE funded with additional support/assistance from:

- University Hawaii Regional Ocean Models
- Validation with NAVFAC sponsored mooring
- John Hamrick (TetraTech) and Matt Church (University Hawai`i)
- NOAA reviews and presentations:
  - OTEC Env. Workshop, Honolulu, June 2010
  - Peer Review w/ Kerry Kehoe, Manassas, Mar 2011

Very Significant Flows

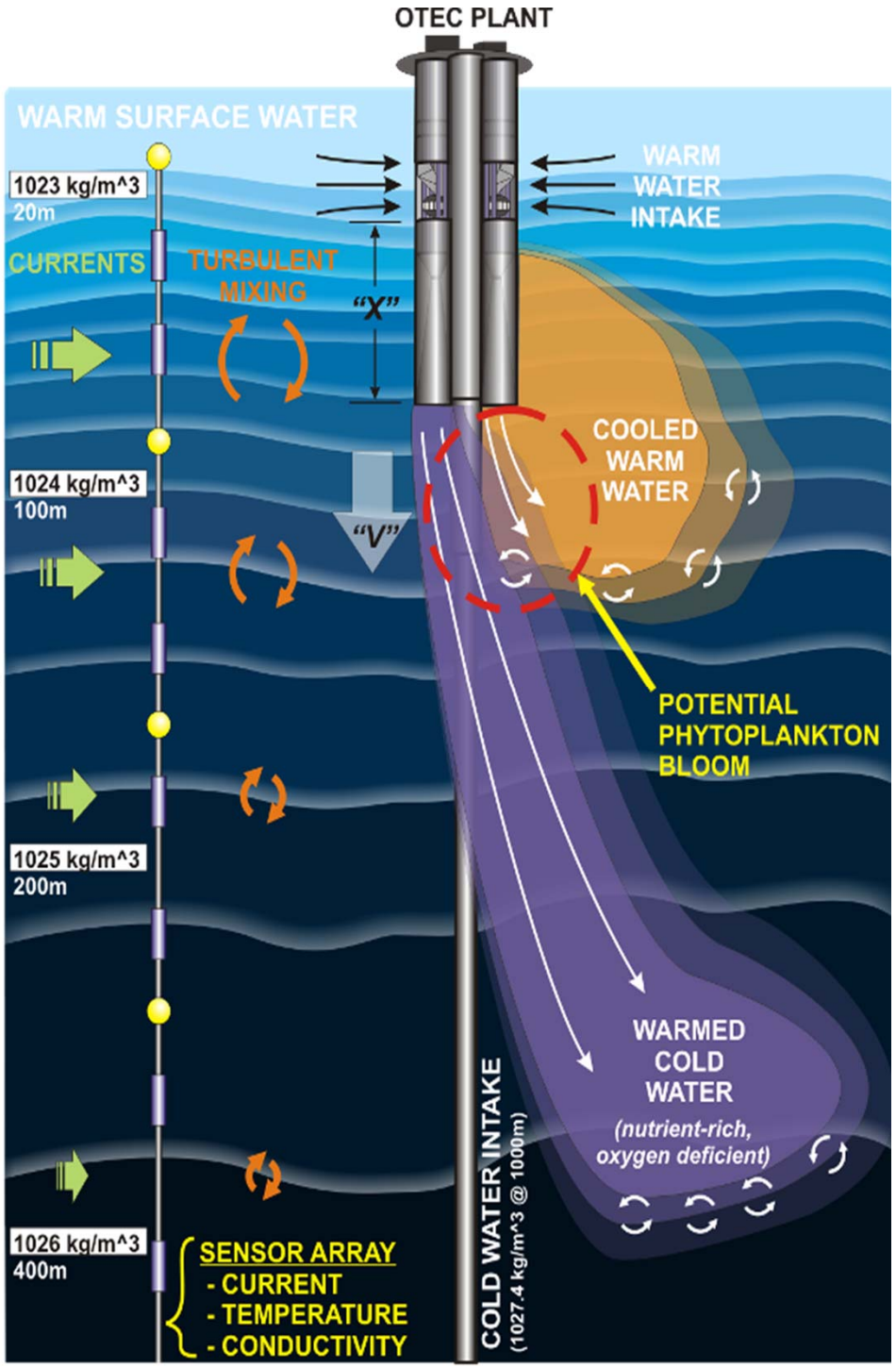
One 100 MW plant:

420 m^3 /sec Warm (~25°C) SW

320 m^3 /sec Deep (~4°C) SW

1000 MW (10 plants, i.e., all Oahu):

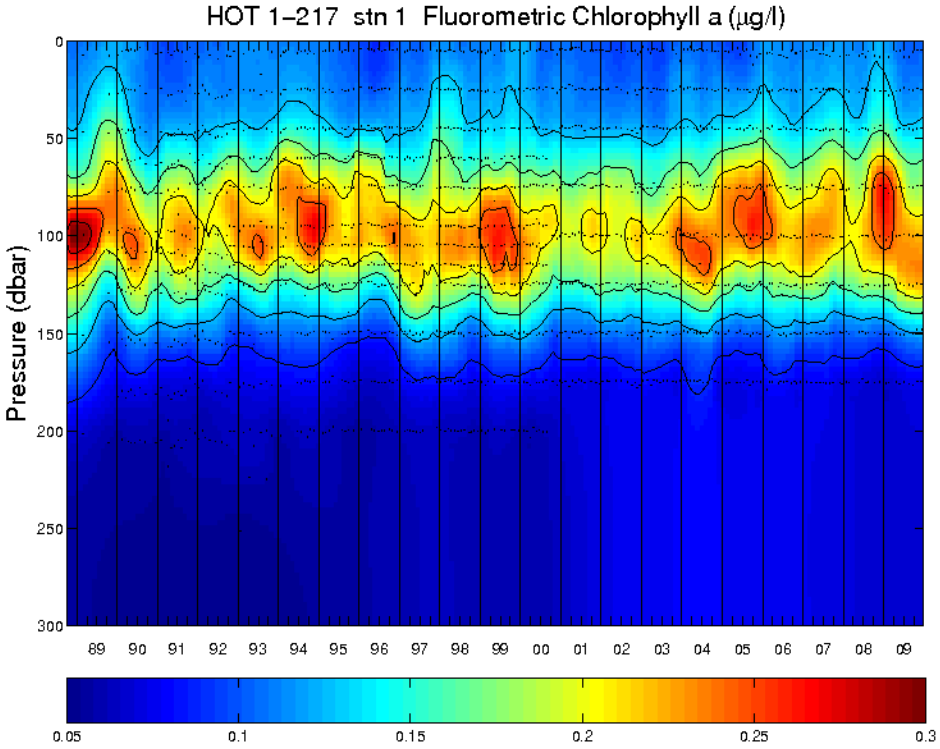
2/3 of cubic km per day

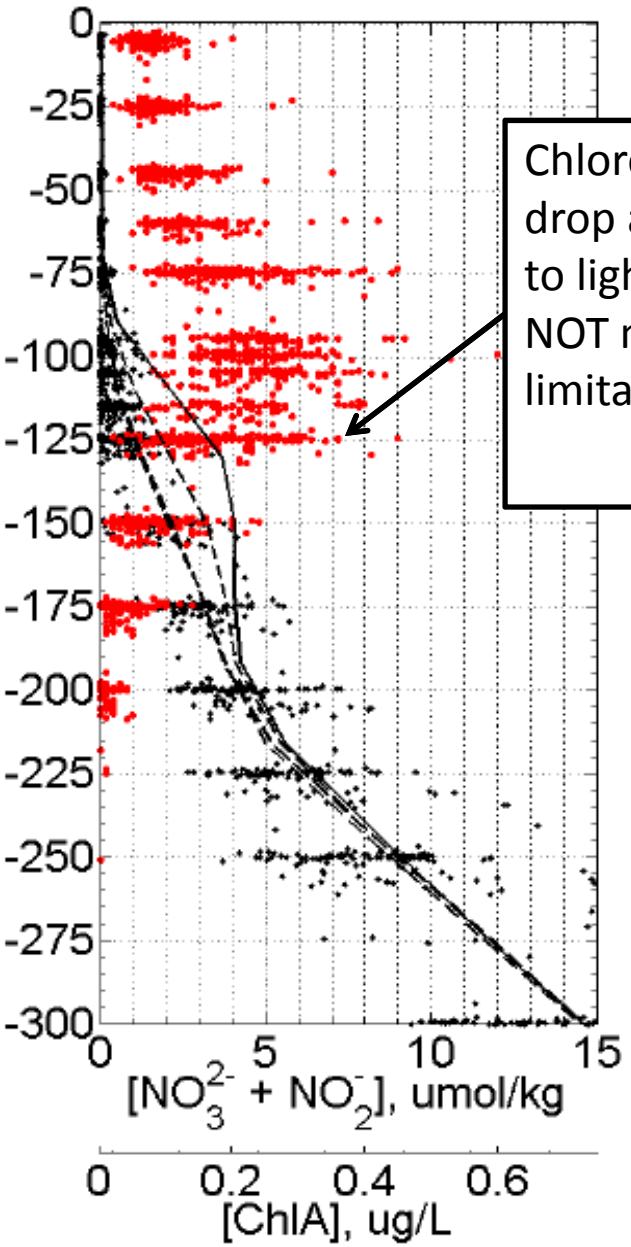


Biological Modeling

•Goal is to provide quantifiable predictions that aid regulators and engineers in the decision making process.

•Is the discharge deep enough?
•What is the potential for increased primary production?





Chlorophyll levels drop at ~120m due to light limitations, NOT nutrient limitations.

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Hurdles:

Cost:

- Everything is big: pipes, pumps, heat exchangers.
- At-sea is costly
- Small Plants are not economical, large ones are.
- Small Pilot Plants are expensive: costly start-up.

Technology:

- Most technologies are mature and ready
- CWP needs demonstration
- Development of cost-effective alternatives
- HX, Platforms, etc.

Frustration:

An OTEC plant can be built at the 100MW scale providing 24/7 power for Oahu at attractive long-term electrical rates (on par with neighbor island wind PPA for non-firm power)

Don’t ignore the elephant