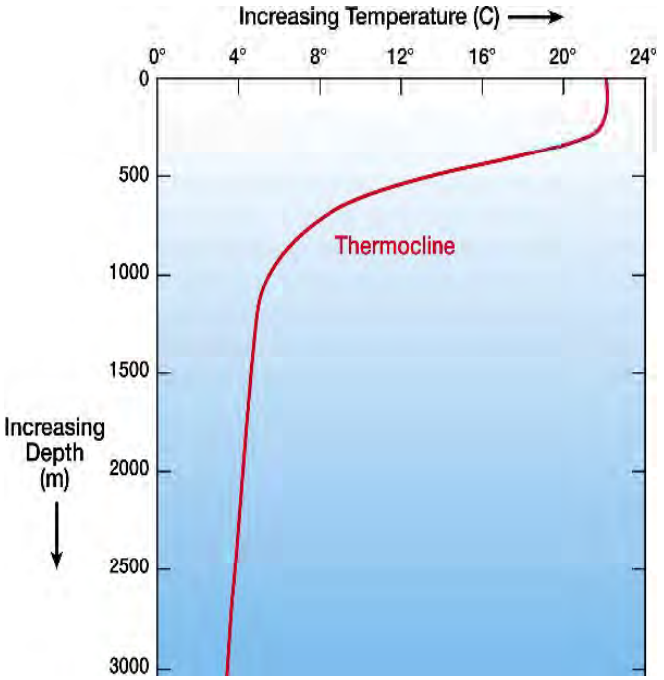
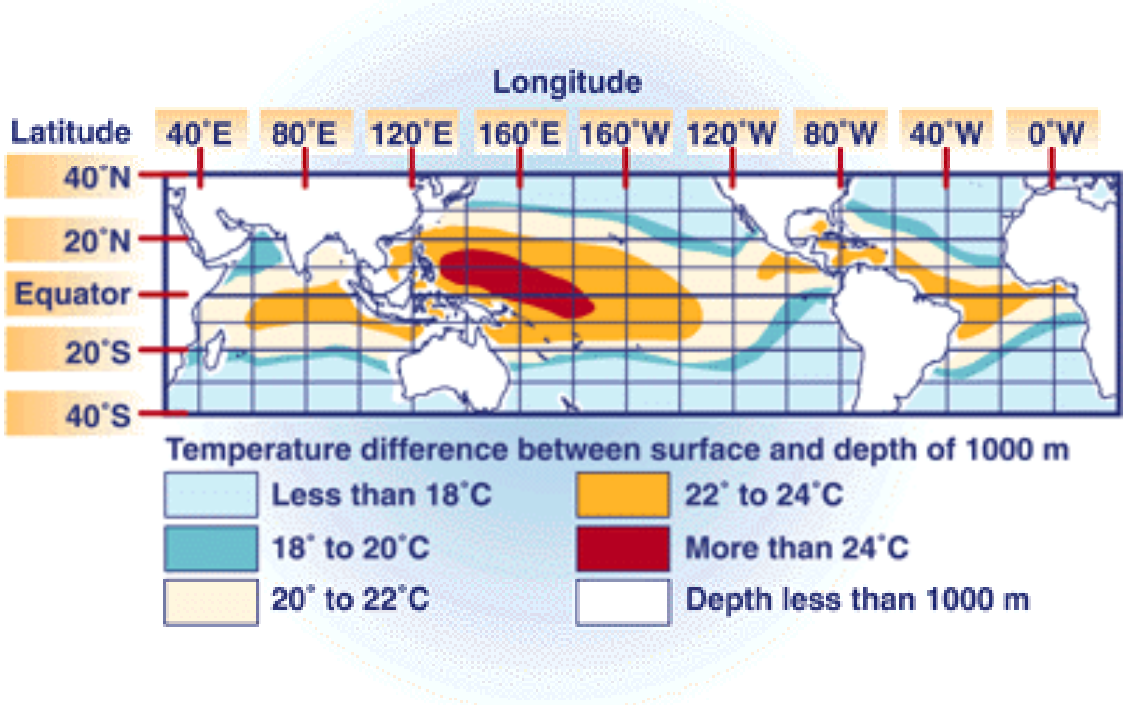
OTEC is coming to Hawaii

Makai Ocean Engineering, Inc.

www.makai.com

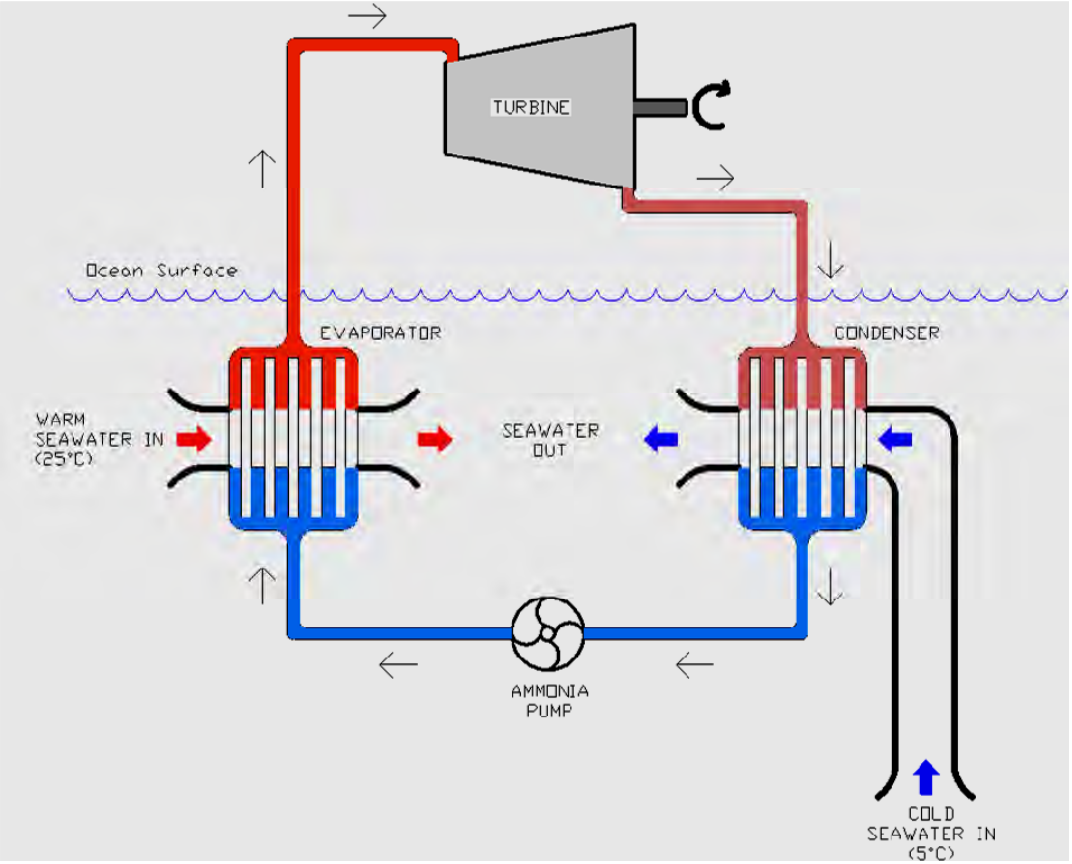
Ocean Thermal Energy Conversion





Using the temperature difference between:
DEEP OCEAN WATER ~5°C
and
SHALLOW OCEAN WATER ~25°C

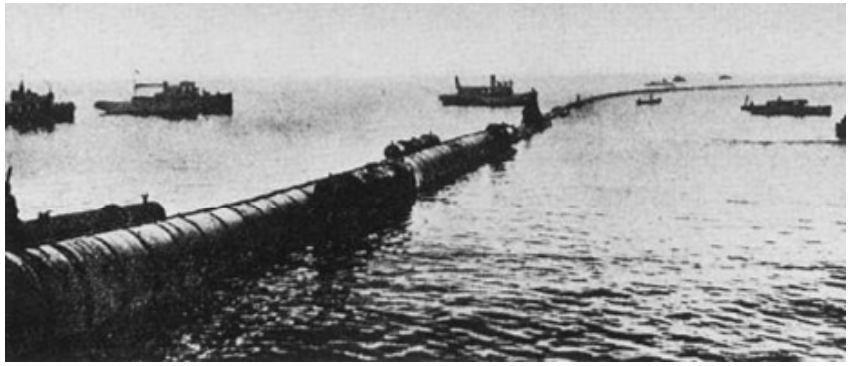
Ocean Thermal Energy Conversion

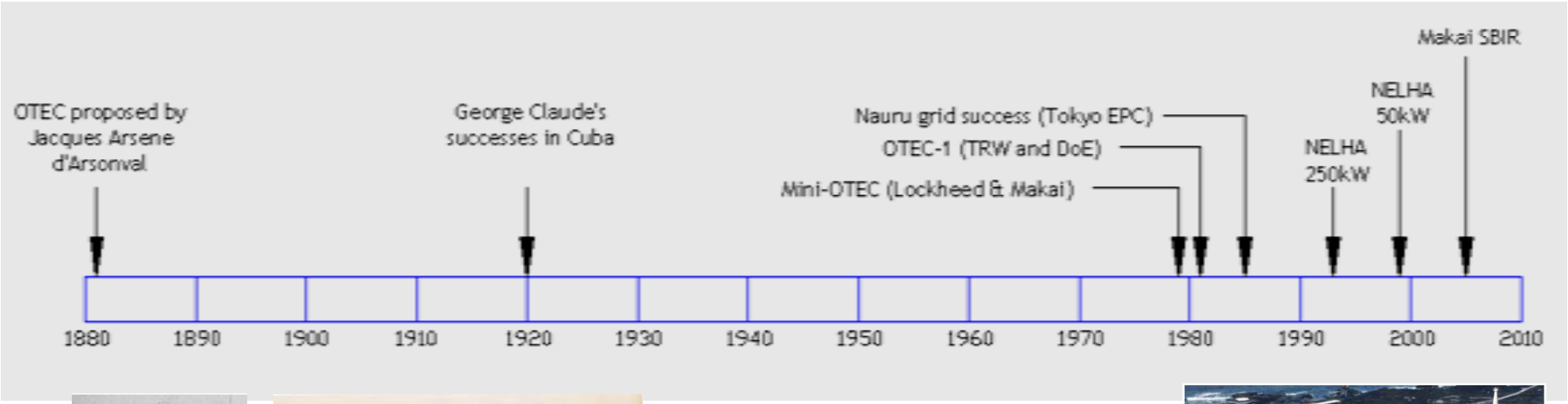


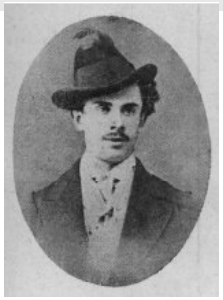
Closed -cycle

1. Warm ocean surface seawater boils a refrigerant liquid at high pressure (130 psi).
2. Refrigerant vapor spins a turbine-generator, becomes low pressure (80 psi).
3. Cold deep ocean seawater condenses refrigerant to a liquid again.
4. Cycle continues -- similar to steam turbine but lower temperature.

OTEC History

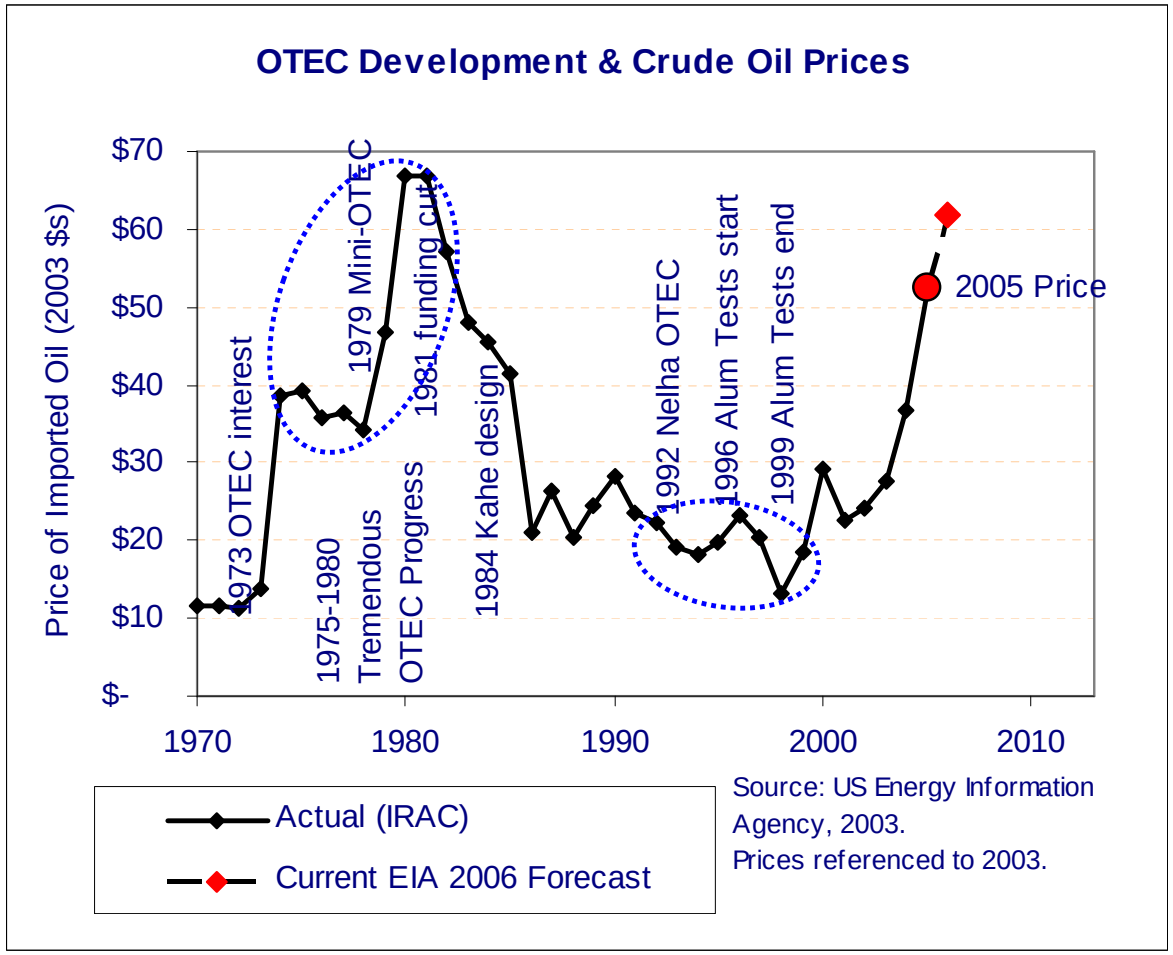




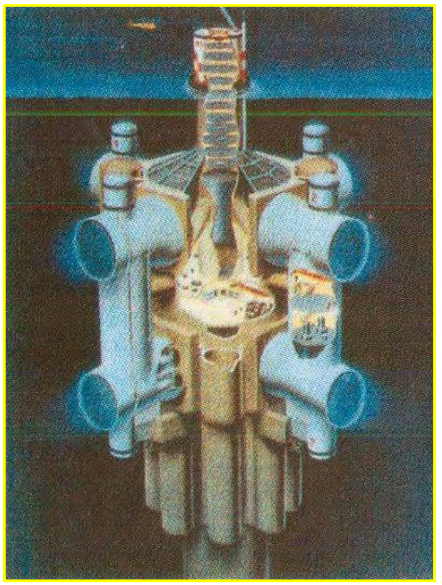


Small OTEC trials have been technically successful.

OTEC Opportunity



Mini-OTEC 1979

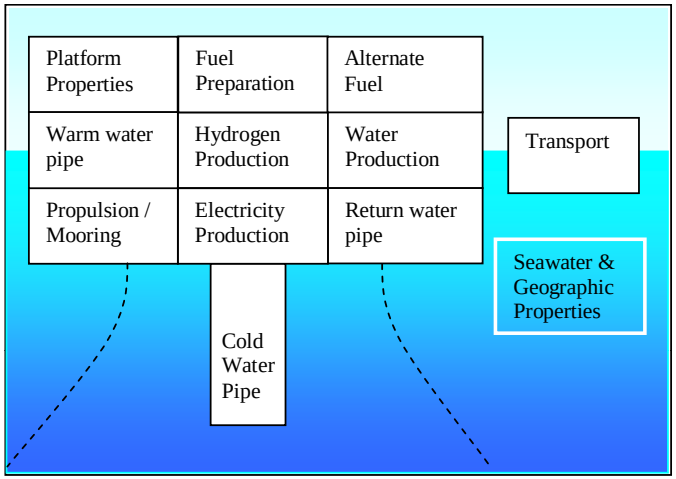


Lockheed Spar 1979

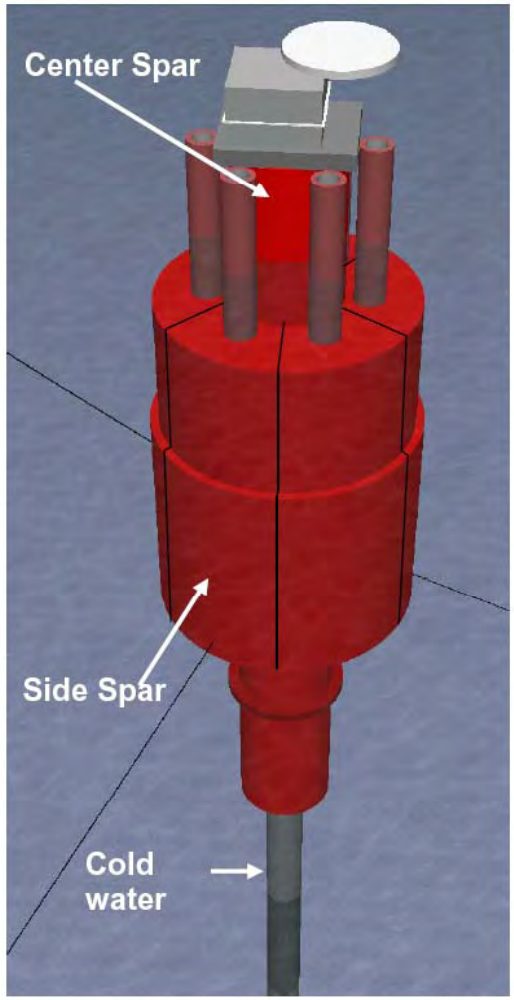
- **Oil prices back up**
- **Energy security issues**
- **Global Warming**

SBIR Goals

- In a world with uncertain oil, is OTEC a credible hydrogen source?

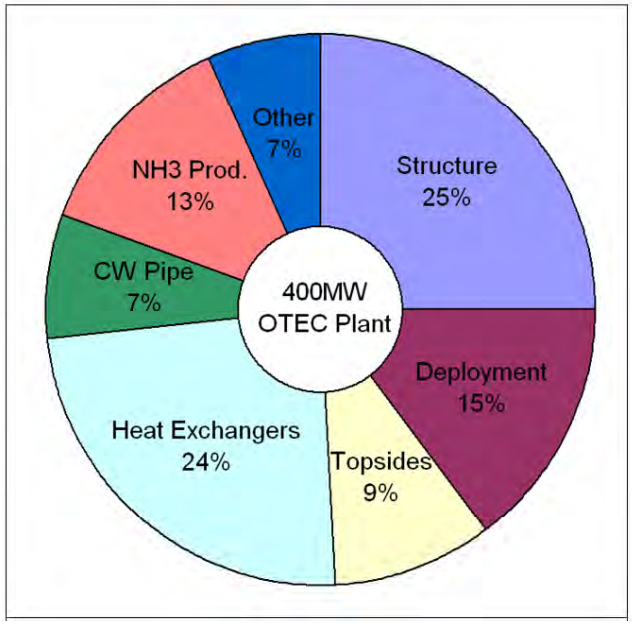


- **2005 Phase 1: Broad Brush**
- Parametric model of one plant
- Economic model of OTEC industry:
- Same benchmarks as DOE Hydrogen Program.

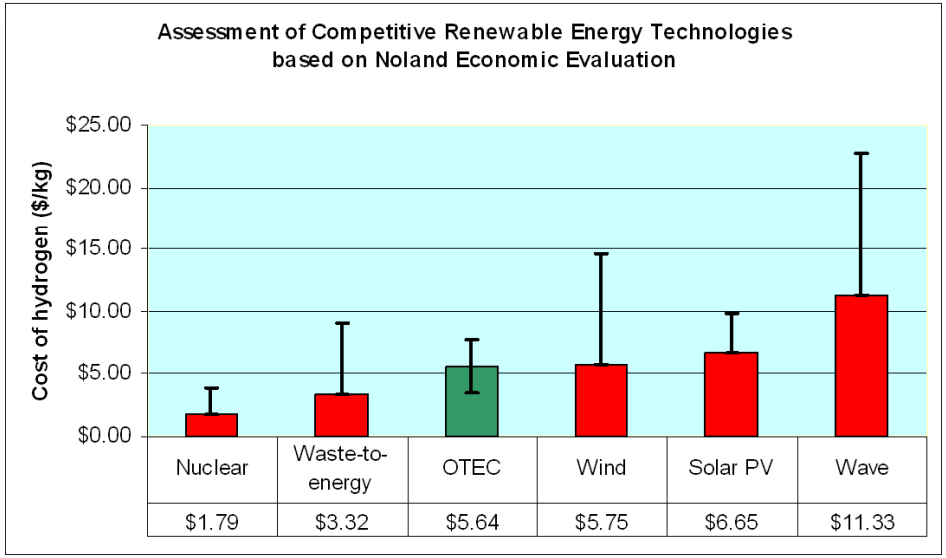


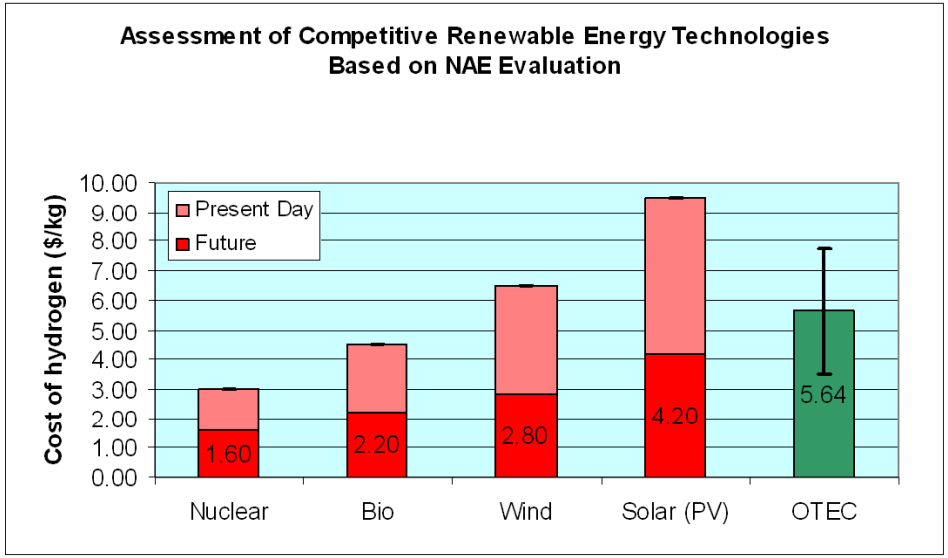
- **2007 Phase II: Greater detail for cost credibility**
- Detailed Rankine Cycle Model w/ Heat Exchangers & piping losses
- Cold Water Pipe - Design & Installation
- 1st level cost optimization
- Seakeeping motions
- Independent fuel product selection
- Industry partners for techniques and costs
- 100 MW net power

Cost of Hydrogen



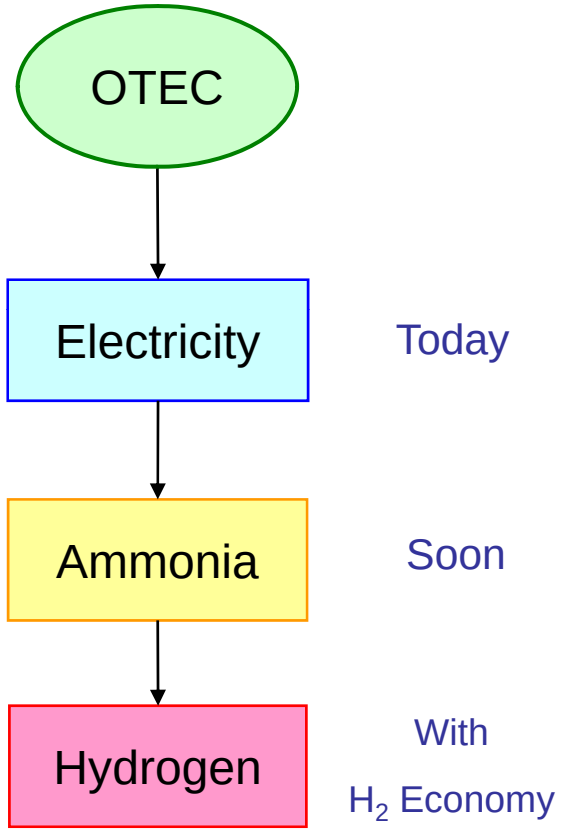
OTEC-NH_3 PLANT	**400** MW	**$2.52bn** (capital cost)





Summary and Conclusions

- Makai's SBIR Study
  - "First Plant" Conceptual Design
  - Developed a Technical and Economic Model
  - Vision of OTEC Industry
  - Partnering – Path to Phase III
- OTEC is technically feasible
- OTEC is economically viable for electricity today
- In H_2 economy, OTEC should be considered alongside other renewables
  - Large sustainable resource
  - Continuously available
  - Cost competitive



OTEC Commercialization Strategy

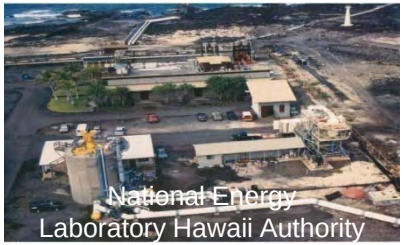
Opportunity Qualification, Staff/Team & Technology Development

2007 – 2010

- Pursue funding opportunities
- Industry/Market Contacts
- Opportunity Development
- Technology to Reduce Cost

Large Scale Testing, Major System Trades, Prelim. Design and Cost

2008 – 2010



10 MW DoD/Hawaii Pilot Plant
(Risk Reduction, Market Entry Size)

2008 – 2014

1st 100+ MW Production Plant

Key Tenets

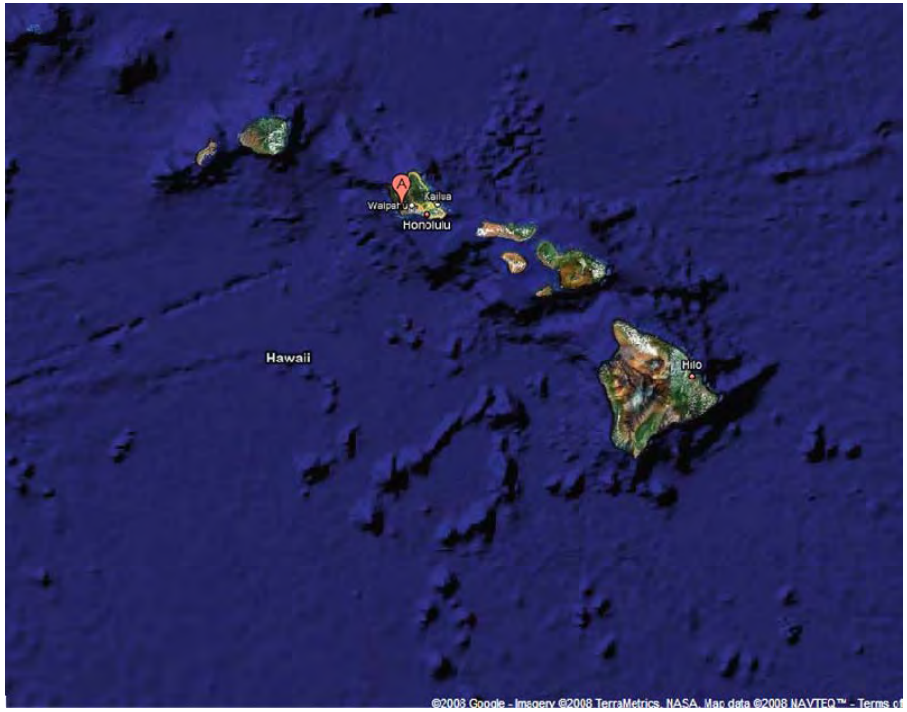
- ✓ Focus on DoD opportunities with 10 MW Pilot Plant
- ✓ Seek DoD / DoE funding for Pilot Plant production
- ✓ Re-Package Pilot Plant design for 100+MW Production Plant

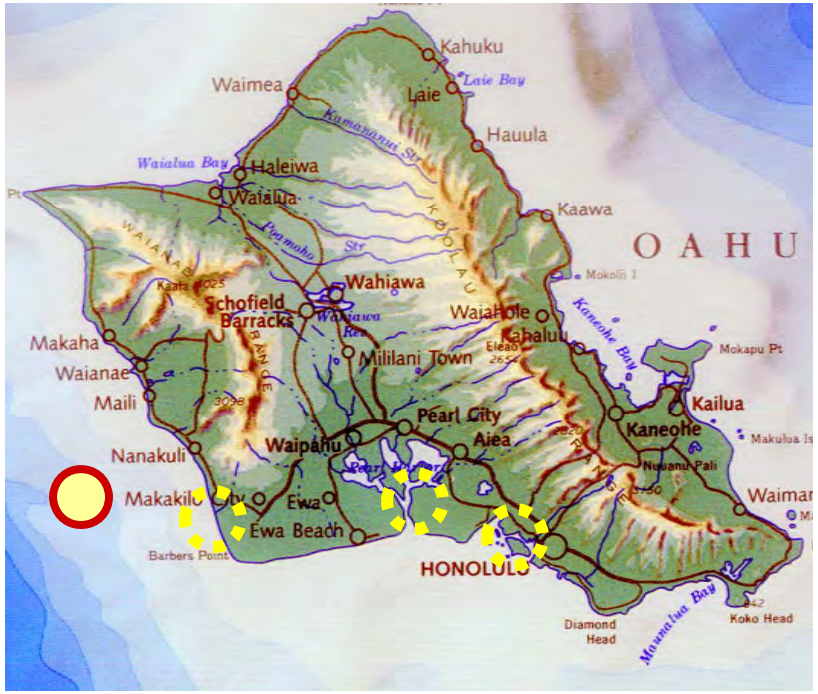
Hawaii is:

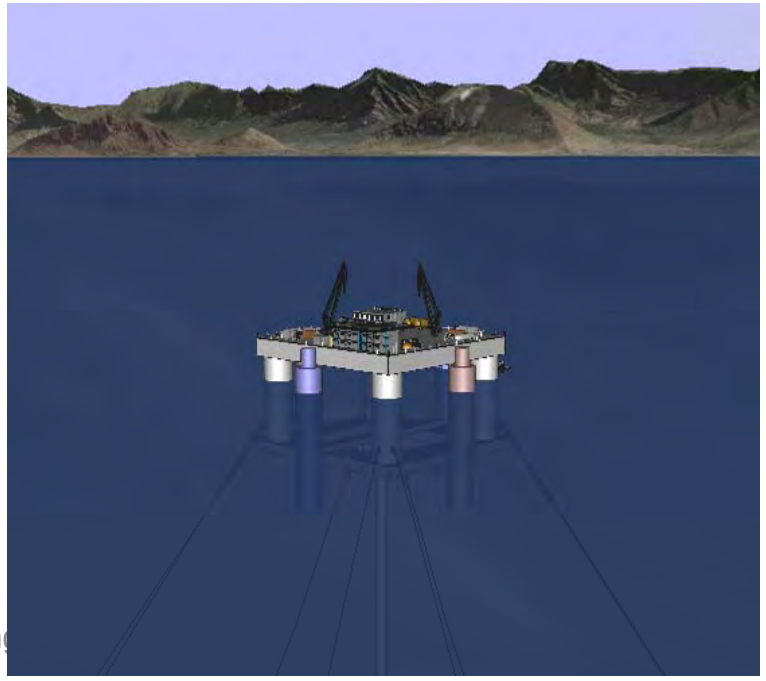
- ~90% reliant on petroleum for energy
- Mandating 20% energy from renewables by 2020
- DoE "showcase" for renewable energy (Clean Energy Initiative)
- Home to numerous DoD bases interested in distributed renewable energy

Site Data

- 6 km to shore
- 1.2 km deep

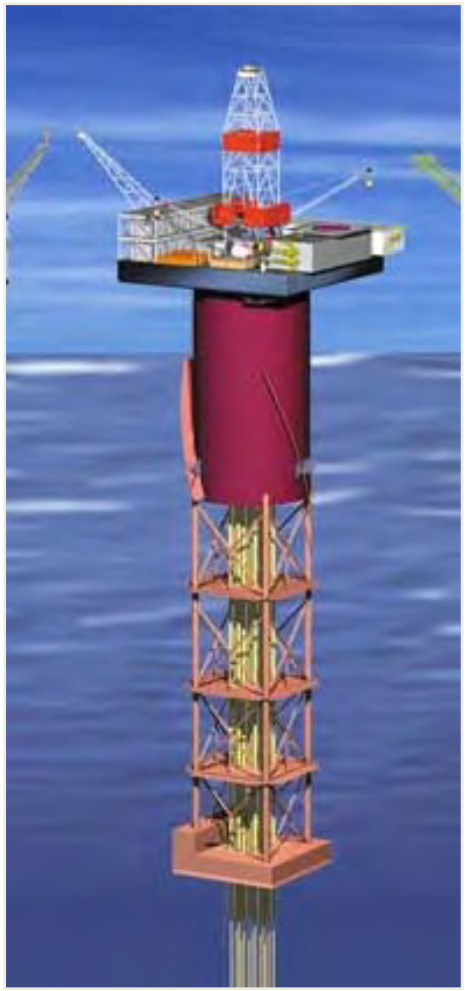




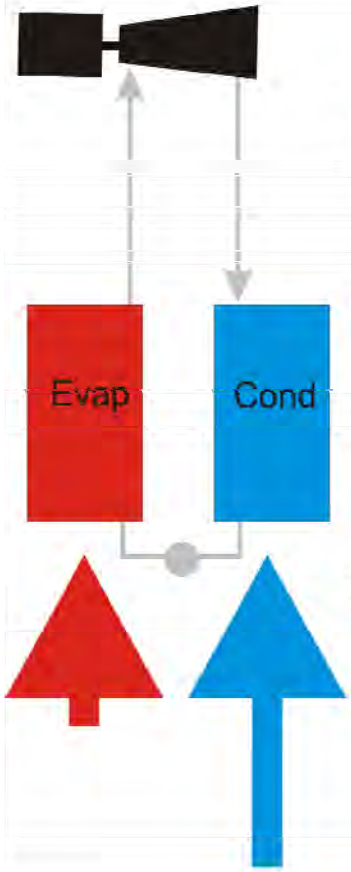


OTEC Challenges:

- Technical
  - CWP
  - Heat Exchangers
  - Cable to Shore
  - Environmental
- Financial
  - Reasonable cost
  - Economy of scale
  - How get started: chicken and egg



OTEC Development



	R&D Opportunities			
	NELHA on shore	~3 MW floating	10 MW floating	100 MW foating
Turbine Known technology	NO (difficult to model)	NO (difficult to model)	YES (full scale)	YES (full scale)
Thermal Cycle Existing & known; New concepts and misc components.	YES (with HX tests, new concepts)	YES, but limited test flexibility	YES, but limited test flexibility	YES, but limited test flexibility
HX Heart of OTEC: material, cost, & performance risks; technical	YES, (long term & new concepts)	YES	YES, but limited test flexibility	YES, but limited test flexibility
Seawater Supply Costly, large structure, deployment and survival issues	NO	Maybe	YES (scale model)	YES (full scale)

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Thank you