Ocean Thermal Energy Conversion (OTEC)

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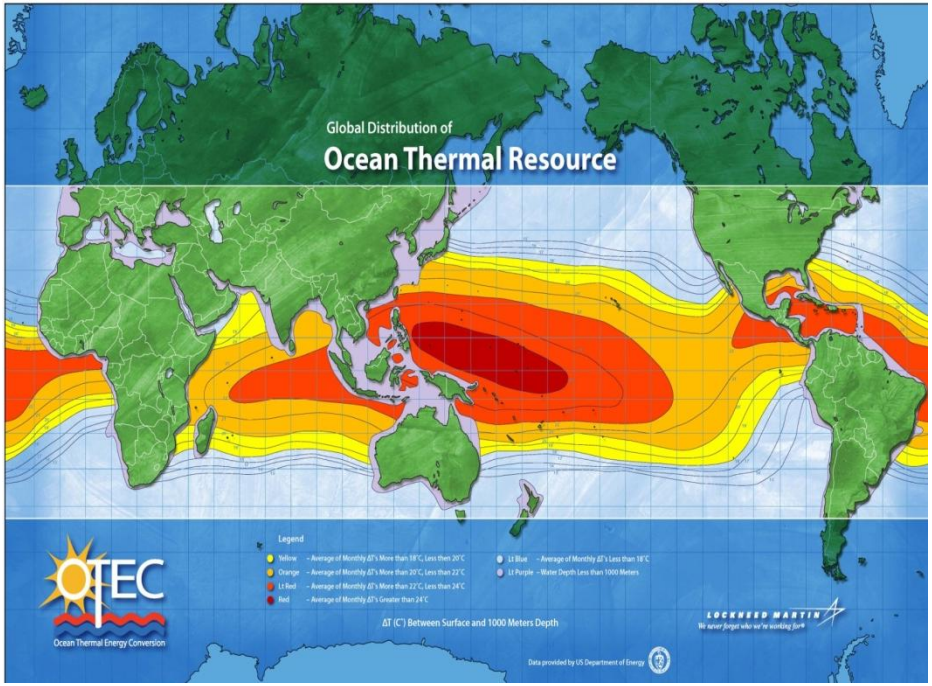
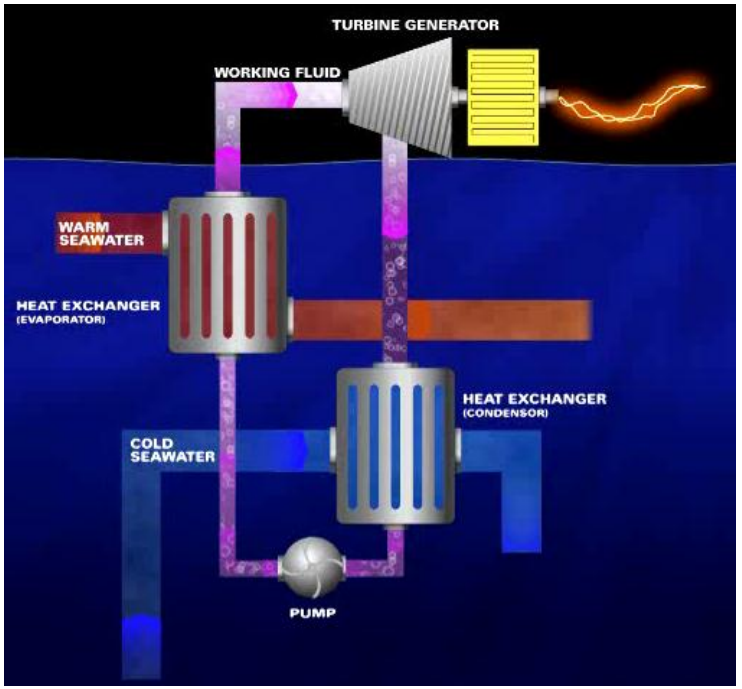
Ocean Thermal Energy

The Resource



The Process



- ✓ **Large Renewable Energy Source**
  - At least 3-5 Terawatts (~30% Global Energy)*
- ✓ **Energy Security**
  - A Secure Energy Source
- ✓ **Base Load Power**
  - Available 24/7
- ✓ **Climate Friendly**
  - No Emissions

* **A Preliminary Assessment of OTEC Resources ASME 3/2007**

A New Clean Renewable 24/7 Energy Source

Why OTEC?

Each 100MW OTEC Plant

SAVES

1.3M Barrels Oil / Yr

$130M / Yr

($100 / Barrel)

0.5M Tons CO_2 / Yr

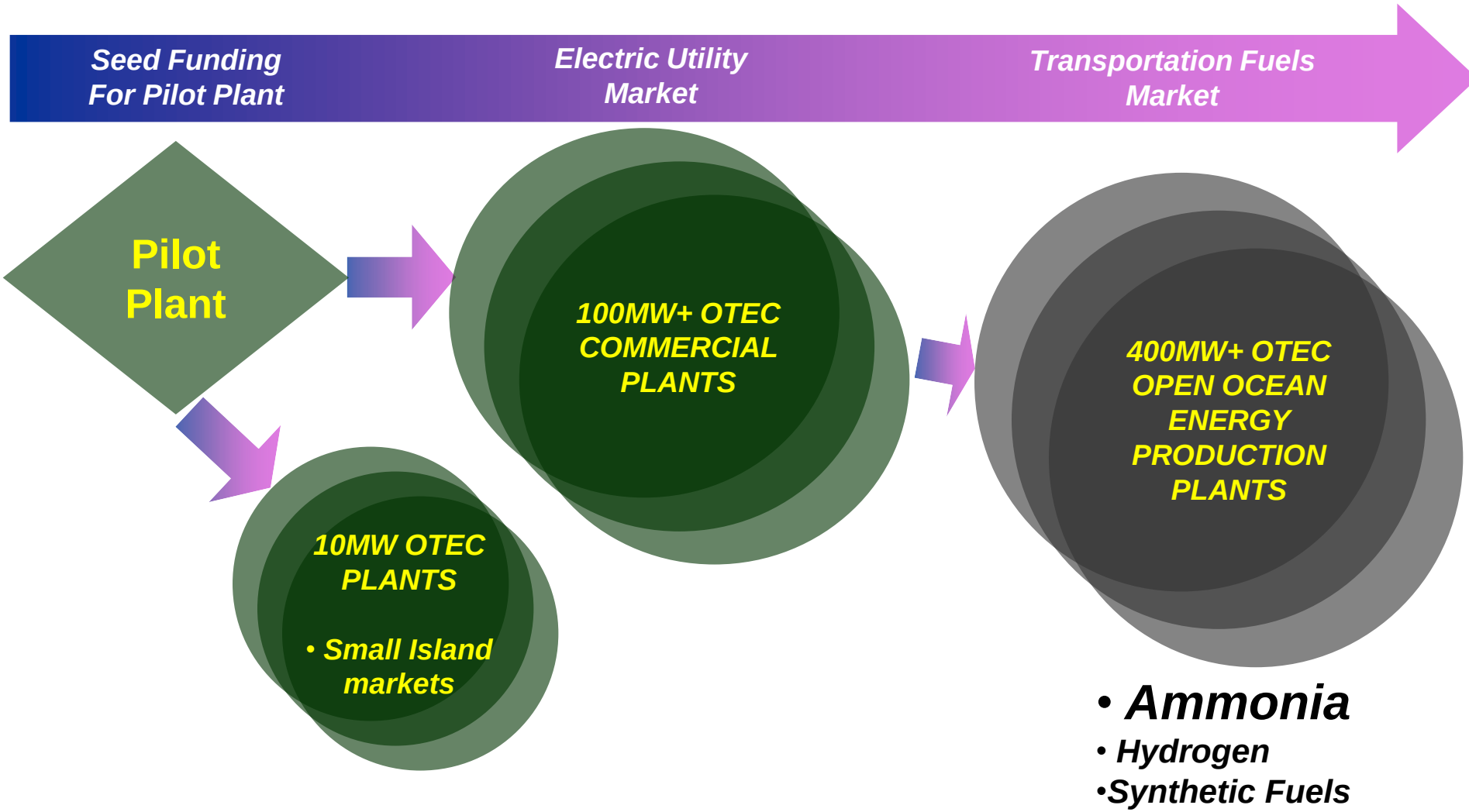
$15M / Yr

($30 / Ton Carbon Credit)

Potential For New Energy Resource

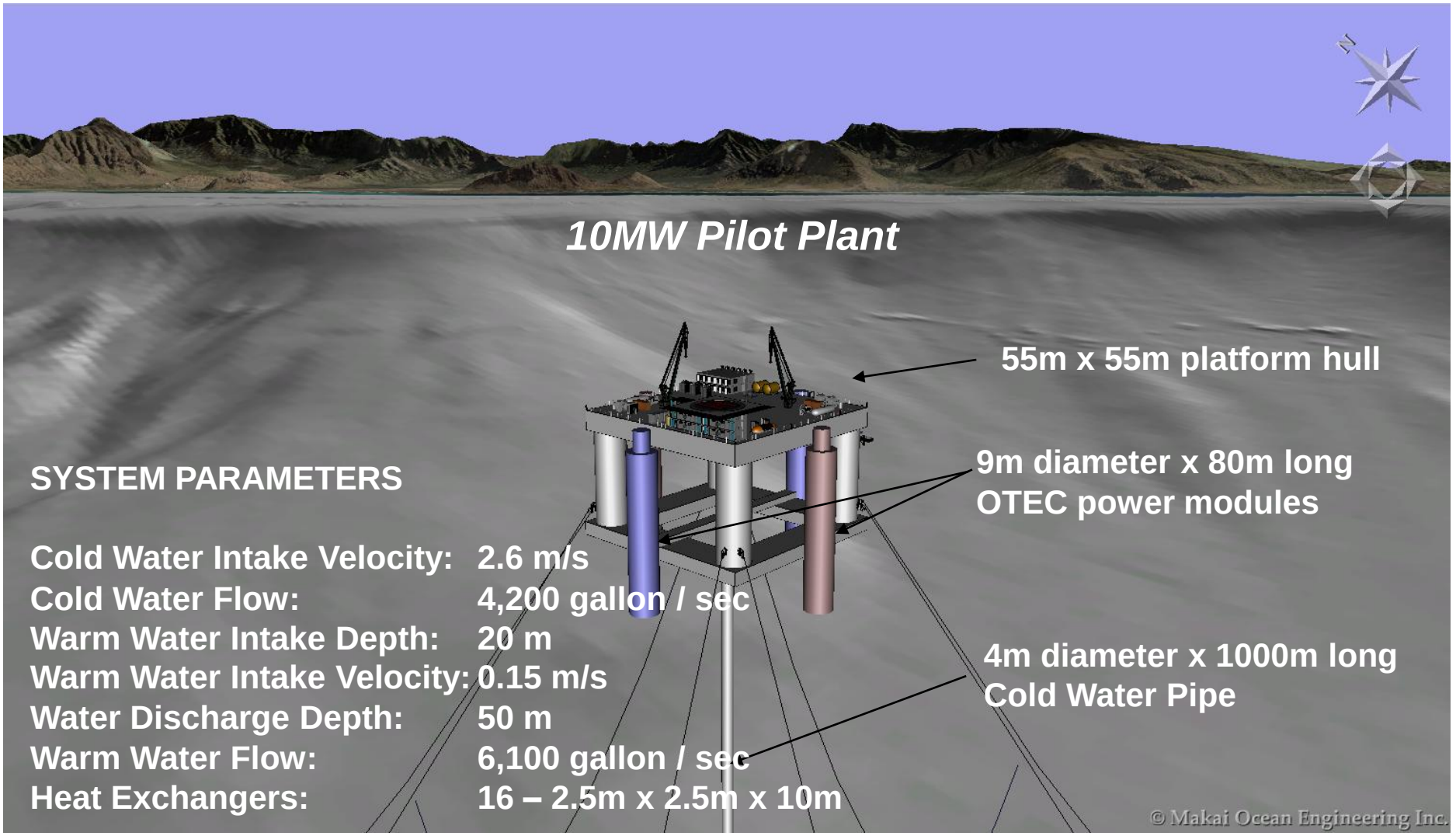
3

OTEC Vision

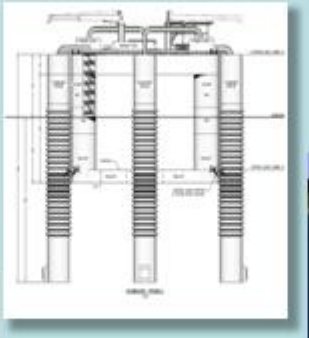


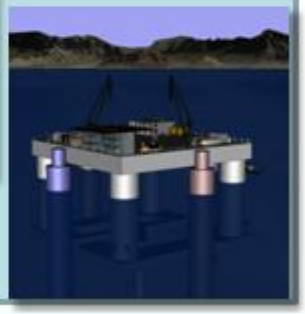
OTEC is Poised to be a Global Energy Resource

Getting a Feel for an OTEC Plant

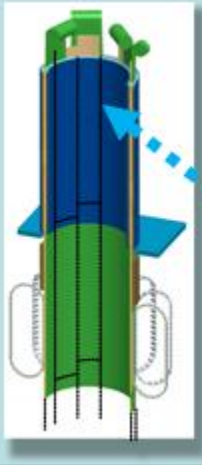


Key Technology Focus Areas



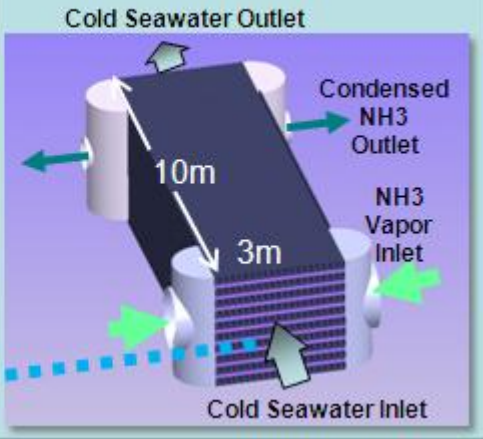


Platform
- Survivability
- Stability

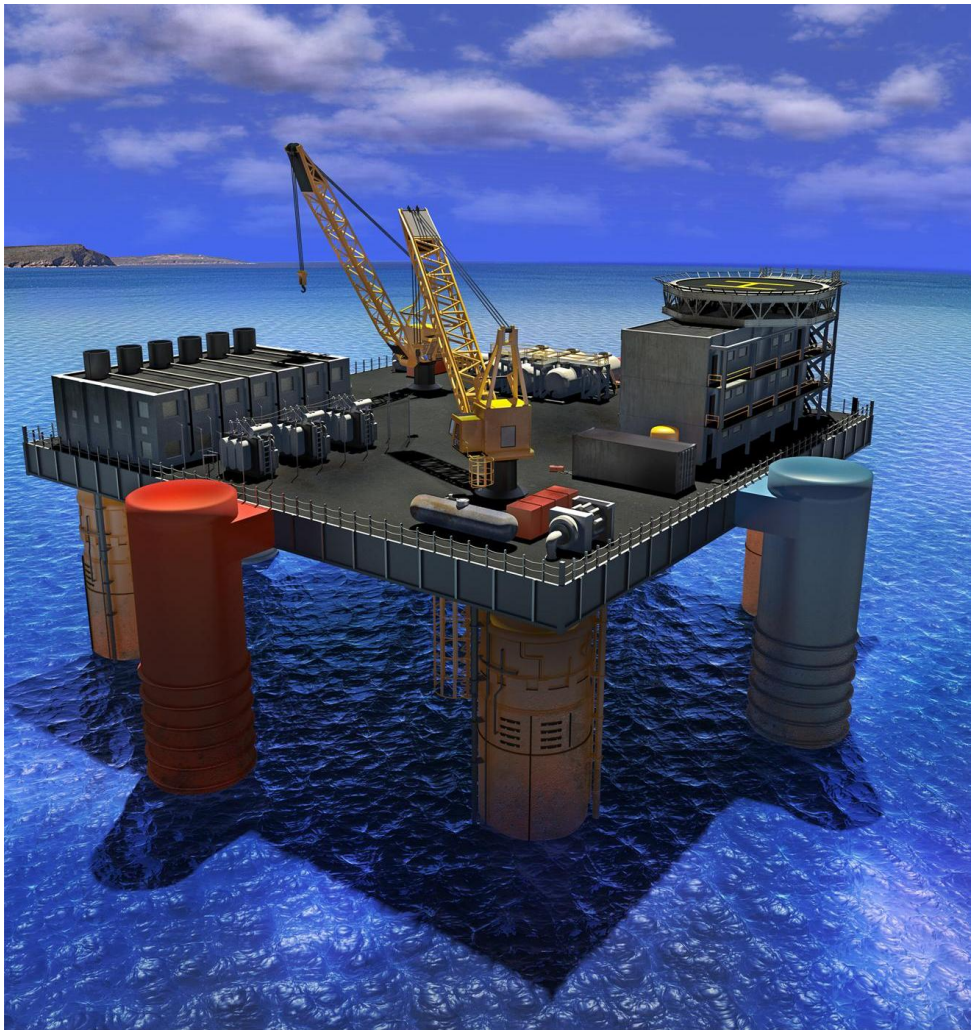


Cold Water Pipe
- Deployment
- Survivability
- Scalability

Heat Exchangers
- Performance
- Corrosion Control
- Biofouling

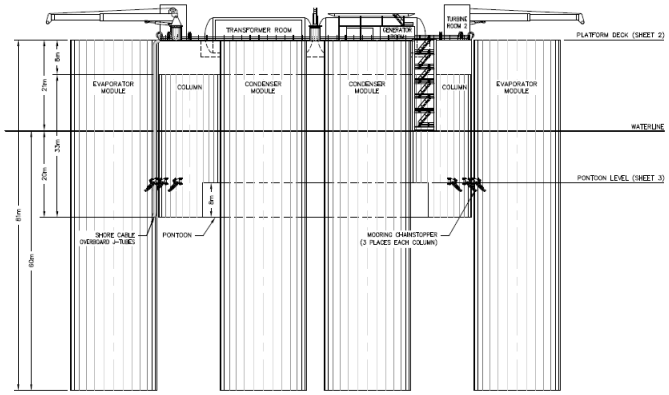


OTEC Platform – Semi-Submersible



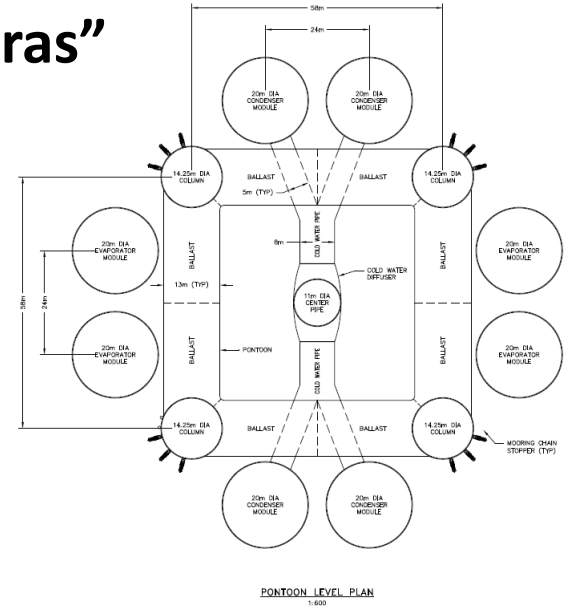
- Based on oil-field practice
- Low motion enables CWP fabrication on-site
- Ideal for CWP & Undersea Power Cable support
- Large deck area
- Accommodates removable power modules (Remoras)

Notional 100 MW Hull Configuration (2008)

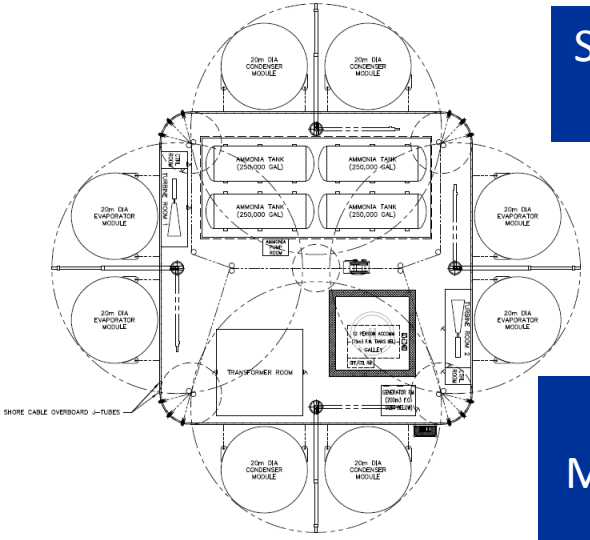


Outboard Profile

- Hull is semi-submersible
- OTEC Power Modules are Separate, detachable units called “Remoras”



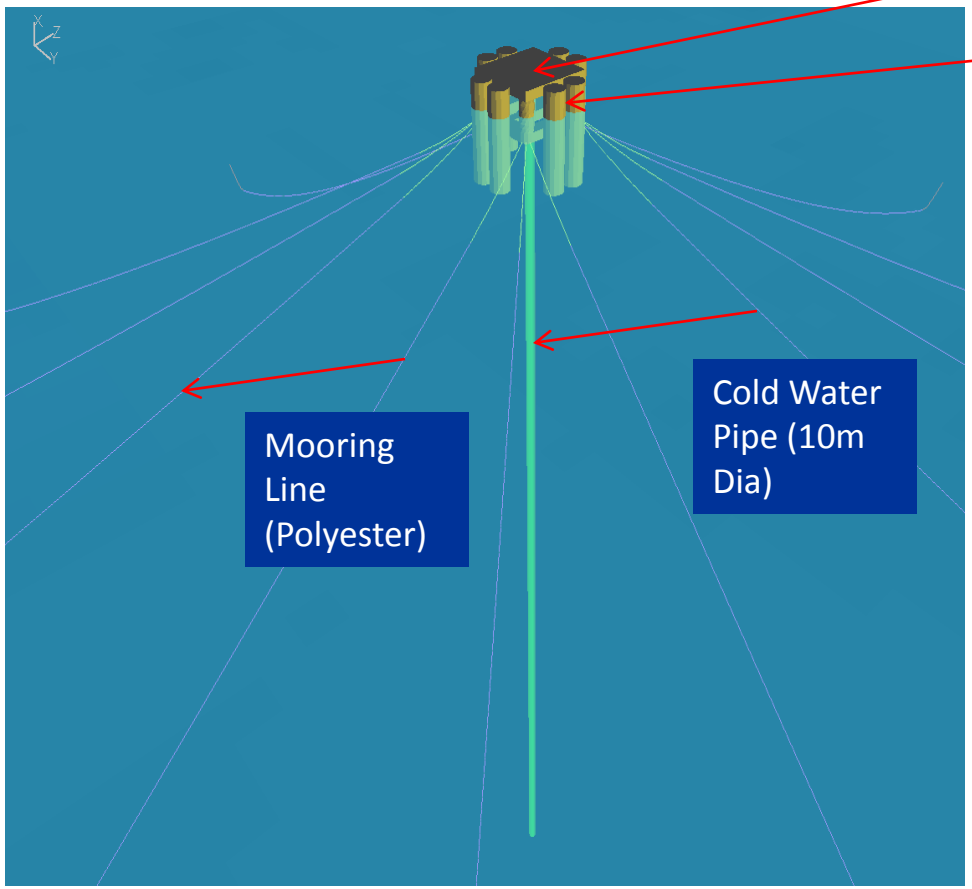
Pontoon Level Deck



Semi-Submersible Hull

OTEC Power Modules, “Remoras” (HX, Pumps)

100MW Platform and Cold Water Pipe (Commercial Platform)

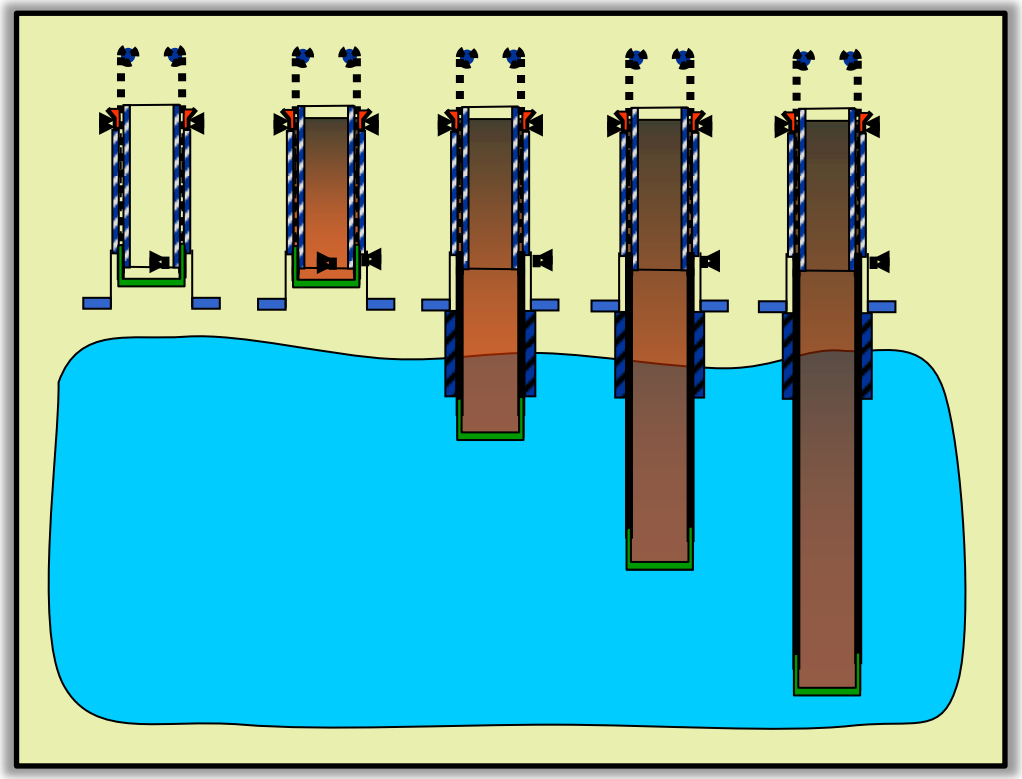


- **Topsides Weight:** 9,091 mT
- **Hull Weight:** 5,864 mT
- **Hull Draft:** 20 m
- **Column Spacing:** 56 m
- **Column Diameter:** 14.25 m
- **No. of Mooring Lines:** 12
- **Remora Draft:** 60 m
- **Remora Diameter:** 20 m
- **Total Displacement:** 192,381 mT
- **Displ. Semi Only:** 37,513 mT

The OTEC Cold Water Pipe (CWP)

The Pipe

In-Situ Fabrication



Cold Water Pipe Parameters

- 10MW Pipe 4m x 1,000m
- 100MW Pipe 10m x 1,000m

Fabrication on Platform Eliminates Major CWP Deployment Risk

CWP Progress

Shear Key & Pipe Core Assembly

Fabric Dispensing & Guidance System

Pipe Molding Region

DOE Cooperative Agreement Successfully Completed

Aluminum HX Challenges in OTEC

Challenge	Technology	Benefits	Results

Corrosion

Cost

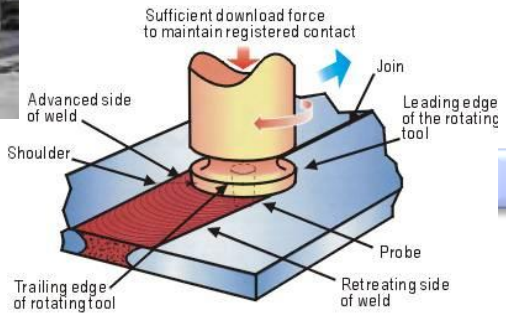
HX Unit Costs

+

Large Size Heat Exchangers

↓

Large CAPEX Costs



Friction-Stir Welding

Corrosion Resistance

Faster Manufacturing Process

Lower cost than Titanium HX

Cost Reduction over Current Processes

Addressing the Key OTEC HX Cost Drivers

Hx Test Facilities

LOCKHEED MARTIN
We never forget who we're working for®

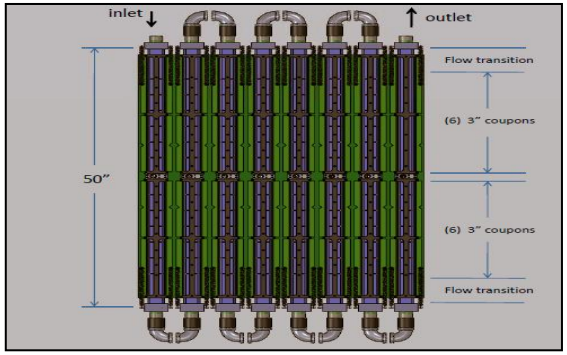
Natural Energy Laboratory of Hawaii Authority
Energy & Ocean Resources & Technology

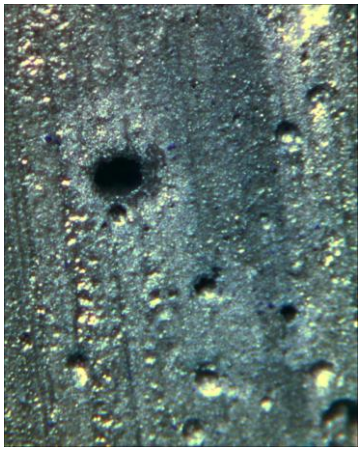
Thermal Duty Capacity: 10-50 kW
Fluid Flow: 1-6 liters/sec
Temperatures: 5-8C and 24-30C
Working Fluid: R410A

Small Turbine Installed to Generate Power

Thermal Duty Capacity : 1-4 MW
Fluid Flow :100-500 liters/sec
900m Deep and Surface Seawater
Working Fluid: Ammonia

Capacity to Test 3 HX Pairs





Corrosion Tests With Various Alloys Ongoing At NELHA

Corrosion Testing Underway the Past 2 Years

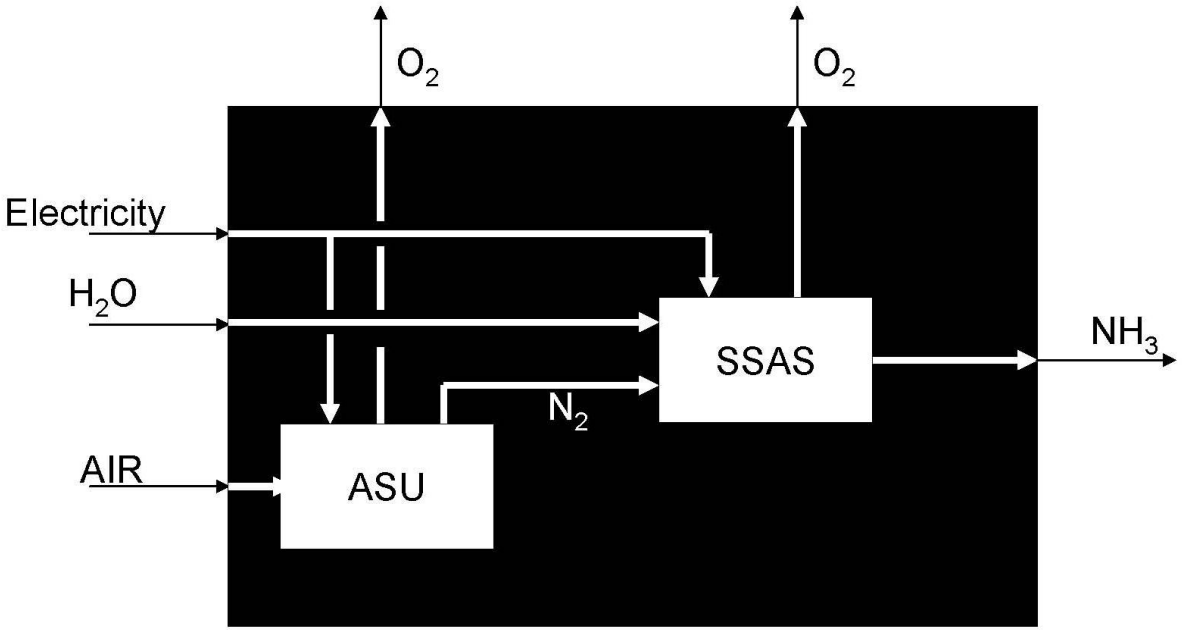
Business Observations

- **Large Scale OTEC plants (100MW greater) are cost competitive in markets highly dependent on petroleum for electrical generation by 2020**
- **OTEC is long-term large opportunity**
- **OTEC CAPEX costs will decrease over time and capacity will increase – opening other markets**
- **Other factors which might increase OTEC competitiveness**
  - **GHG penalties**
  - **Premiums for clean, renewable, baseload stable power**
  - **Investment and Production credits**

"Ammonia - A Sustainable, Emission-Free Fuel"

Inside the Black Box: Solid State Ammonia Synthesis

$$6\ H_2O + 2\ N_2 \rightarrow 3\ O_2 + 4\ NH_3$$



Energy consumption 7000 - 8000 kWh per ton NH_3

NHThreeLLC;
Jason C. Ganley, John H. Holbrook, and Doug E. McKinley;
October 15, 2007

Incredibly Simplistic View

SSAS	8,000	kWh per ton	
MW	100	500	1,000
h/day	24	24	24
MWh/day	2,400	12,000	24,000
MWh/ton NH3	8	8	8
Ton NH3/day	300	1,500	3,000
Ton NH3/year	109,500	547,500	1,095,000

Ocean Thermal Energy Conversion (OTEC)

Features

- Standard Rankine cycle technology
- Scalable up to 500MWe or more
- Deployable over large geographic area
- OTEC can produce fresh water
- Can provide energy carriers and other products

Benefits

✓Reliable, base load power for utilities.
✓Nonpolluting
✓Can create ~ 3,425 jobs / 100 MW plant
✓Export technology
✓Will not compete for water resources
✓Avoid visual impacts with offshore locations
✓Does not crowd out valuable land uses
✓Solves many critical energy challenges

OTEC Has Significant Benefits as a Clean Energy Solution