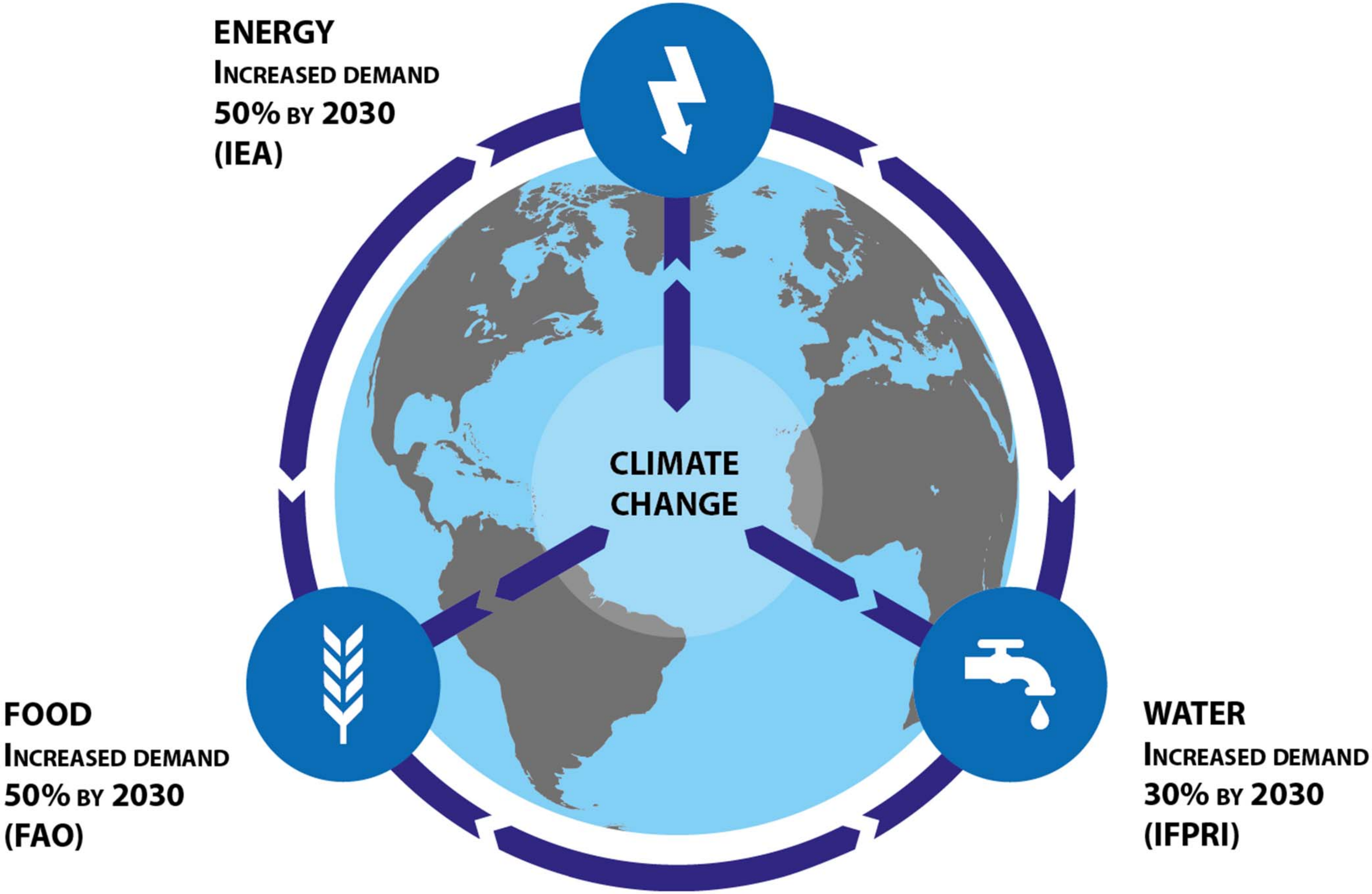
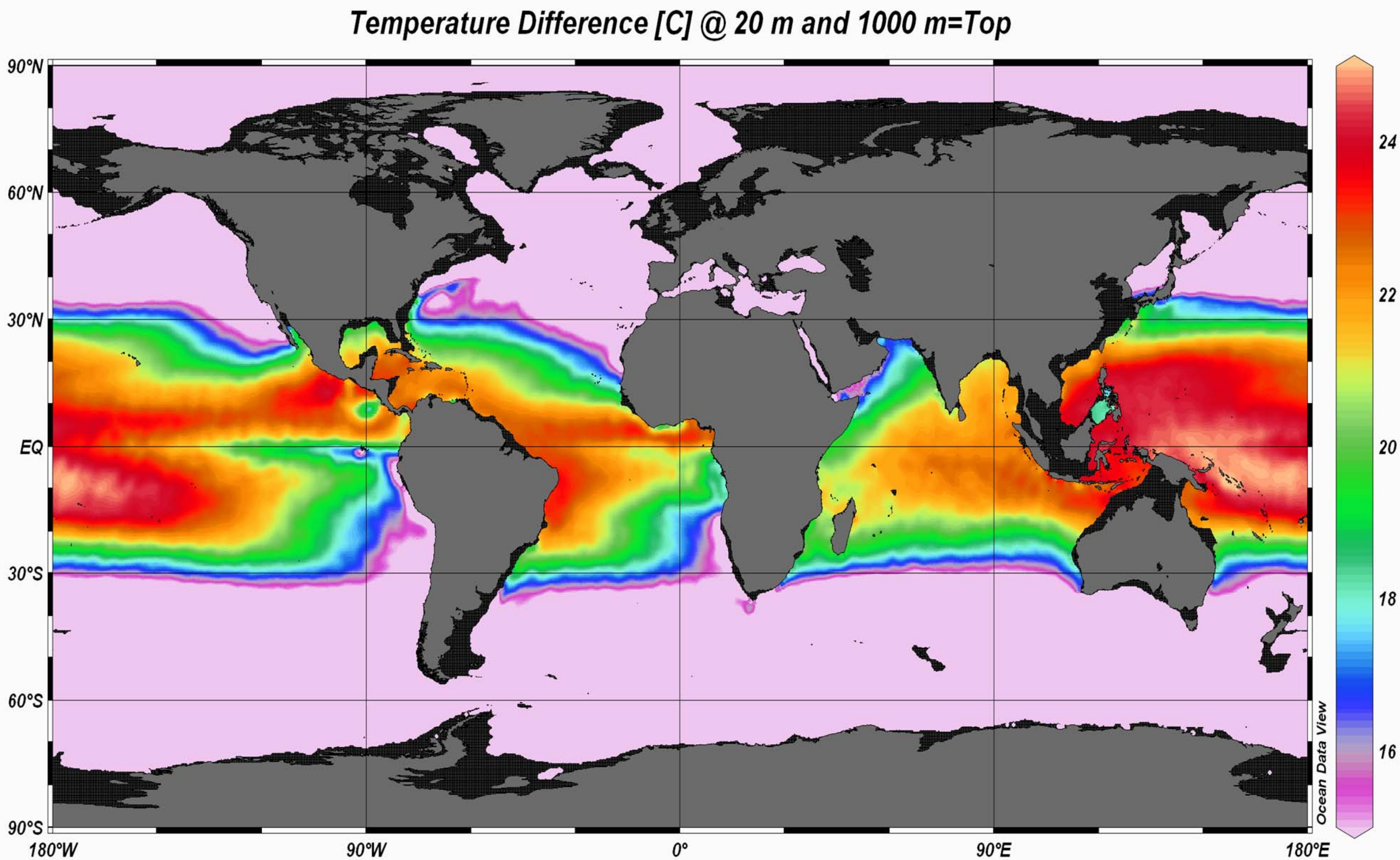
Deep Ocean Water (DOW)
A Catalyst for
Economic Development,
Food, Water & Energy Security

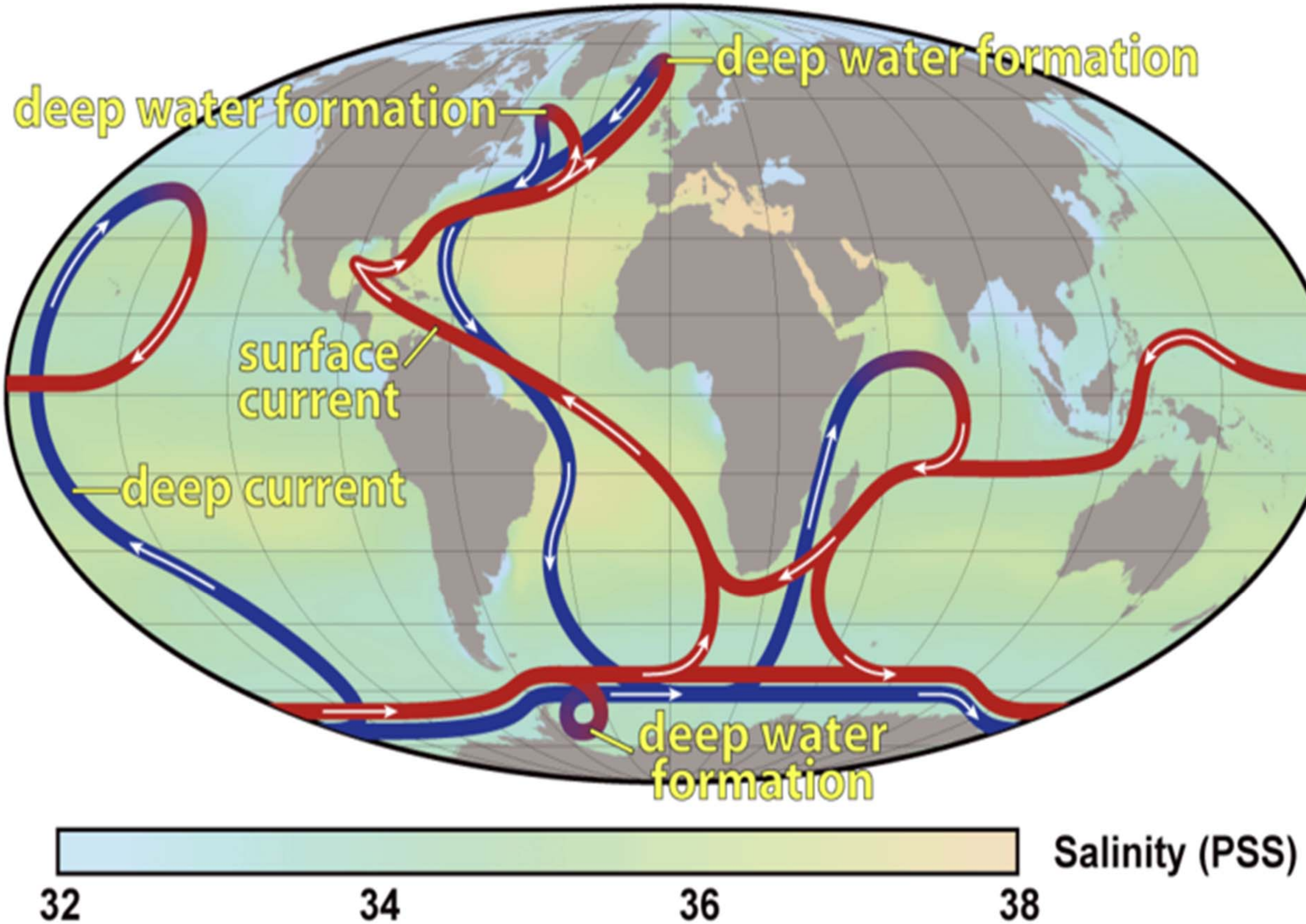
Jan C. War
NELHA

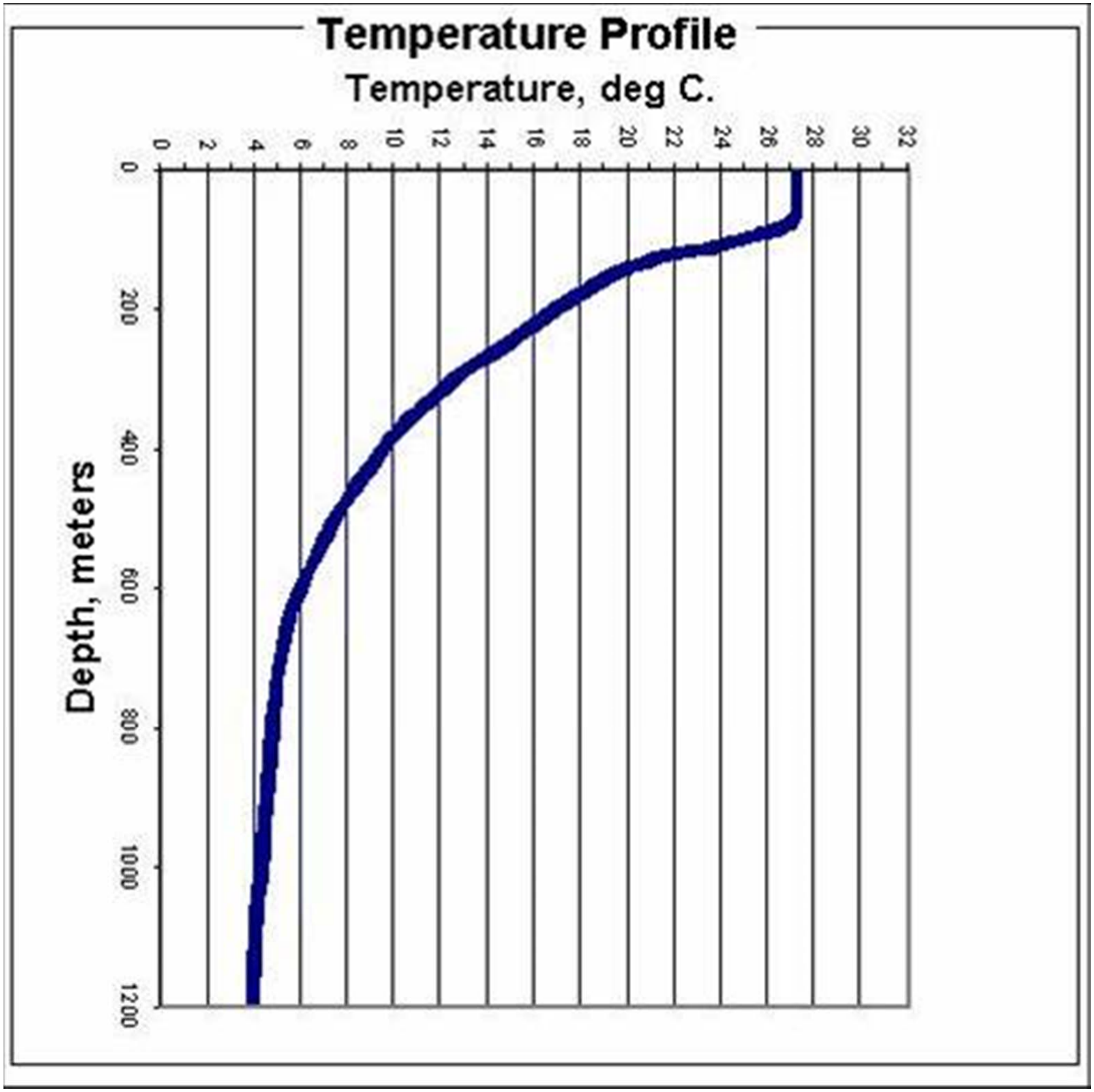
Pacific Economic Cooperation Council (PECC) – Noumea, New Caledonia / November 27, 2014


ENERGY
INCREASED DEMAND
50% BY 2030
(IEA)
CLIMATE
CHANGE
FOOD
INCREASED DEMAND
50% BY 2030
(FAO)
WATER
INCREASED DEMAND
30% BY 2030
(IFPRI)


Temperature Difference [C] @ 20 m and 1000 m=Top
90°N
60°N
30°N
EQ
30°S
60°S
90°S
180°W
90°W
0°
90°E
180°E
24
22
20
18
16
Ocean Data View

Thermohaline Circulation

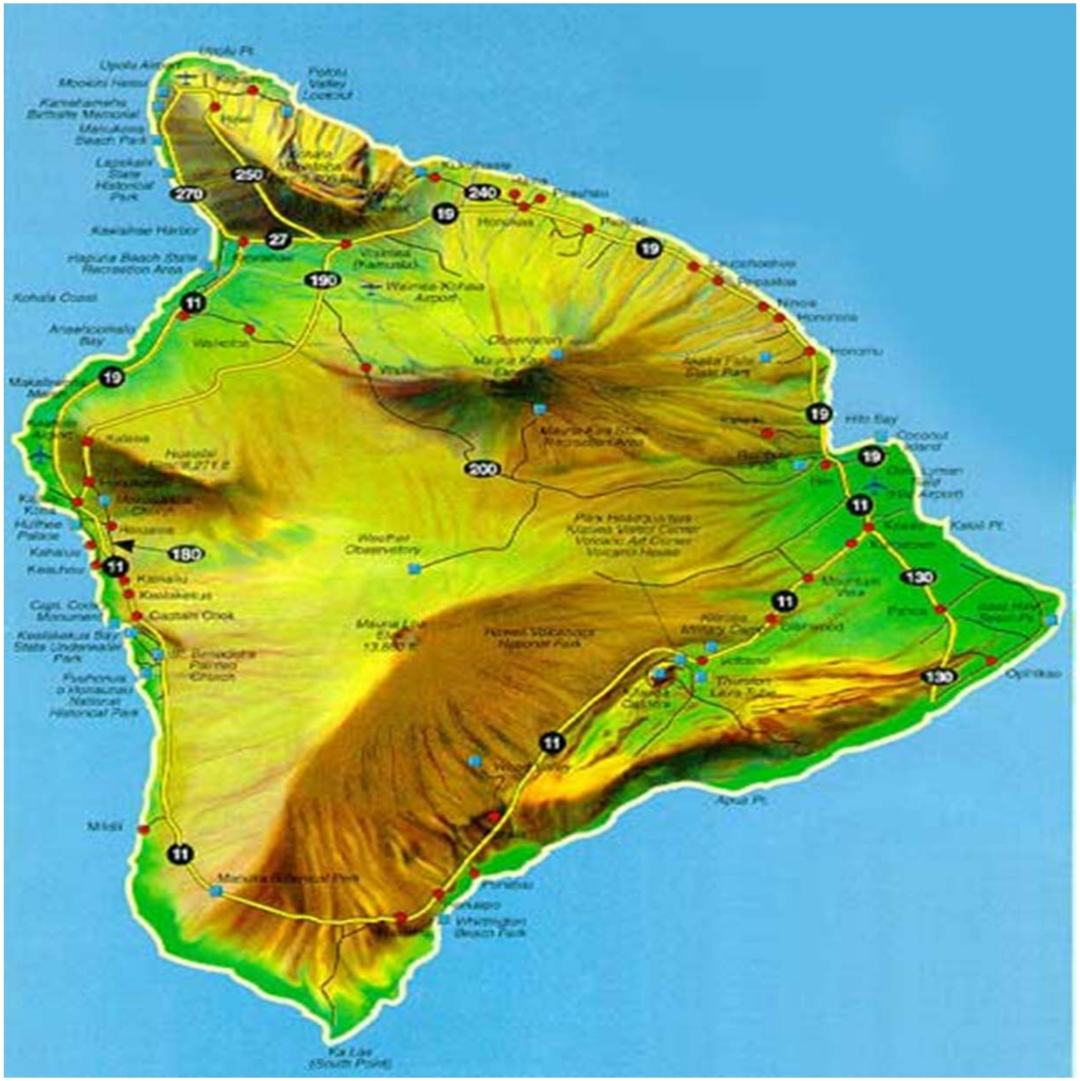




Temperature Profile
Temperature, deg C.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Depth, meters
0
200
400
600
800
1000
1200

Natural Energy Laboratory of Hawaii Authority (NELHA)

Ke-ahole Point



HISTORY
NELH / HOST PARK

- NELH Establish as an Act of Legislation by the State of Hawaii in 1974 – Government Corporation (RCUH)
- NELH was Developed in Response to ERDA (DOE) Funding for OTEC R/D – 5 Sites Chosen / NELH Premier Site
- 1981 First DOW Pipeline for OTEC (Seacoast Test Facility)
- 1983 First Aquaculture Projects
- 1984 Commercialization / Education / Outreach
- 1987 HOST Park Created (Commercial Offshoot)
- 1990 NELH and HOST Park Merge to become NELHA
- Administratively attached to DBEDT

NELHA

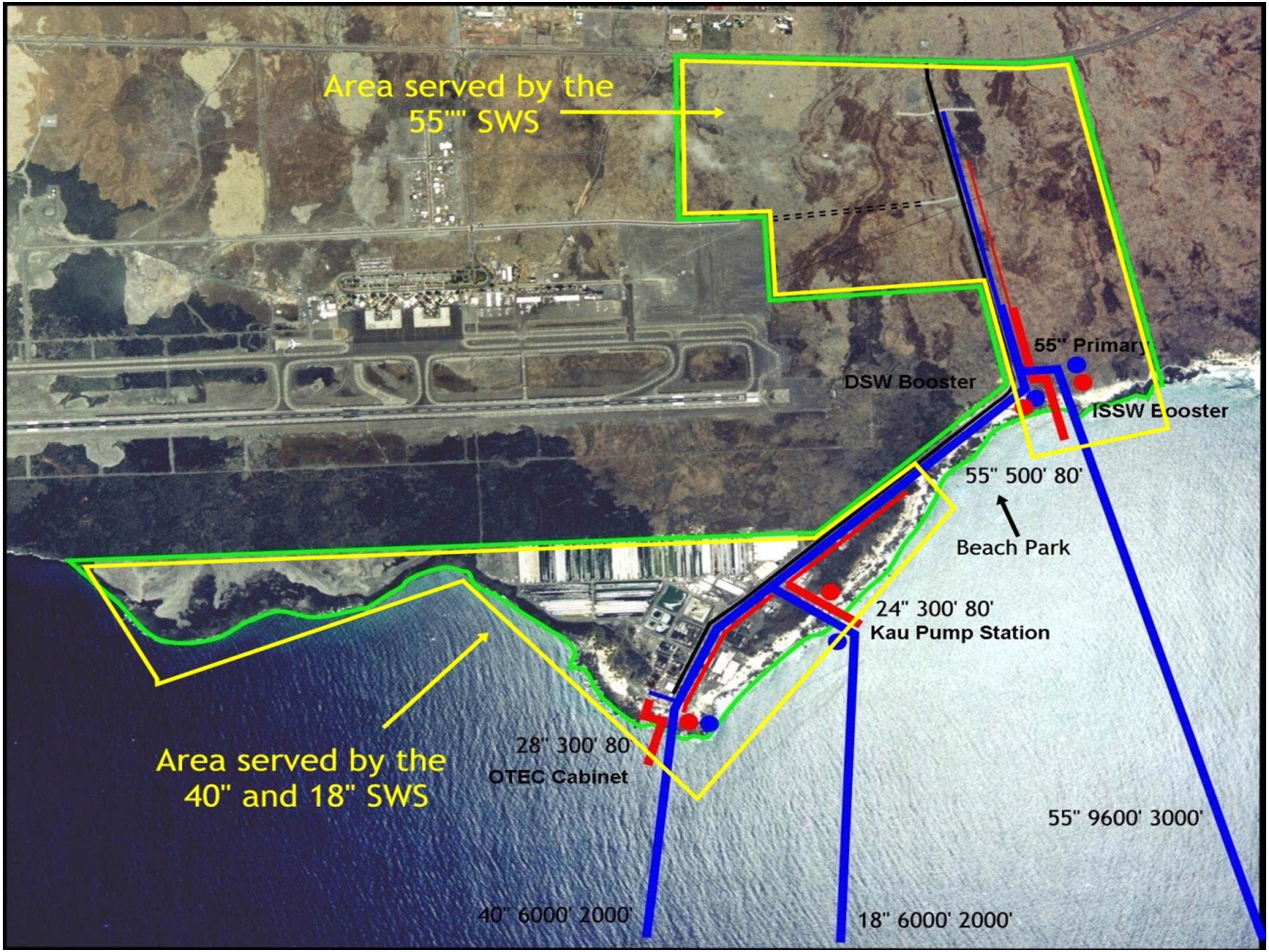
NELHA MISSION STATEMENT

To Develop *and Diversify*

the Economy of Hawaii

by Providing Resources and Facilities for

Energy and Ocean-Related Research, Education, and Commercial Activities in an Environmentally Sound (Sustainable) and Culturally Sensitive Manner


Area served by the
55"" SWS
55" Primary
DSW Booster
ISSW Booster
55" 500' 80'
Beach Park
24" 300' 80'
Kau Pump Station
28" 300' 80
OTEC Cabinet
Area served by the
40" and 18" SWS
55" 9600' 3000'
40" 6000' 2000'
18" 6000' 2000'

WATER CHEMISTRY COMPARISON
SURFACE VS DEEP OCEAN WATER

PARAMETER	SURFACE SEAWATER (SSW)	DEEP SEAWATER (DSW)
TEMPERATURE	**24 – 28 ° C**	**4 – 7 ° C**
SALINITY	34.7 o/oo	34.3 o/oo
Ph	8.3	7.6
ALKALINITY	2.31	2.36
NITRATE / NITRITE	**0.24 µm/l**	**39.0 µm/l**
PHOSPHATE	**0.15 µm/l**	**2.89 µm/l**
SILICATE	**2.64 µm/l**	**74.56 µm/l**
AMMONIA	**0.20 µm/l**	**0.06 µm/l**
DON	**5.39 µm/l**	**41.36 µm/l**
DO	**6.87 mg/l**	**1.24 mg/l**
TOC	**0.68 mg/l**	**0.50 mg/l**
TSS	**0.88 mg/l**	**0.34 mg/l**

NELHA TODAY
(333 Hectares)
42 Commercial & Research Tenants

Special NELHA Attributes

- Marine Science and Technology Park
- Master Permits for Rapid Development
- Research Campus / Business Incubation
- Tenant Support Services
- Self Sustaining (Strong Support from State of Hawaii)
- Unique Resources
  (DSW / SSW / High Solar Insolation, Winterless Climate)

Seek Collaborations as Part of HOST PARK PRODUCT PIPELINE

Product Improvement

Research and Laboratory Experiments

- Unversities
- National Labs
- Corporate Labs
- Home workshops

Pilot Scale Demonstration Projects

- HOST Park Campus
- Incubation Facility
- Laboratories
- Master Permitted
- Turn key set-up
- Short-Term Lease

Large Scale Commercial Applications

- HOST Park
- Small business compound
- Applied technolgy areas
- FDI Investment Attraction

Usable Products and Benefits

- Consumer Products
- Jobs
- State and National Revenues

NELHA
Natural Energy Laboratory of Hawaii Authority

ECONOMIC BENEFITS

- Total State Investment = $150 M
- Total Economic Impact = $87.7 M
- State Tax Revenue = $4.5 M
- ROI = $42.8 per dollar invested
- 600 Jobs Created
- 25 % in key areas of research, science and technology

NELHA
Natural Energy Laboratory of Hawaii Authority

RESEARCH CAMPUS

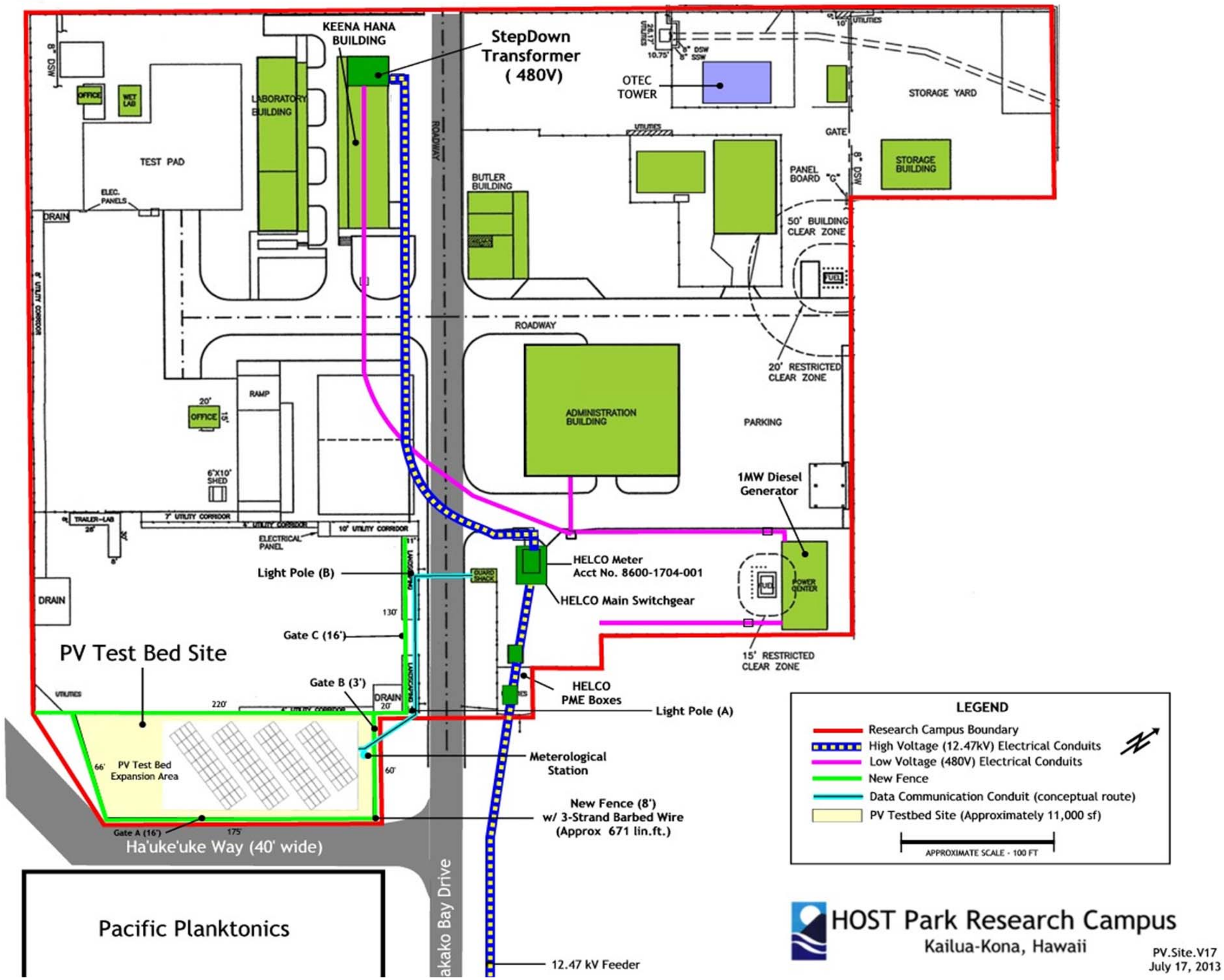
Support Ecosystem
for
Business Incubation

Research Campus

- 6A Master Permitted
- Immediate Ocean Water Access
- Turn Key Setup – 1 day
- Short Term Leases by Size
- Main OTEC R/D Area
- Small College Campus
- Seminars/Conferences
- Additional Office and Lab Buildings

RENEWABLE ENERGY PROJECTS

CONCEPTUAL PLAN AND BASE MAP FOR MICROGRID AND SOLAR TEST BED



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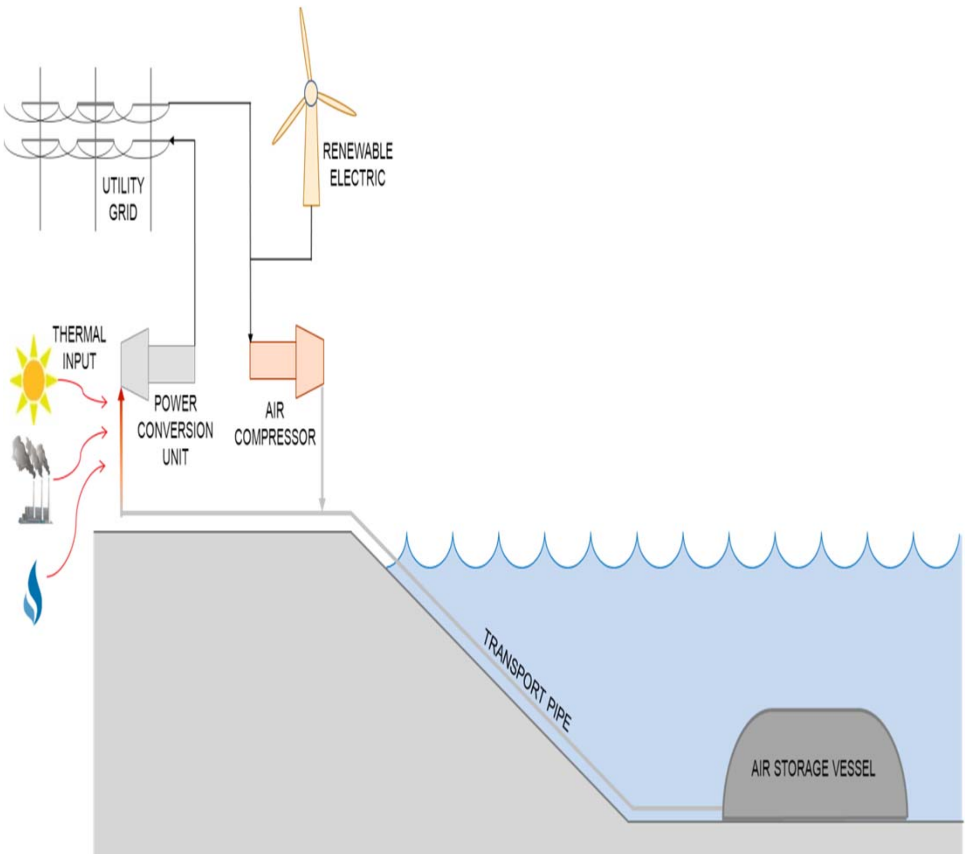
Energy Storage Installations & Considerations For NELHA



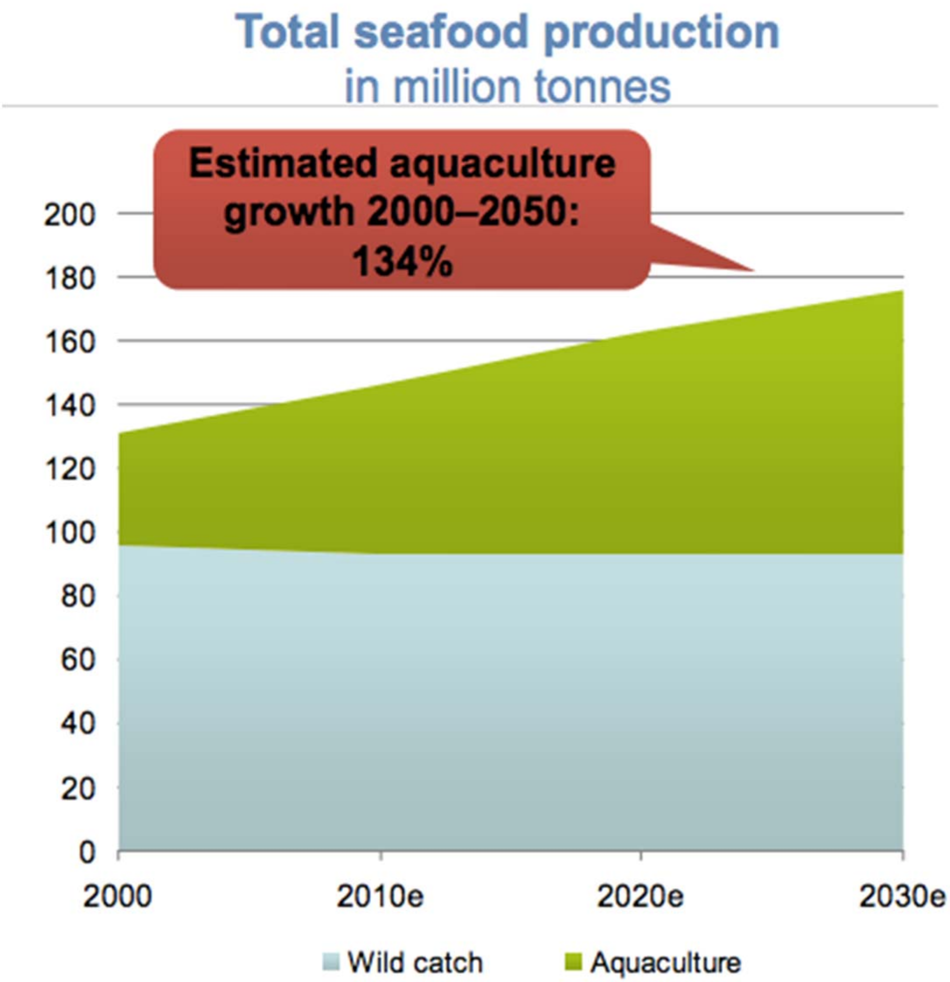
Compressed Air Storage – Ocean Bottom

Lithium Ion Battery Installation – Koyo USA

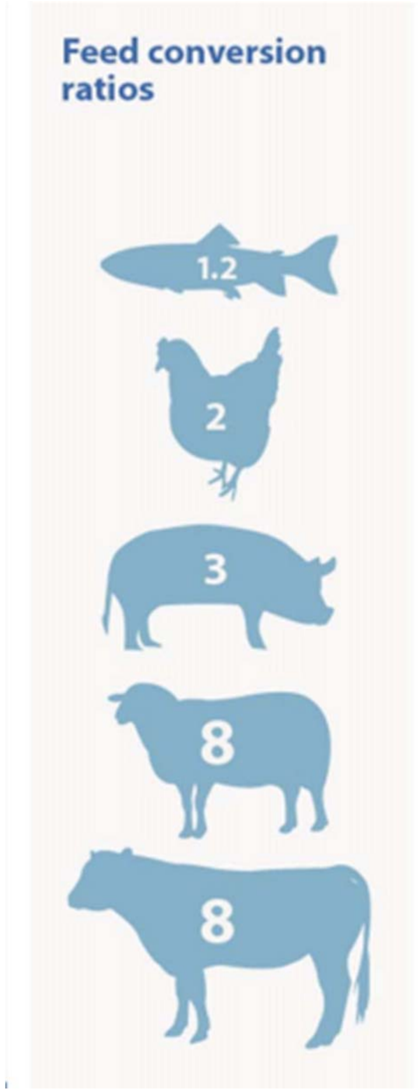
Aquion Batteries

Desalination and Aquaculture

Why Aquaculture?



Source FAO, 2014

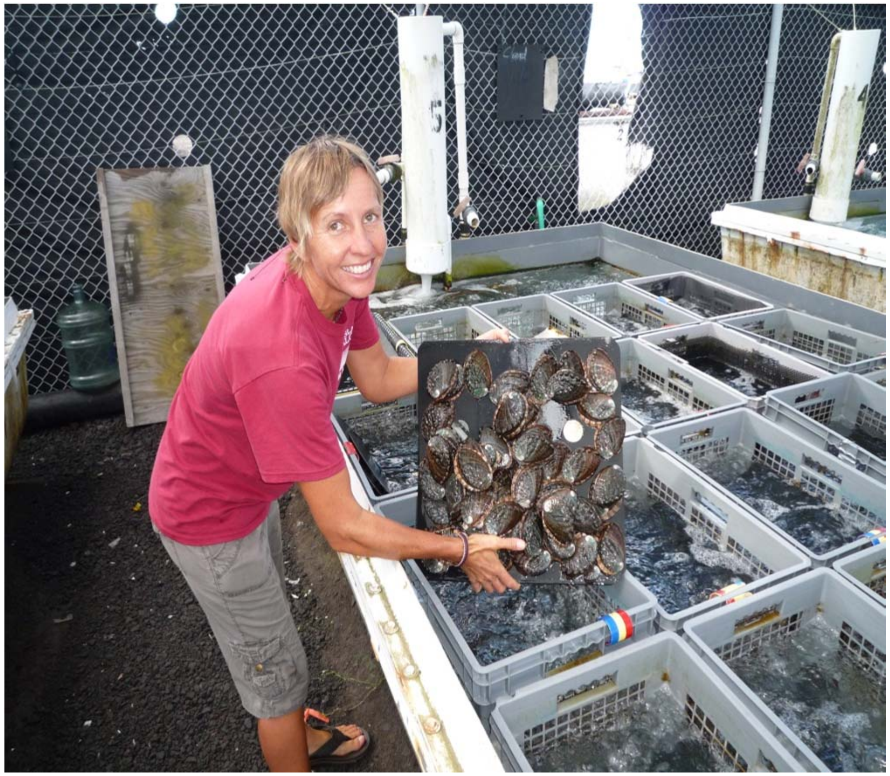


NELHA
Land Based Aquaculture Area

Big Island Abalone Corporation

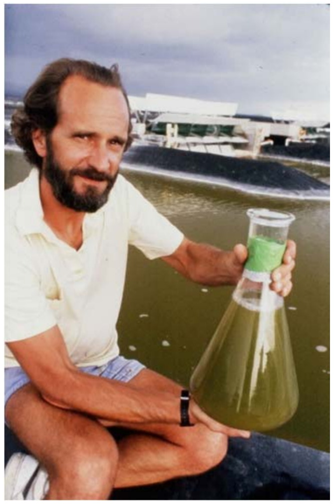
Ezo: Japanese Abalone

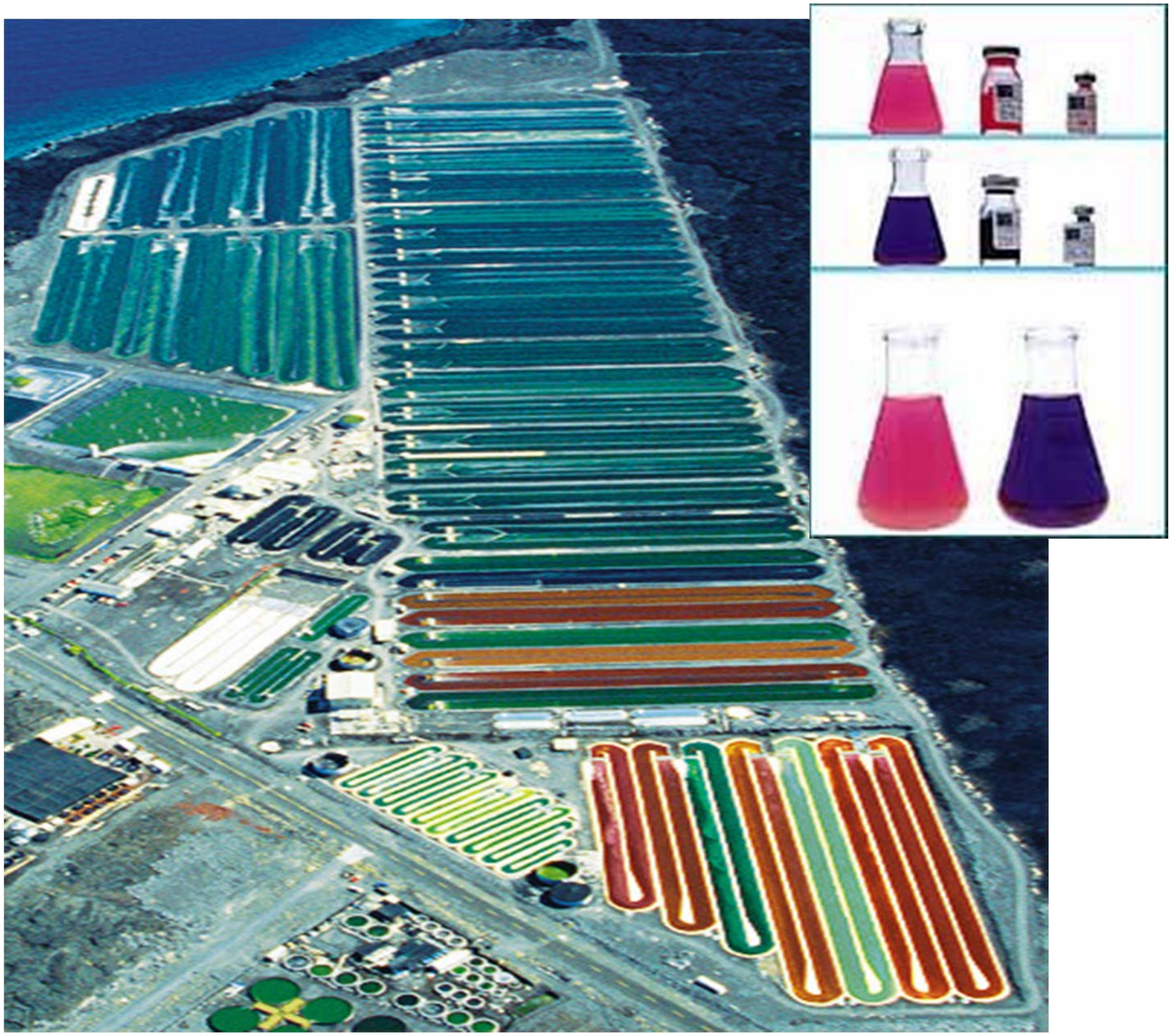
(Holiotis discus hannai)



Cyanotech Corporation

The World Leader in Microalgae Technology



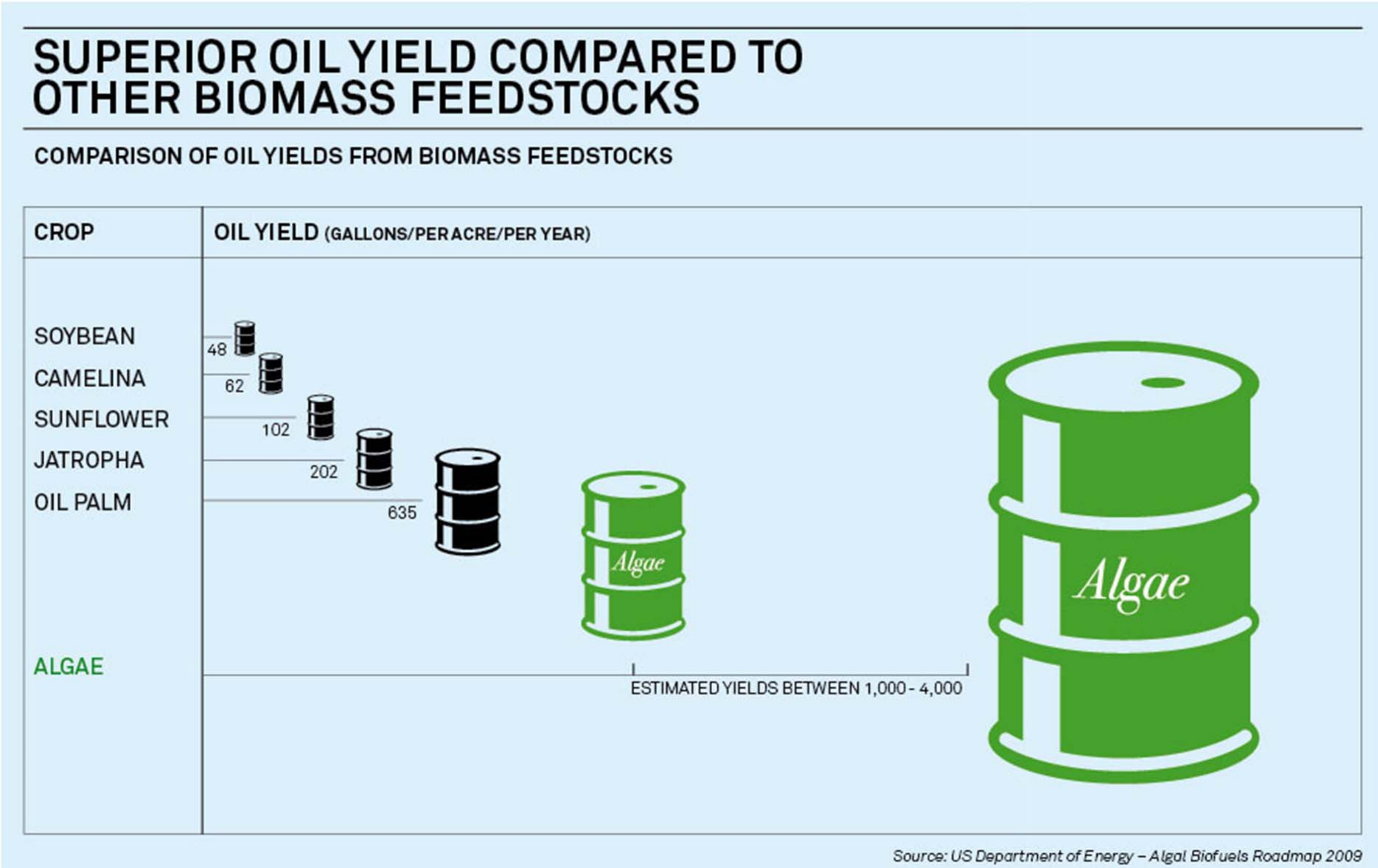


Product: Astaxanthin

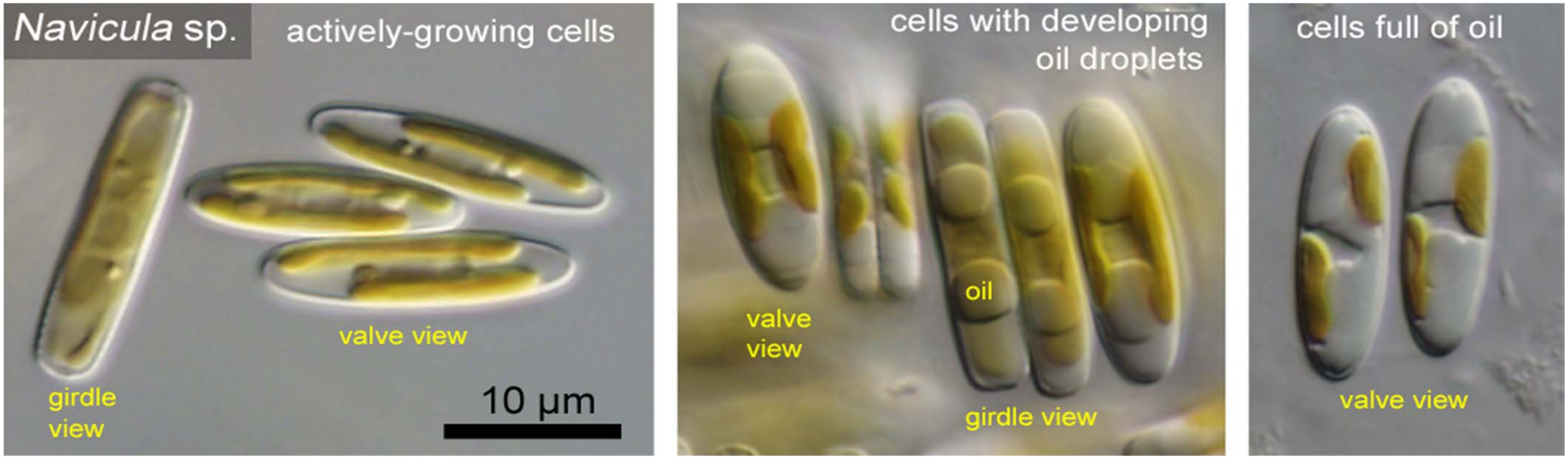
Human Nutraceutical from Microalgae:

- Powerful Antioxidant
- Sunburn Protection
- Health Benefits for:
  - Carpal Tunnel Syndrome
  - Rheumatoid Arthritis
  - Macular Degeneration

Why Algae ?



The Residual Defatted Biomass and Carbohydrates can also be used to make a Fishmeal (Protein) Replacement for the Animal Feed Industry.



Lipid Content Can be 20-50% of Cell Mass

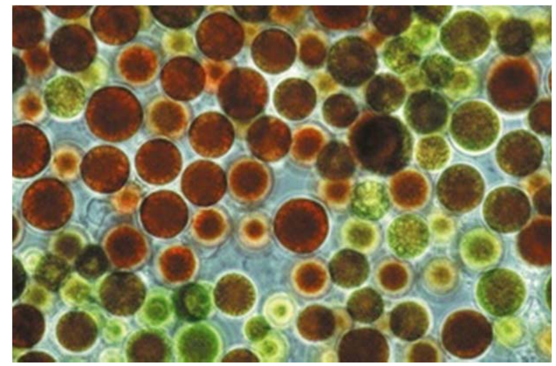
Biofuels from Microalgae

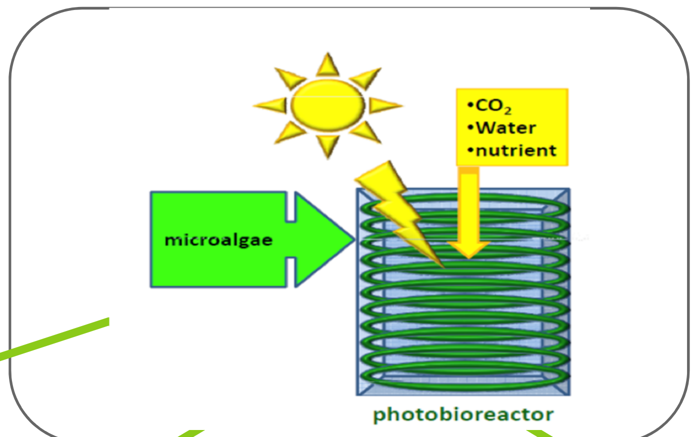
Scale Up is Needed to Prove Competitive Status with Fossil Fuels

The Opportunities are Promising

Microalgae Production Opportunities for your Location?

- **Microalgae are aquatic single cell organisms**
- **Valuable = Omega 3, Protein and Pigment**
- **Well established production technologies**





Omega 3

Food and supplements

Feed

Astaxanthin

Food and supplements

Feed

Protein

Feed, Human food

Biomass

Food and Feed

Organic Fertilizer

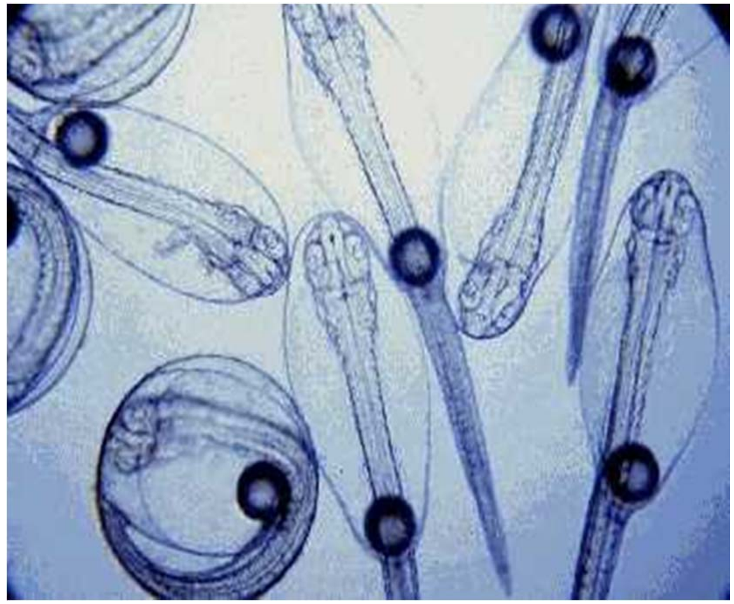
Specific Pathogen Free
&
Disease Resistant Shrimp Broodstock

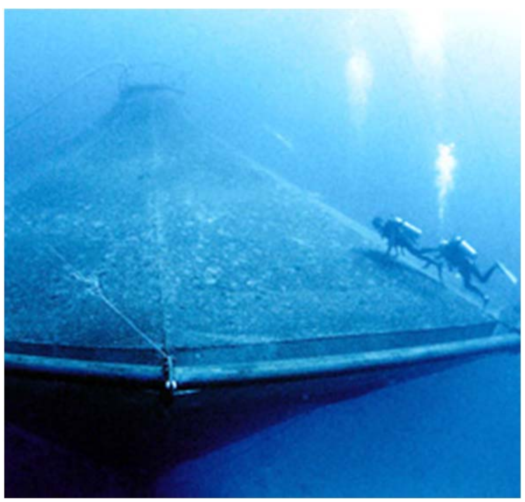
- SPF Certified Shrimp Broodstock
- Stronger, more Resilient Genetic Lines developed through traditional breeding techniques
- Requires Strict Biosecurity Protocols

Shellfish Larvae & Seed

- Shellfish Seed Ready for Sale or Transplant after 2.5 months
- Nursery Production not Limited by Nature's Seasons
- Cost Effective

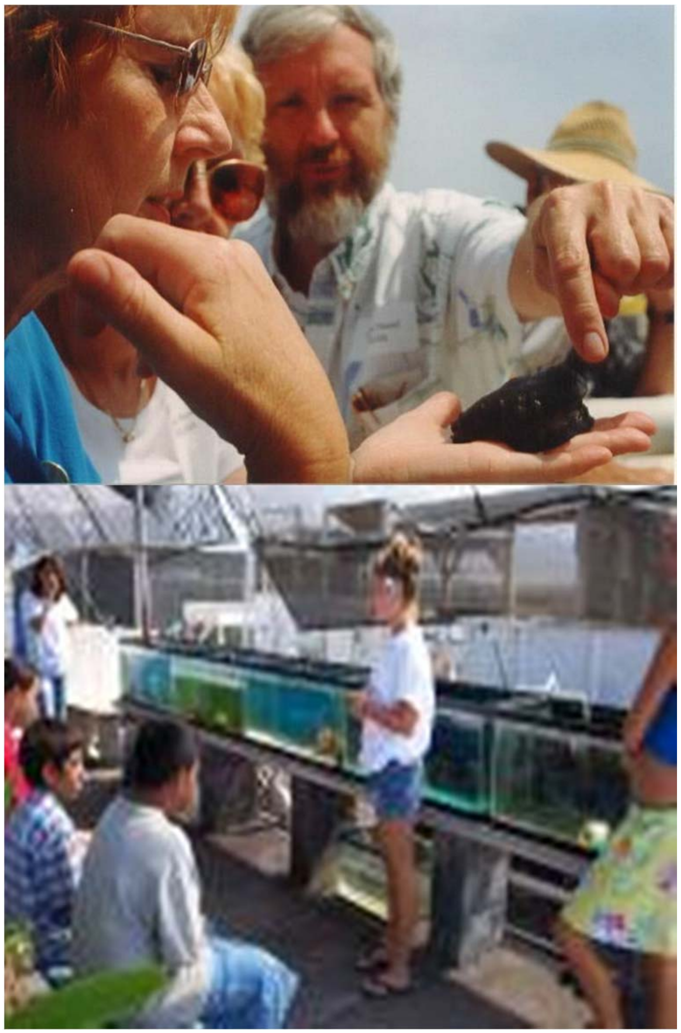
Blue Ocean Mariculture

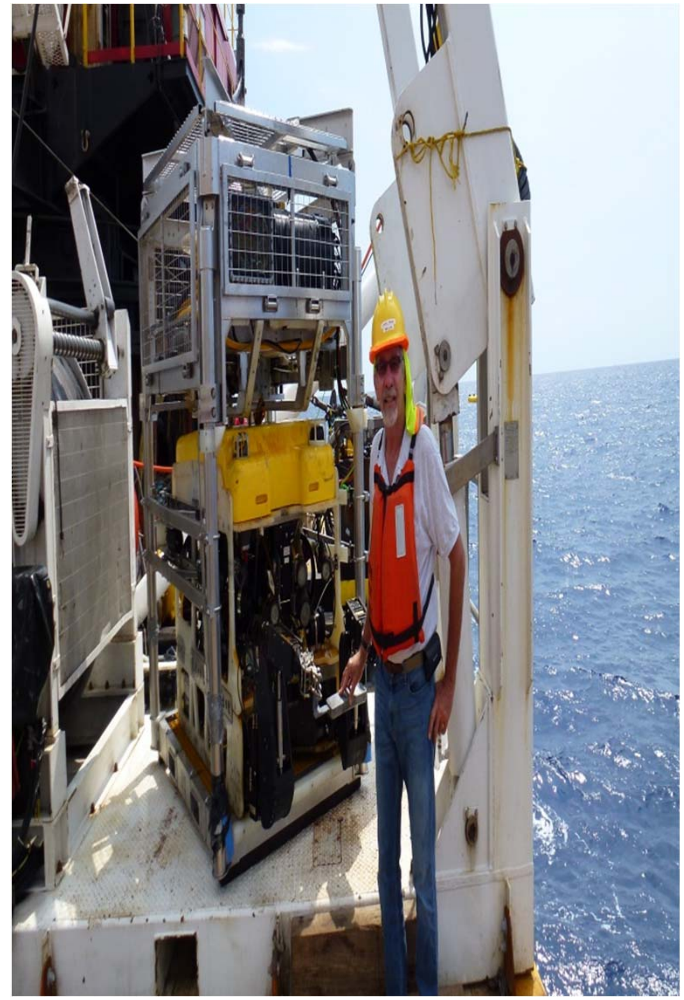


Land Based Hatchery/Nursery - Offshore Growout

Research / Development / Education



A Little About DOW Pipelines

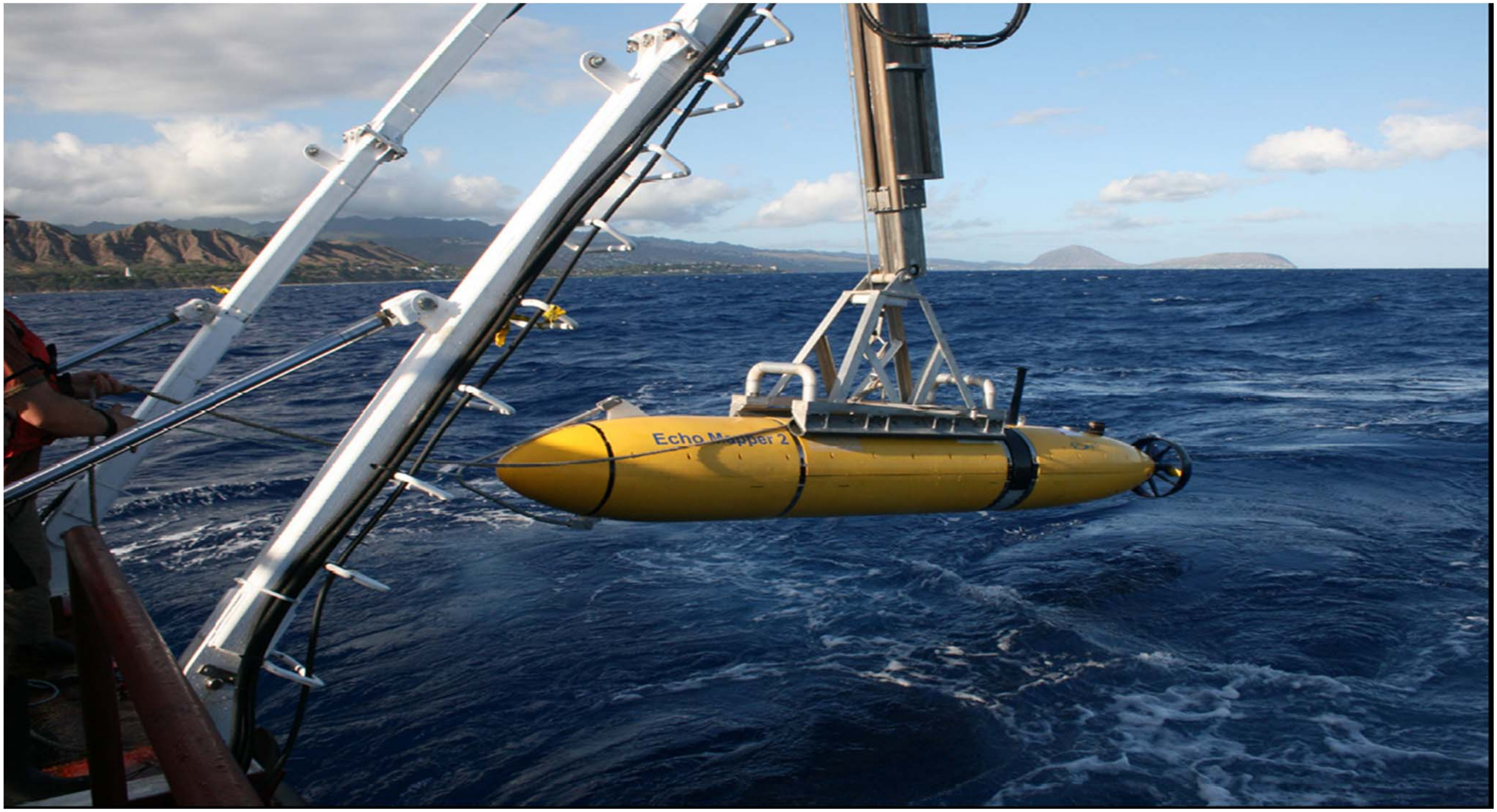


Side Scan Sonar

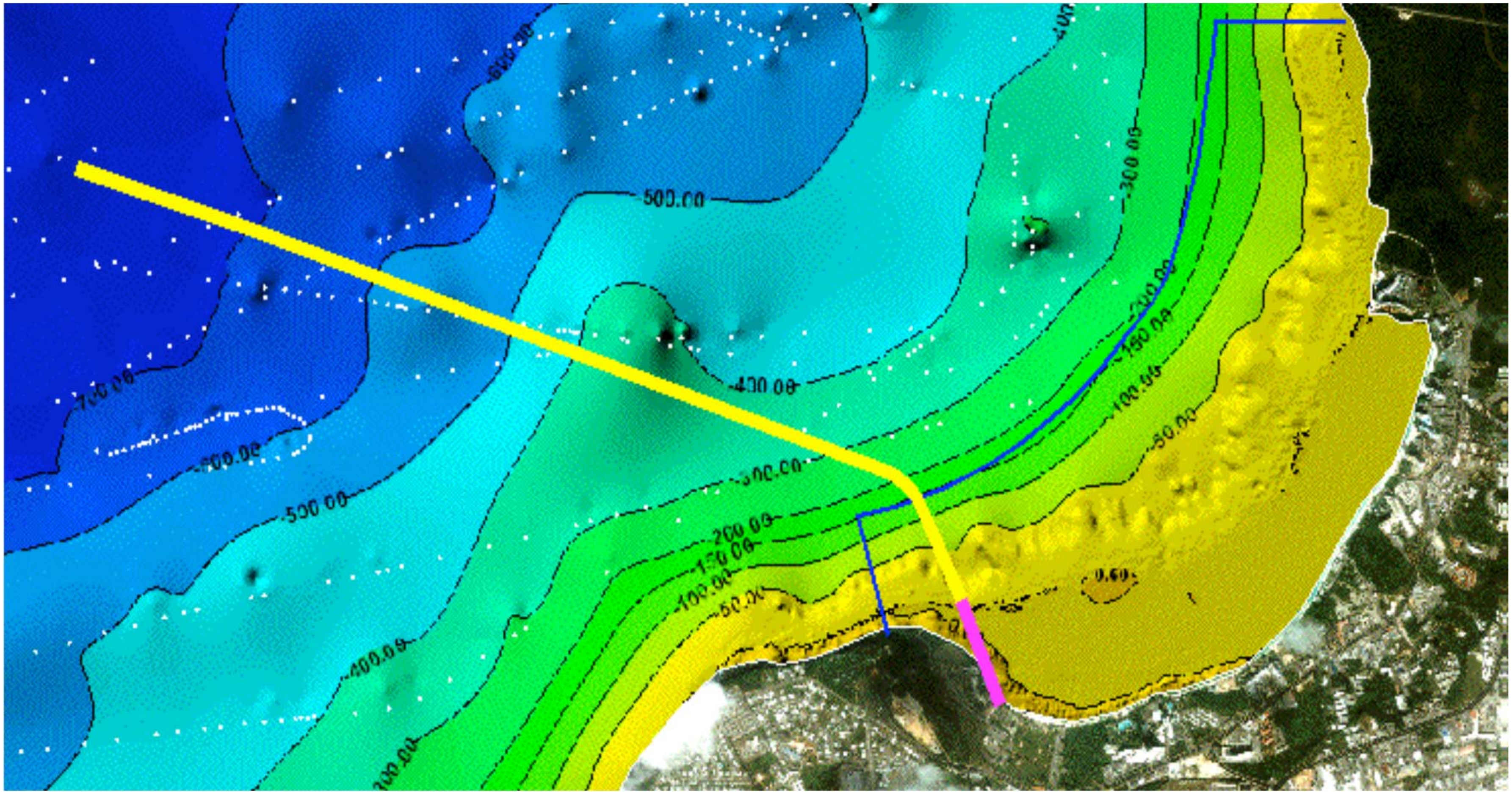
FOR

Offshore Bathymetry Profile

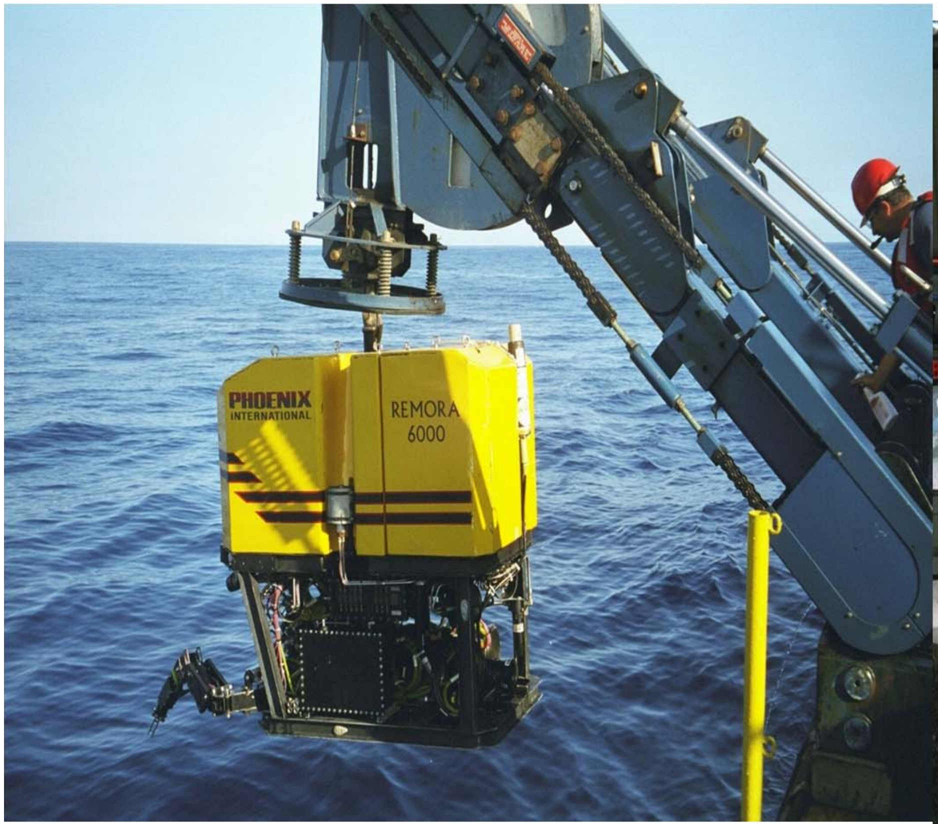
(CAN ALSO NOW BE ROV OR AUV)



Tumon Bay Guam – Proposed Offshore Route of DOW Pipeline

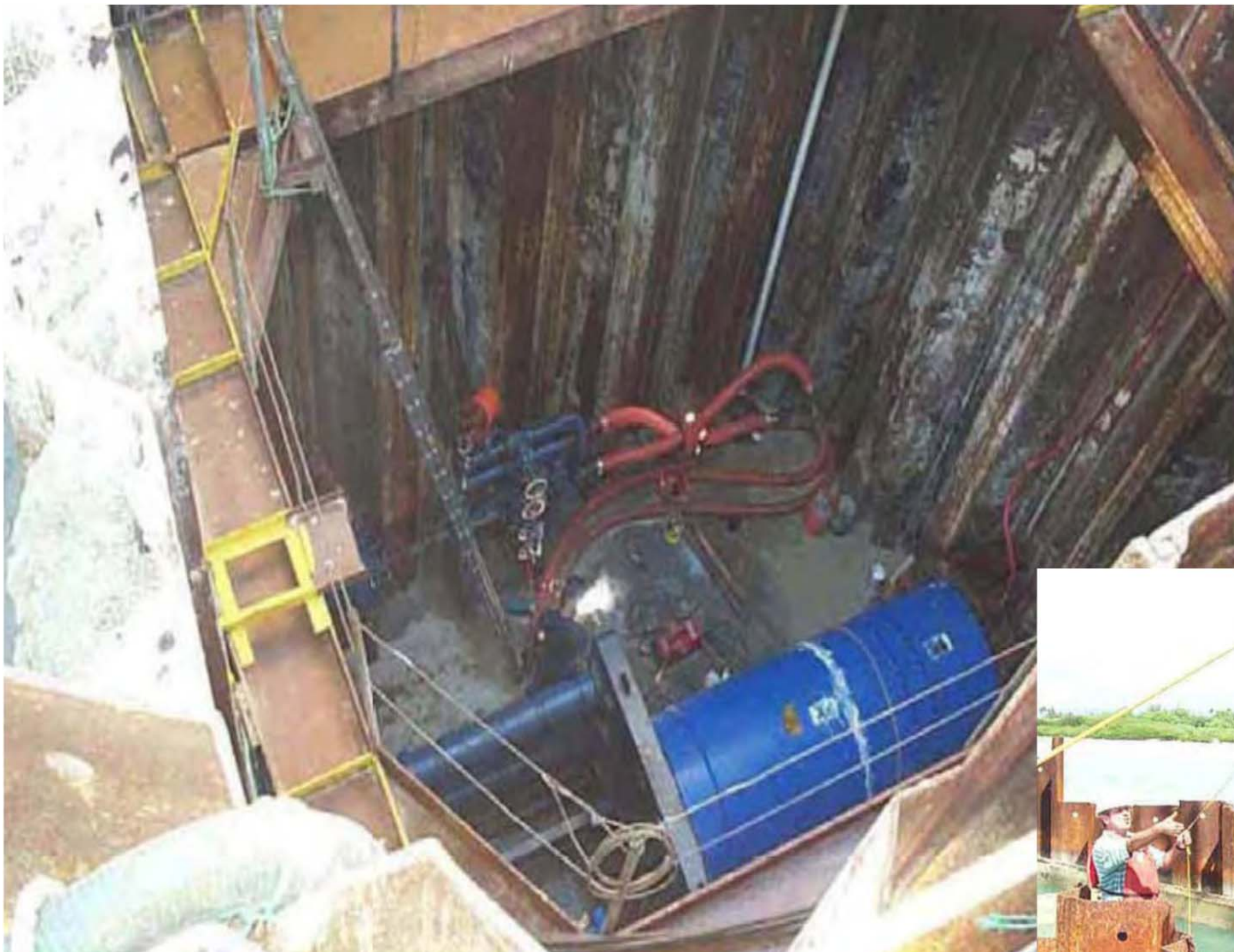


Detailed Visual Bottom Survey
(Close Inspection for Pipeline Route)



Remotely Operated Vehicle
(ROV)

Shoreline Crossing
(Trenching / Micro Tunneling)

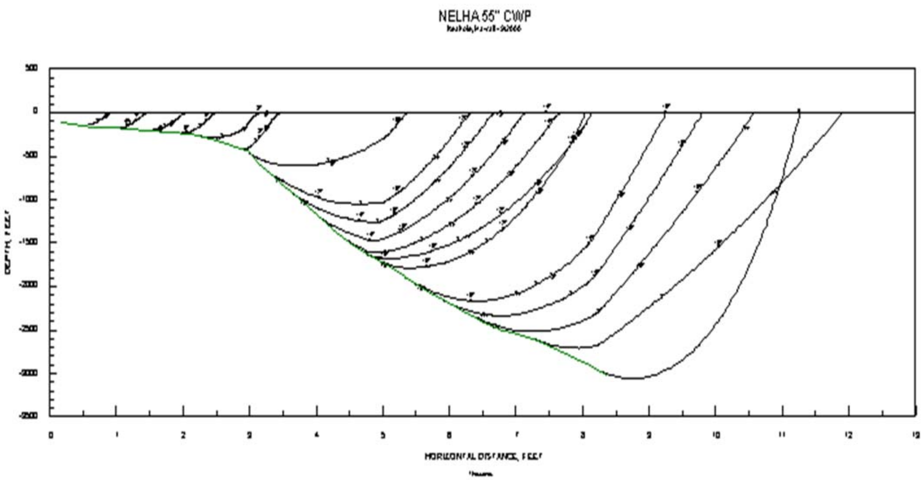


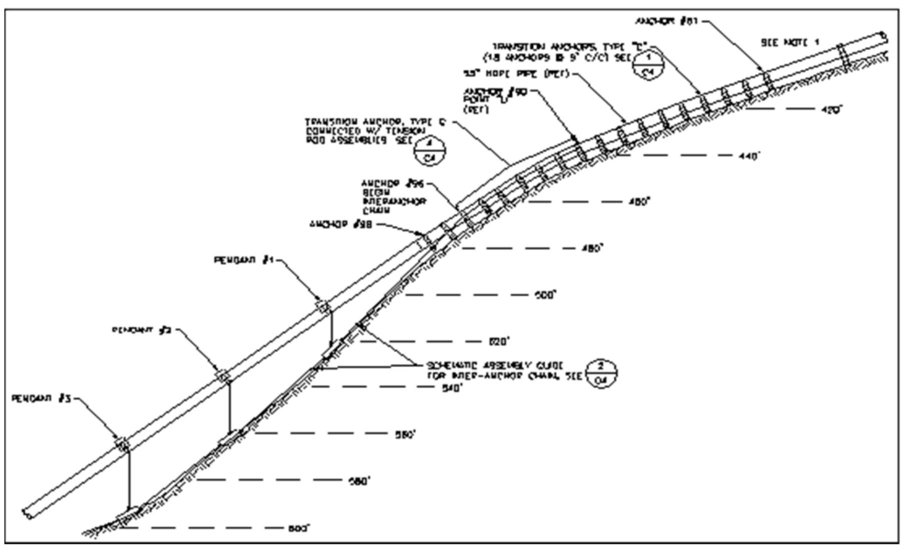
Deep Ocean Water Pipeline Construction

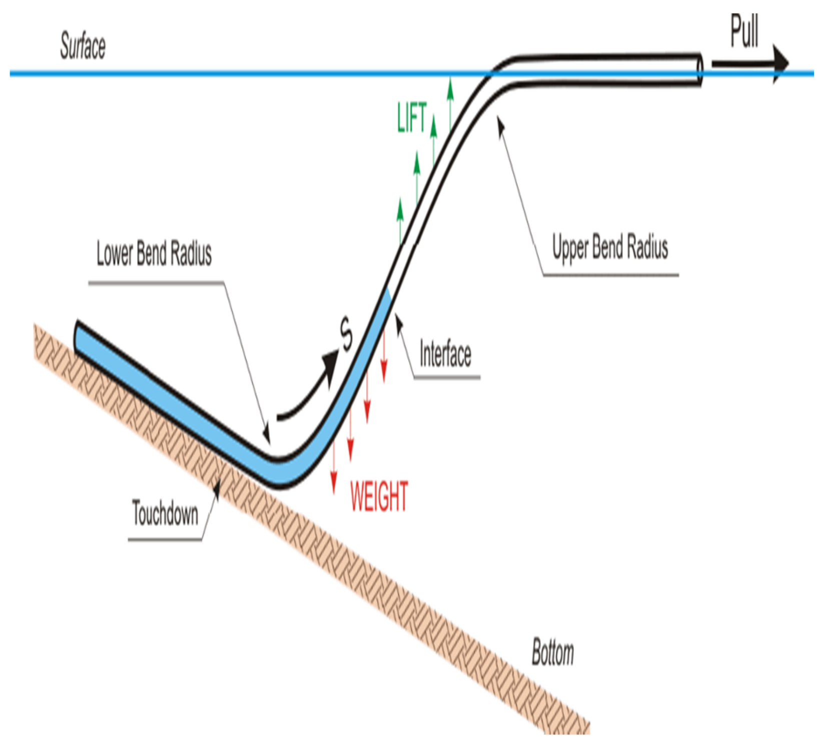
Deep Ocean Water Pipeline Deployment

Pipeline Deployment Process

(The Most Critical Aspect of Construction)

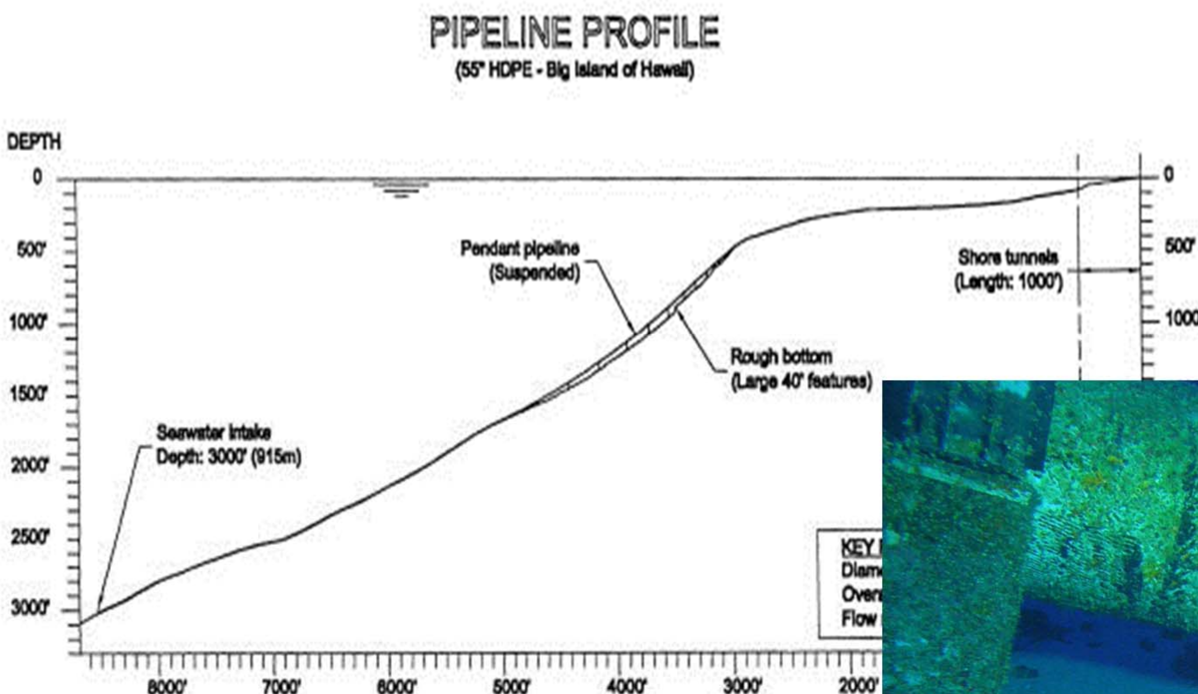






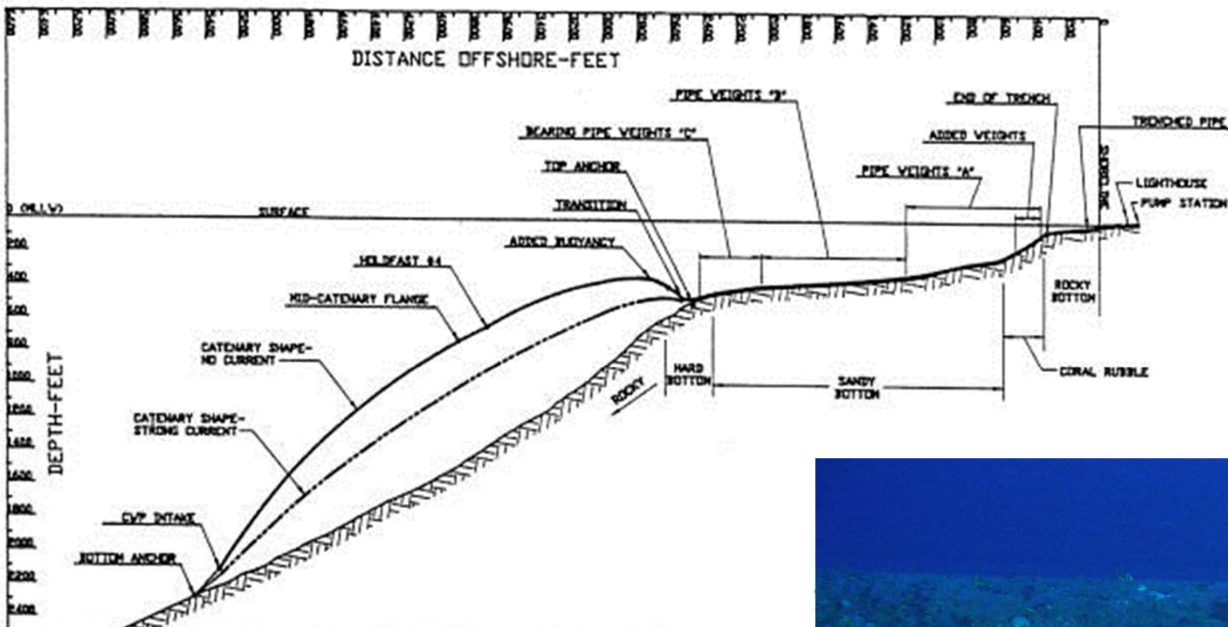
NELHA 1.4 M DOW Pipeline

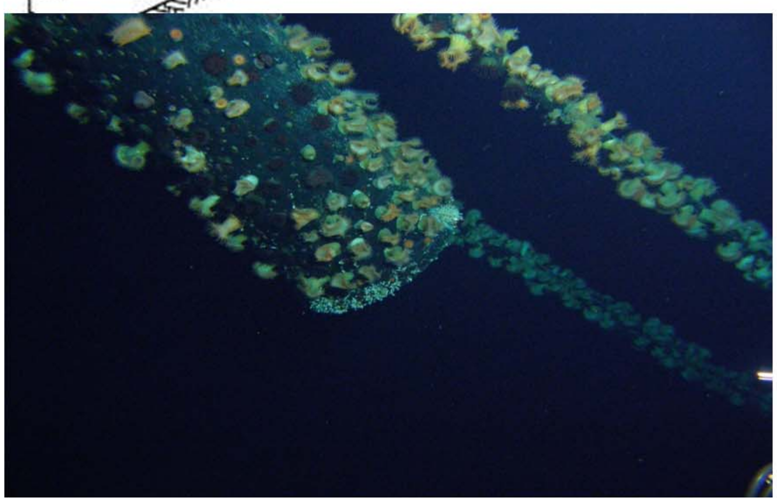
Depth: 927M (2005)



NELHA 1.0M DOW Pipeline

Depth: 623 M (1987)





Primary Uses
of
Deep Ocean Water

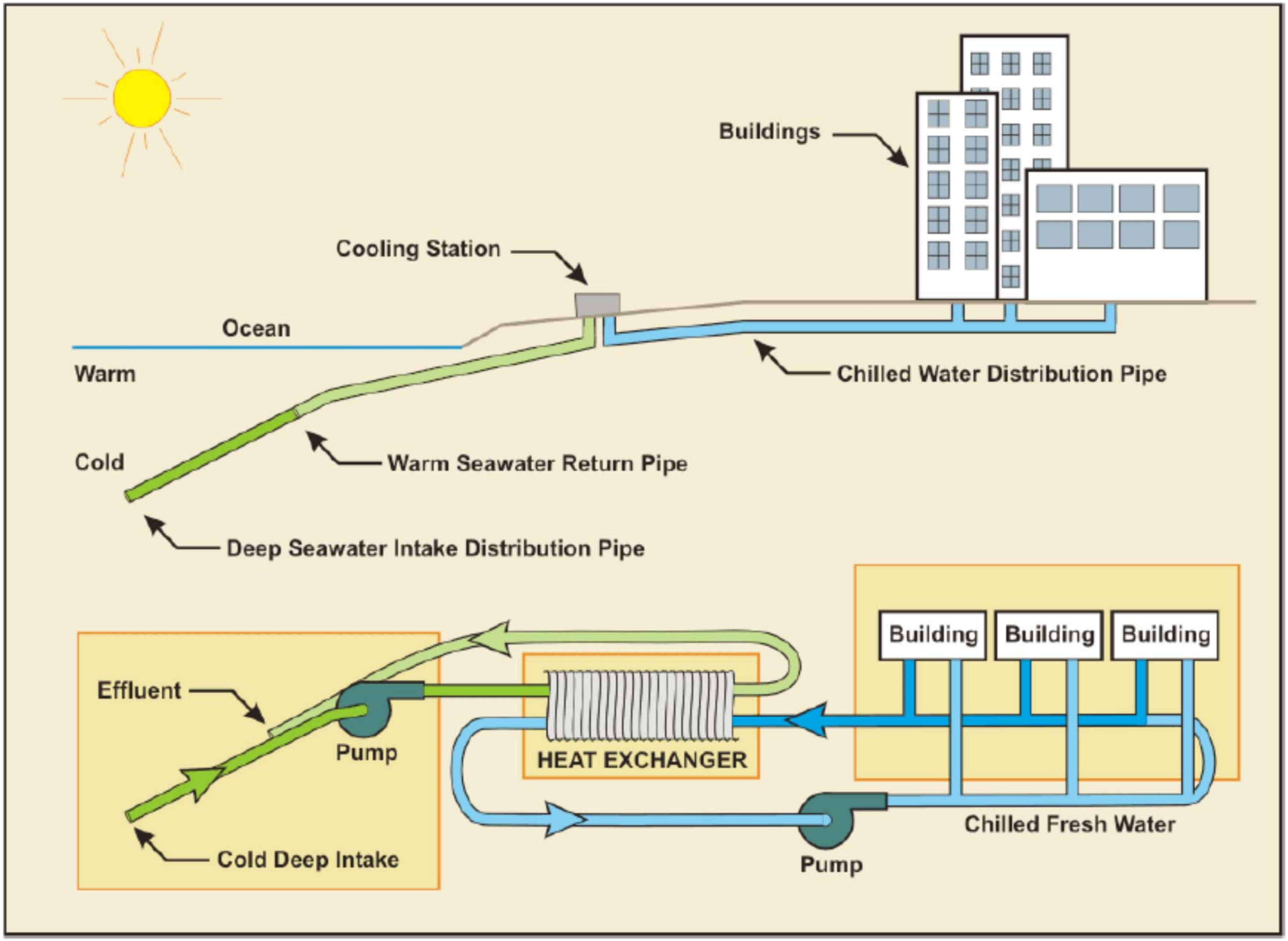
- **Seawater Air Conditioning (SWAC)**
- **Space Cooling / Refrigeration (Data Centers)**
- **Ocean Thermal Energy Conversion (OTEC)**
- **Desalination**
- **Mariculture**
- **Agriculture**

DEEP SEAWATER AIR CONDITIONING
SWAC

- SWAC uses Cold, Deep Ocean Water as an Energy Resource for Air Conditioning and other Space Cooling Applications

- Chilled Water Resource can be Cold Seawater, Lake Water, Reservoir Water, River Water or any Chilled Solution of compatible quantity

- Chilled Water is used as the Primary Substitute for the Refrigeration Process


Buildings
Cooling Station
Ocean
Warm
Chilled Water Distribution Pipe
Cold
Warm Seawater Return Pipe
Deep Seawater Intake Distribution Pipe
Building
Building
Building
Effluent
Pump
HEAT EXCHANGER
Chilled Fresh Water
Cold Deep Intake
Pump

Factors Affecting Economic Viability

- Optimal Access to Cold Water

  (Shorter pipelines are more economical)

- Large Size (Economy of scale – Systems <1,000 tons are difficult to justify)

- Concentrated Customers Close to Shore (Small Distribution System)

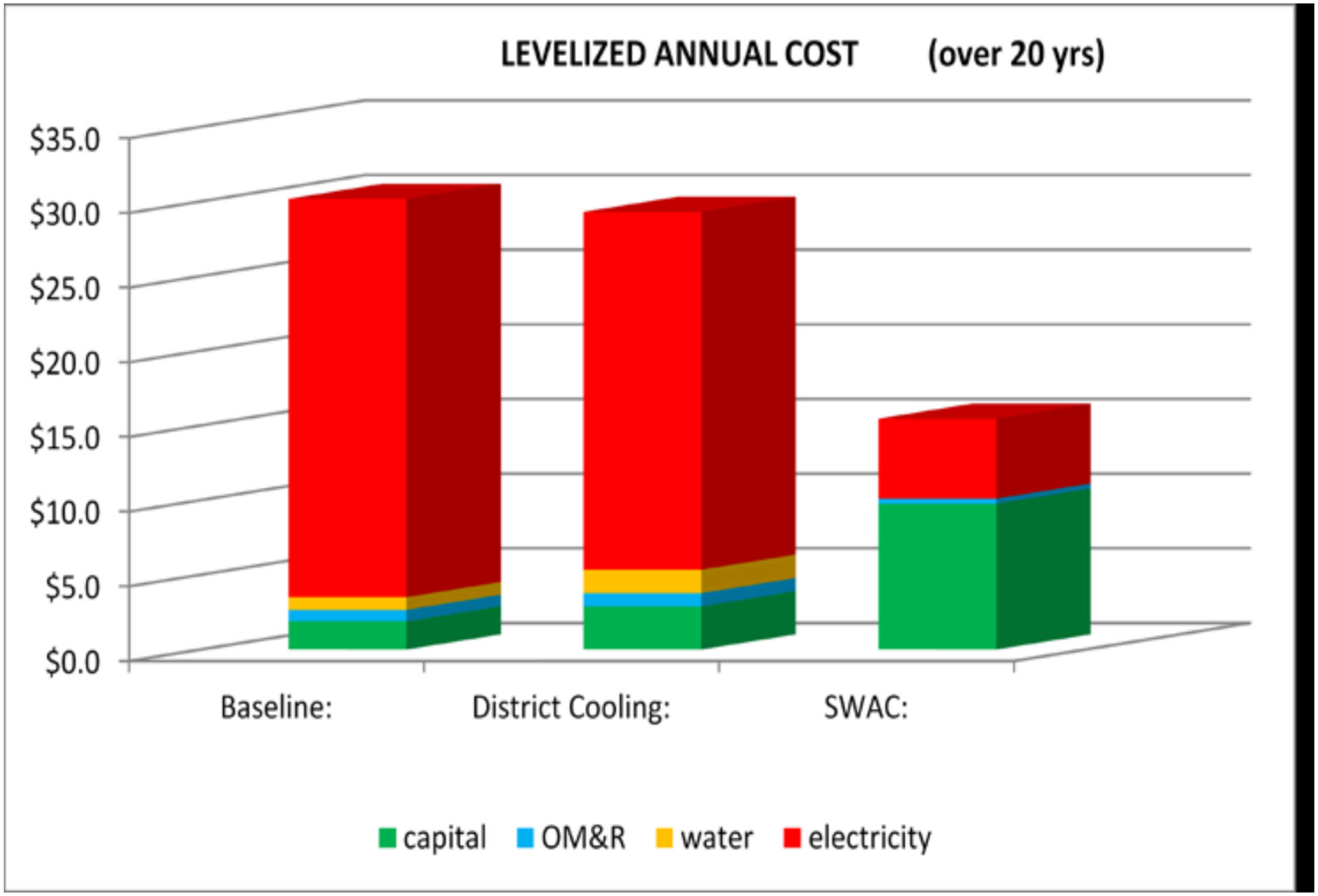
- High AC Utilization Throughout the Year

- High Electrical Rates / High Reliance on Importation of Fossil Fuels

Advantages of SWAC

- Technologically Ready Today – Low Risk
- Offsets Electrical Demand - Guaranteed
  (Each ton of AC saves ~ 0.7 kW)
- Reduces Reliance of Fossil Fuels
  (Deep Seawater = Renewable Resource / Reduces Power Plant Emissions)
- Saves 75-85% of Energy Costs
- Reduces need for Chillers & Cooling Towers
  (Eliminates Ozone-Depleting Greenhouse Gases, Saves Potable Water and Reduces Sewage)
- Rapid Return on Capital Investment (5-7 Years)
- Easily Adaptable to Conventional Chill Water Air Conditioning Systems

Levelized Cost Comparison



Courtesy – NAVFAC

Current SWAC Installations

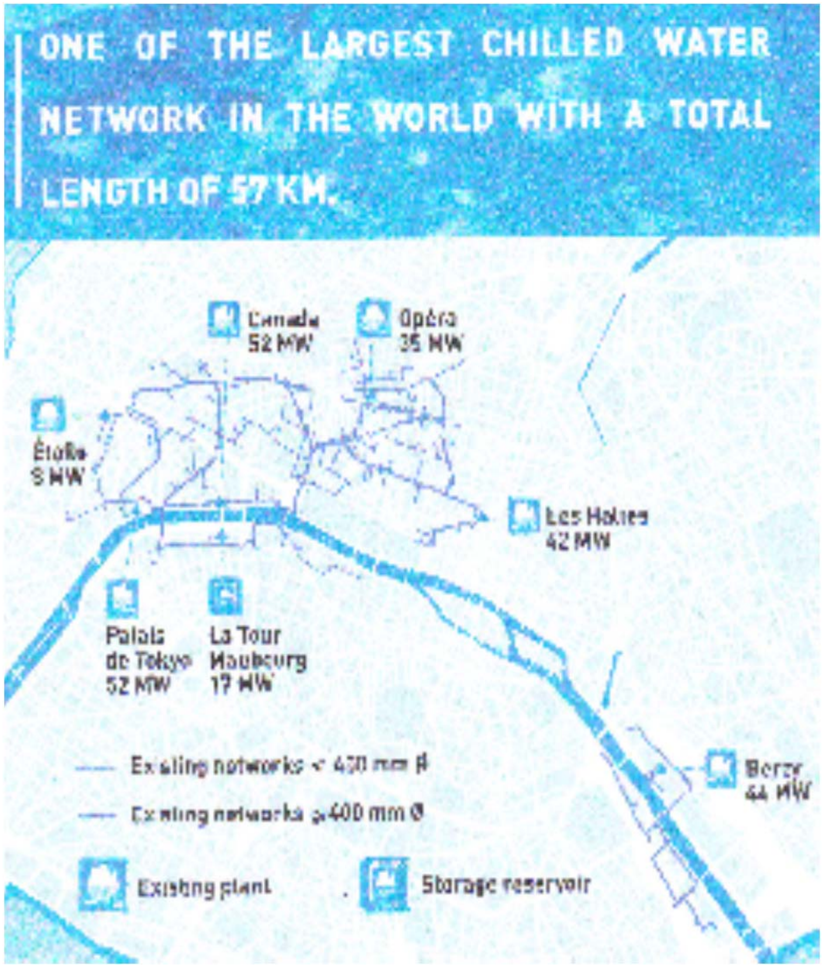
- City of Stockholm (100,000 tons)
- City of Toronto (80,000 tons)
- Cornell University (20,000 tons)
- Purdy’s Warf – Nova Scotia (1,000 tons)
- Intercontinental Hotel – Bora Bora (450 tons)
- NELHA (100 tons)

Proposed SWAC Installations

- Honolulu, Hawaii (25,000 tons)
- Waikiki (35,000 tons)
- Tumon Bay, Guam (11,000 – 16,000 tons)
- Reunion Island (20,000 tons)
- Curacao (2,400 tons)
- Mauritius
- Aruba
- Kona International Airport (4,000 tons)
- Many More Freshwater Installations (Netherlands / France)

Climespace – District Cooling System
Paris, France

- Uses Freshwater from the Seine River
- 6 Production PlantS
- 1 Storage Center for Ice (17 MW)
- Connected Load = 270 MW
- 57 KM Chillwater Network
- Connected Offices = 4 million square meters



JACQUES D'ARSONVAL

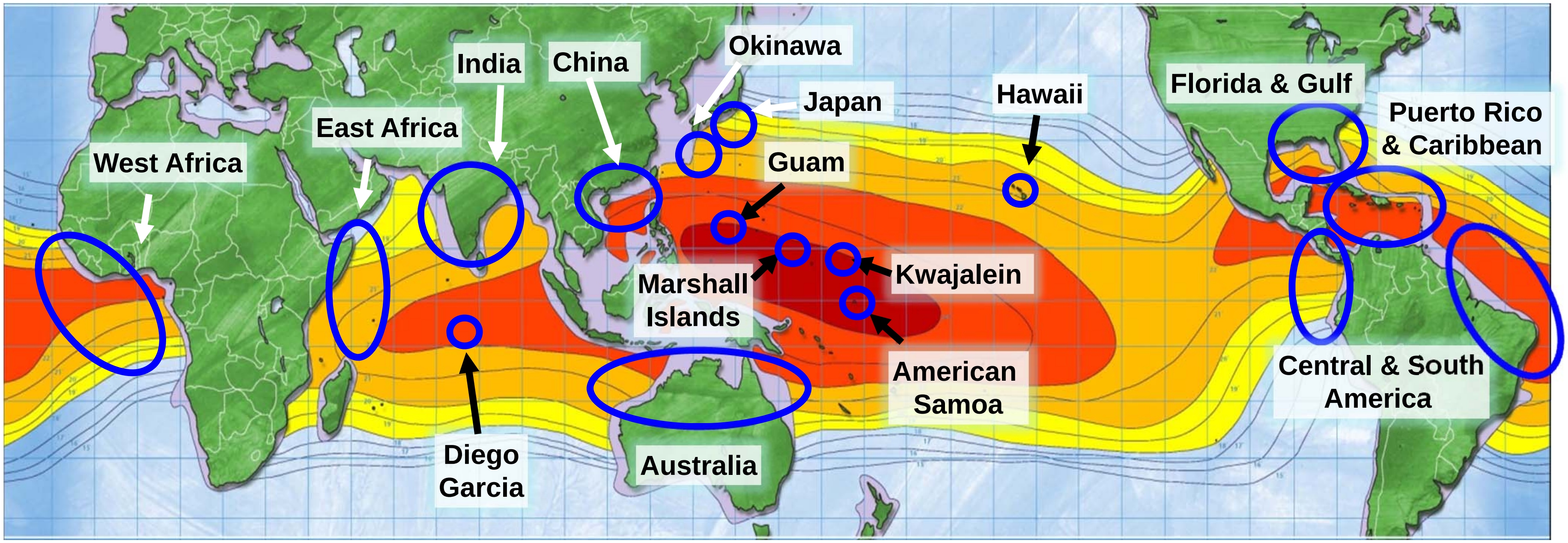
OCEAN THERMAL ENERGY CONVERSION (OTEC)

- 1881 CLOSED CYCLE OTEC CONCEPT PROPOSED BY JACQUES D'ARSONVAL
- 1930 - 1ST OTEC PLANT MATANZAS BAY, CUBA BY GEORGES CLAUDE (OPEN CYCLE - NO NET POWER)
- 1979 - MINI-OTEC - WORLD'S FIRST NET POWER PRODUCING OTEC PLANT (NELH - KEAHOLE POINT HAWAII)

OTEC is a Solution for

Large scale baseload power

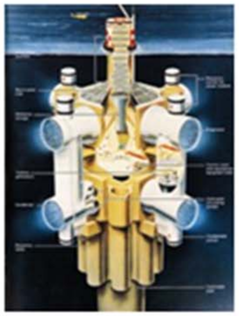
A New Secure Renewable Energy Source



Over 84 Countries have direct access to the OTEC Resource

OTEC History

1974: Hawaii established Natural Energy Laboratory
(NELHA)



1975: NSF OTEC Studies
(Lockheed, TRW)

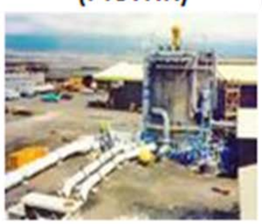
1979: 50 kW Mini-OTEC
(Lockheed & Makai)

1981: OTEC-1 Test
(DOE)

1981: 100KW OTEC Nauru Plant
(Toshiba)

1983: CWP At Sea Test
(TRW for DOE)

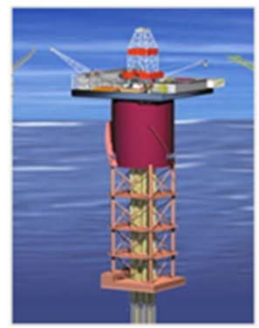
1993: 250kW Open Cycle
(PICTHR)



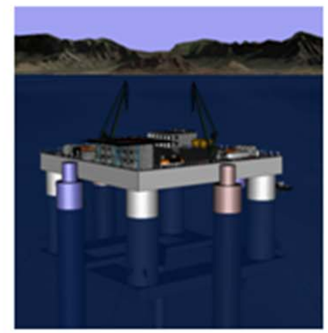
1996-2000: 50KW Hx testing
(NELHA)

2000: India 1MW OTEC Plant
(NIOT)

2005: Diego Garcia Feasibility
(OCEES SBIR)



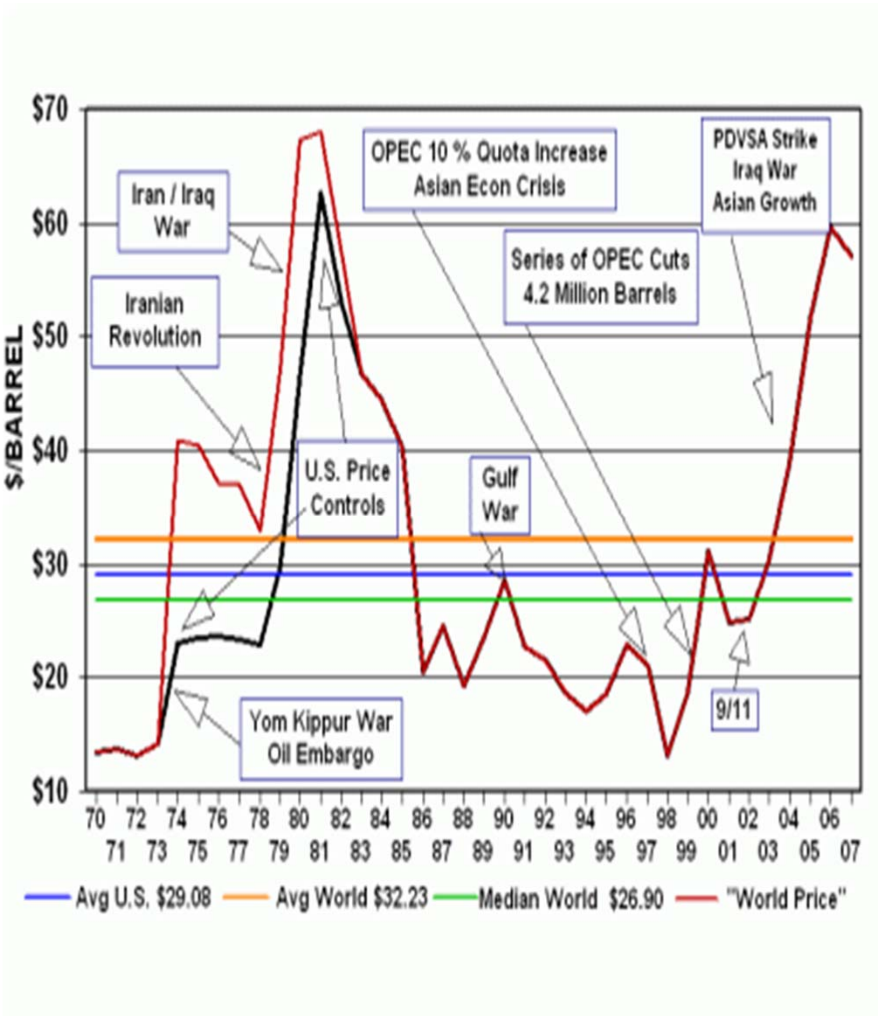
2006: OTEC Study
(Makai SBIR)

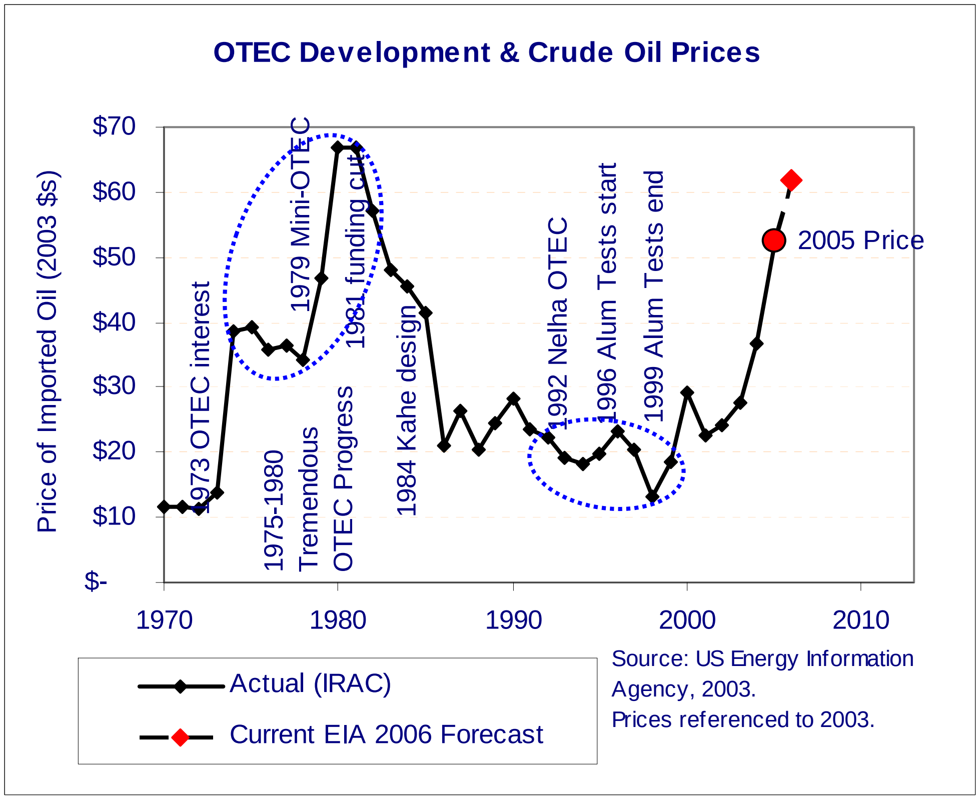


2007-present: Pilot Plant Design
(Lockheed Martin Team)

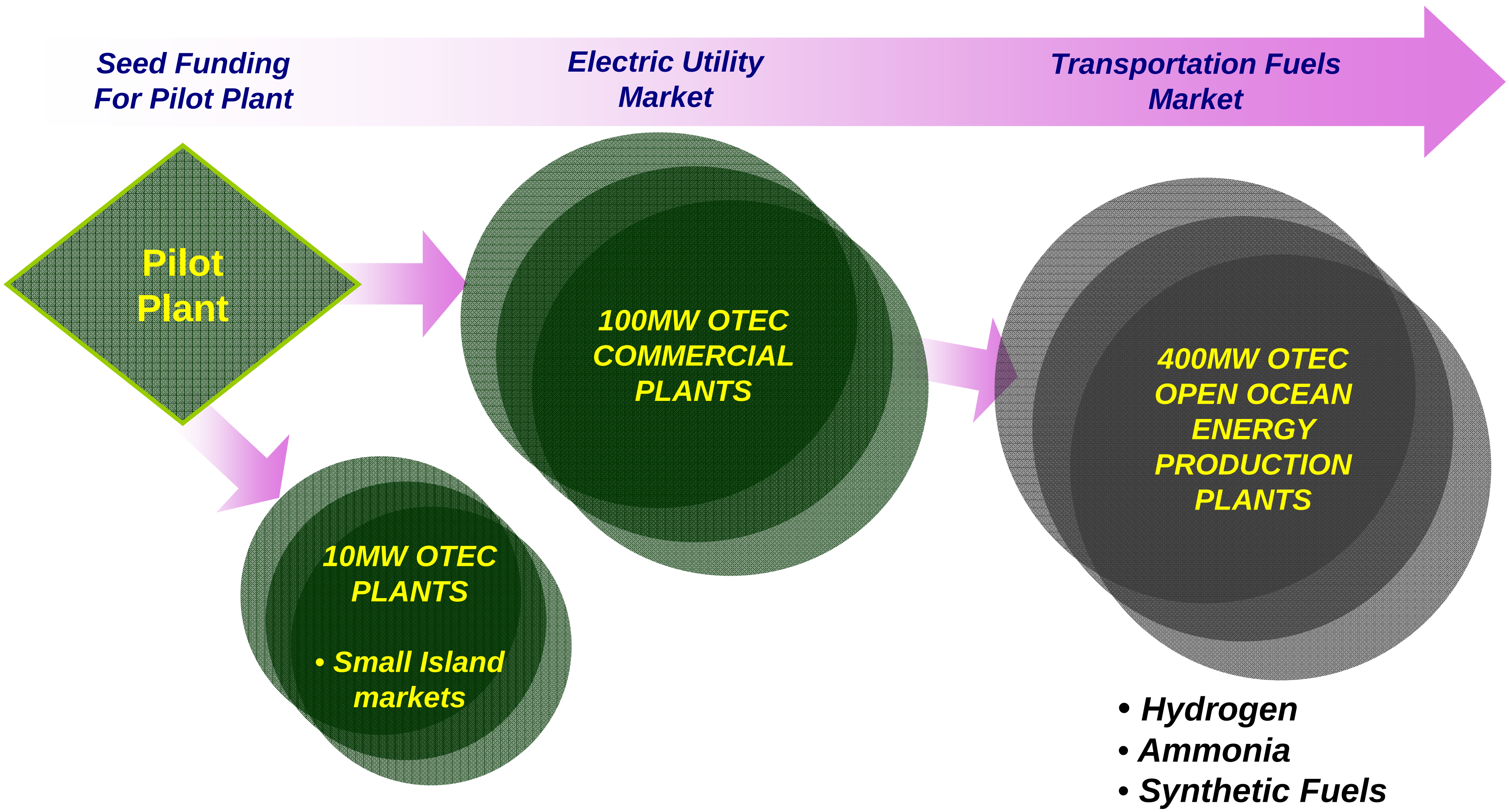
Conceived in Late 1800s; First Tested in 1900s; Implemented in 2000s

There is an Interesting Relationship between the Price of Oil and Investment in OTEC





The OTEC Vision for the Future



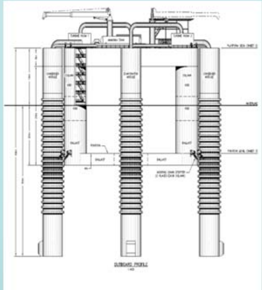
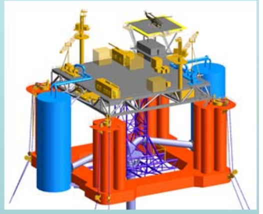
OTEC is Poised to be a Global Energy Resource

Challenges of OTEC Development

- **Currently No OTEC Industry**
  (Only Small Scale Testing So Far – Baby Steps - Just Toys So Far)
- **Scaling Up is Unproven and Expensive**
- **Funding is Difficult to Obtain**
  (World Bank Will Not Fund Unproven Technologies)
- **Several Technological Challenges Still Exist**
  (Heat Exchangers / DOW Pipe / Platform / Platform-Pipe Interface)
- **Independent Development Slowing Progress**
  (There is a Need for Large Scale International Cooperation's)

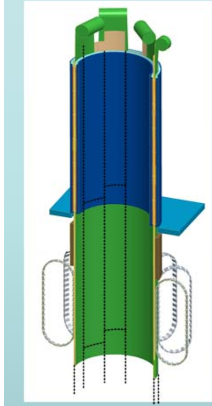
Key Advances Needed

Platform

Platform
- Survivability
- Stability

Cold Water Pipe



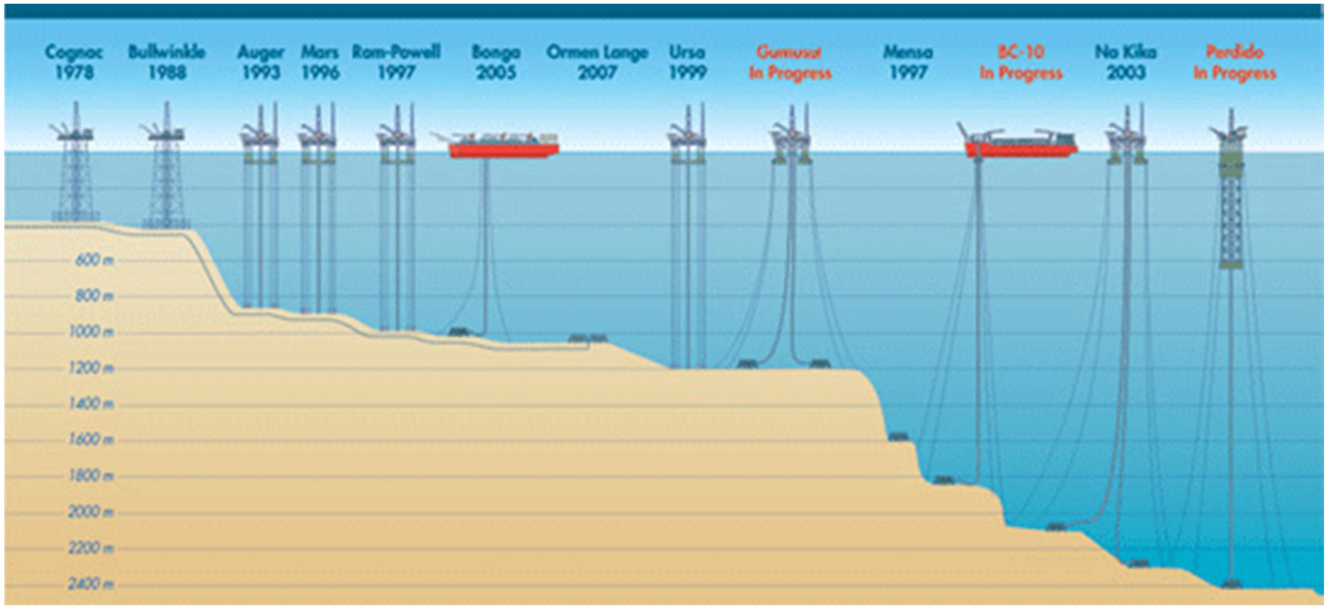
Cold Water Pipe
- Deployment
- Survivability
- Scalability

Heat Exchanger



Heat Exchangers
- Performance
- Corrosion
- Biofouling

Offshore Platform Advancements



OTEC Operating Depths

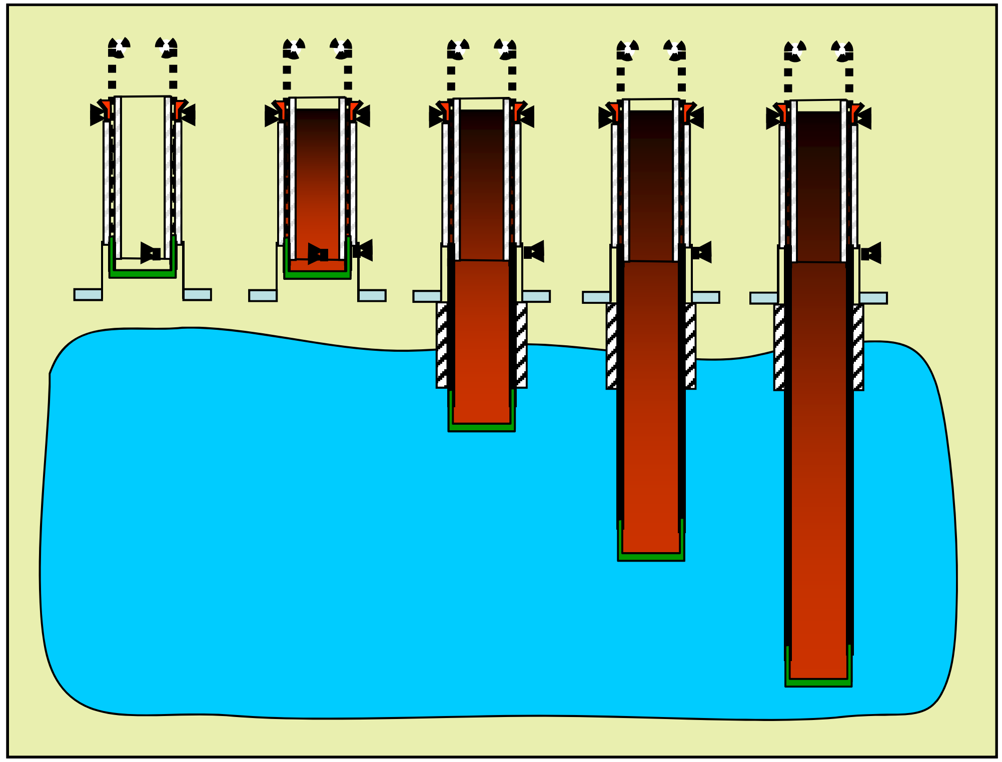
- ***Proven platforms and installation methods (anchors, moorings, risers)***
- ***Proven dynamic and static power cables at OTEC compatible ratings (depths, voltages)***
- ***Validated complex modeling and prediction of coupled dynamic responses***
- ***Advanced Model Basin capability for early concept validation***

OTEC operating depths are well within the capabilities and experience of today's offshore industry

The OTEC Deep Ocean Water Pipe

The Pipe

In-Situ Fabrication



Cold Water Pipe Parameters

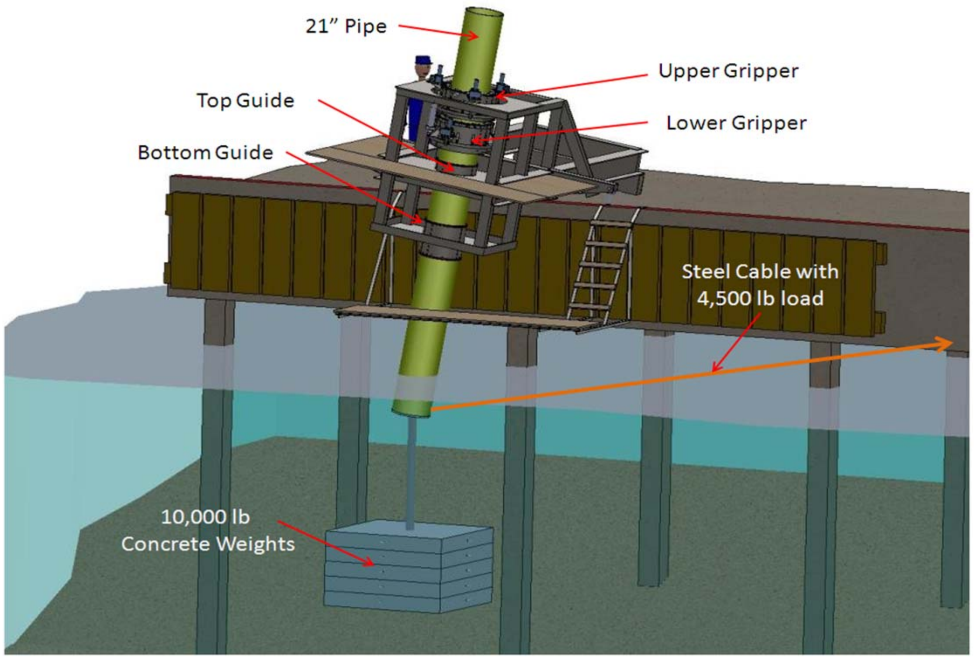
• 10MW Pipe	4m x 1000m
• 100MW Pipe	10m x 1000m

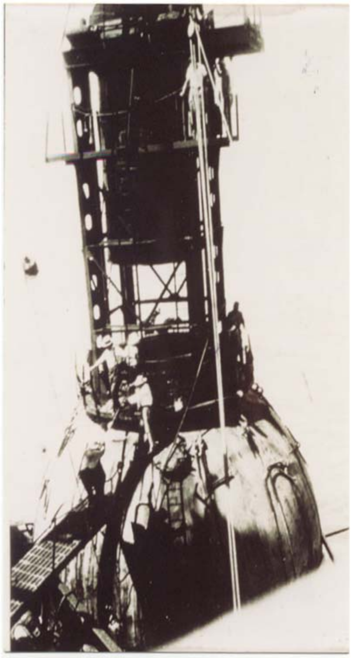
Fabrication on the platform eliminates major DOW deployment risk

Pipe Gripper Test Configuration

- Hold and Lower CWP From Any Point Along Its Length

- Minimize Relative Motions Between Platform and CWP



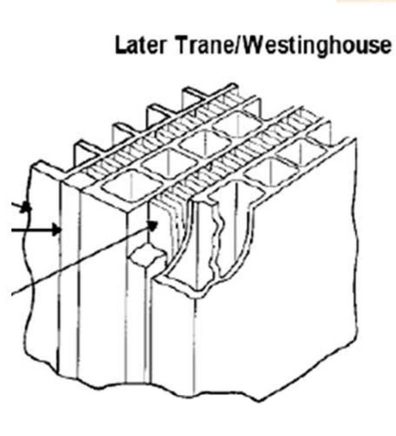


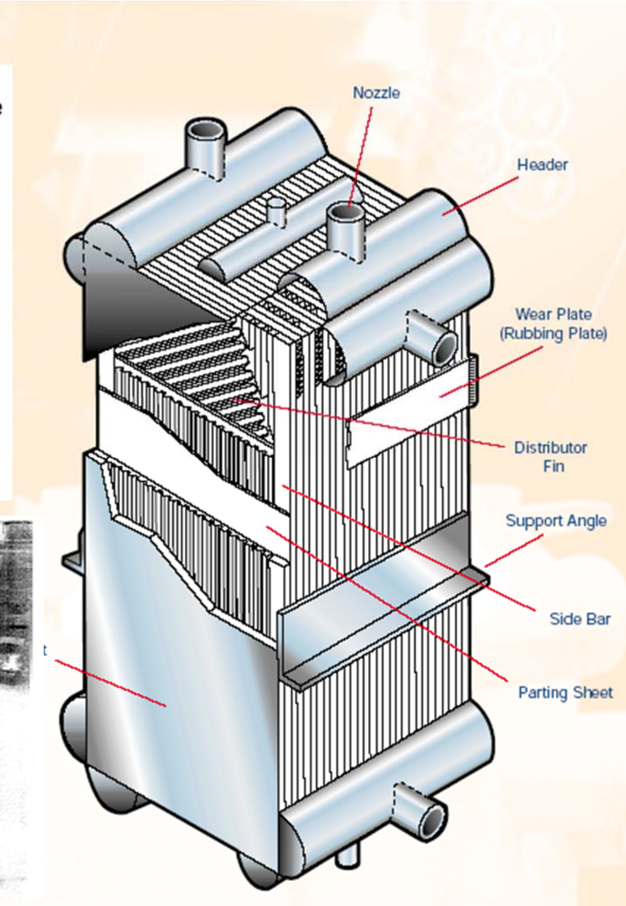
Claude's Gripper 1930's

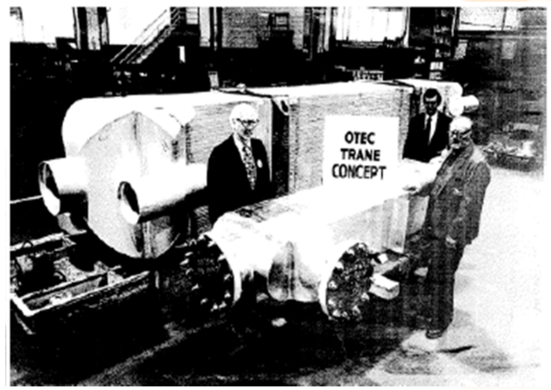
Prototype Configuration Fully Exercised in Hawaii Summer 2010

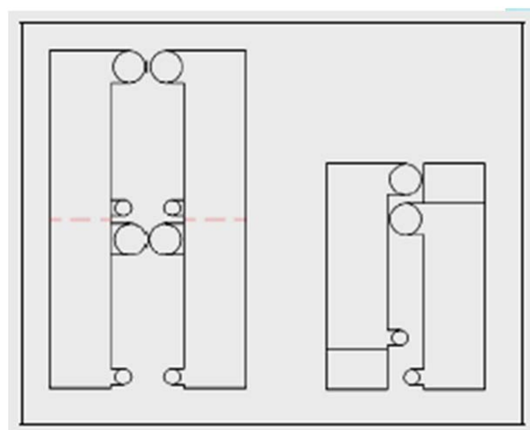
Heat Exchangers

- **Best HXs Tested for OTEC - ANL in 1981**
- **Brazed Aluminum**
- **Costs – Manufacturer**
- **Sizing Rationale**
- **Highly Scalable**
- **Laid out into Spar**









Lockheed Martin Heat Exchangers at NELHA





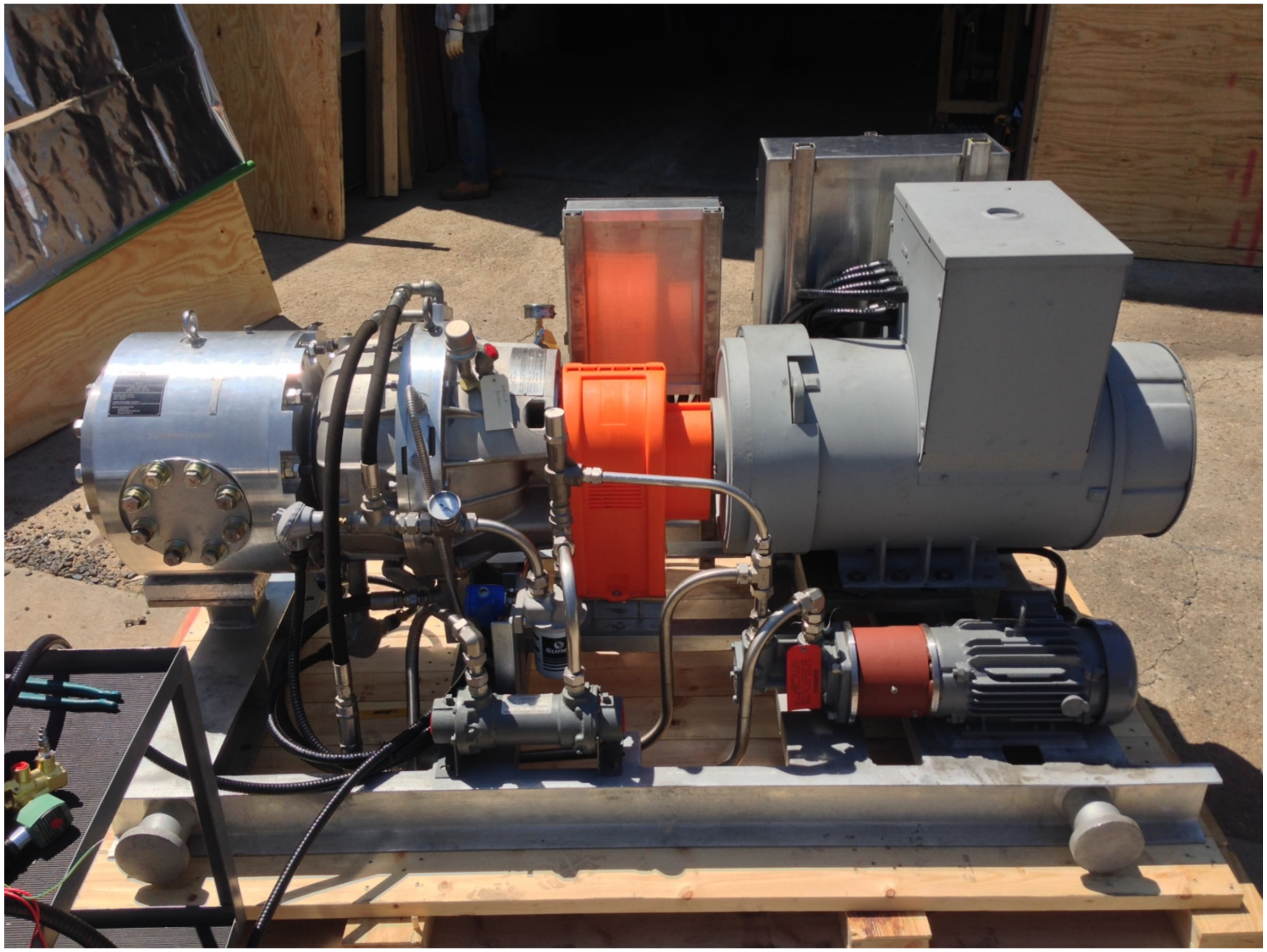



Most Recent Installations at MOE Ocean Energy Research Center (OERC) @ NELHA

Initial Thermal Performance Matches Expectations / Braised Aluminum Evaporator Possible

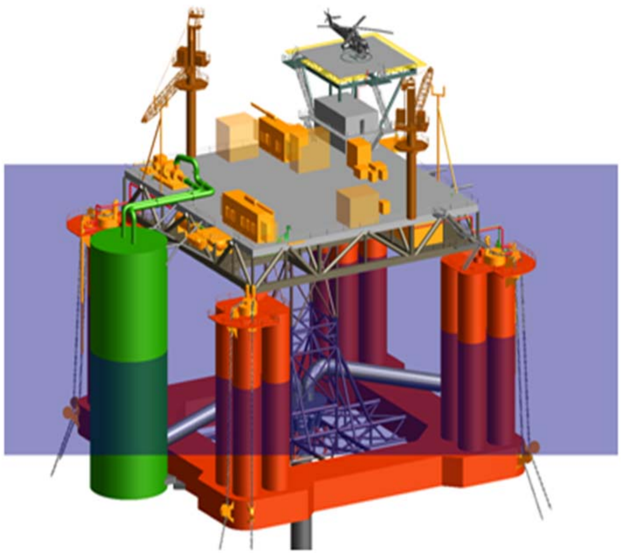
MAKAI OCEAN ENGINEERING

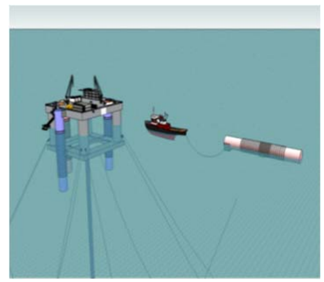
100 KW TURBINE GENERATOR

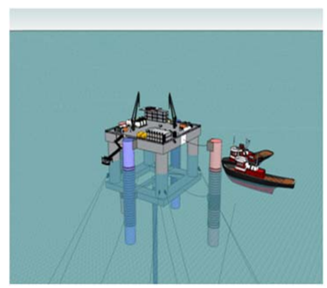


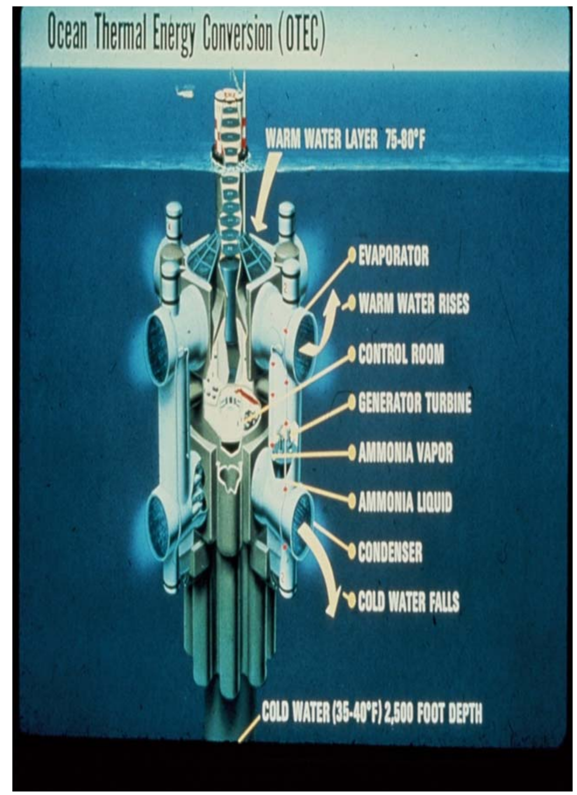
Japanese OTEC Test Facility
(Kumejima, Okinawa)

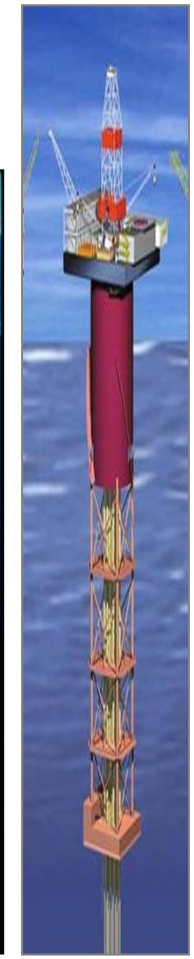
Possible OTEC Plant Configurations

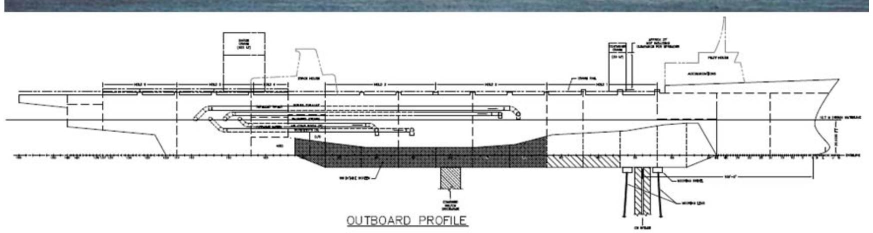






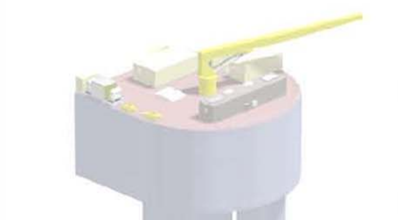






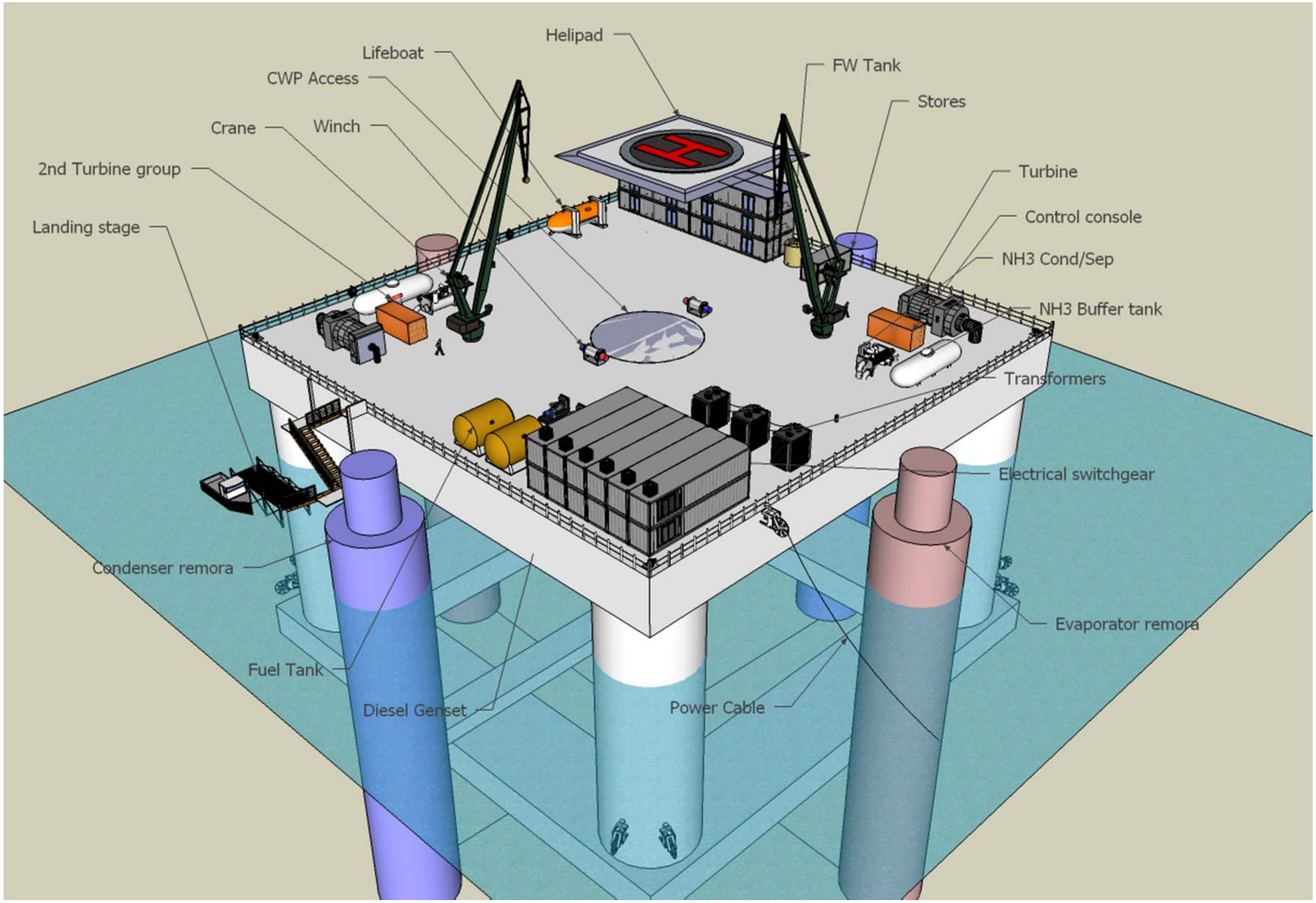
OTEC Plant

Flow & Discharge Configurations

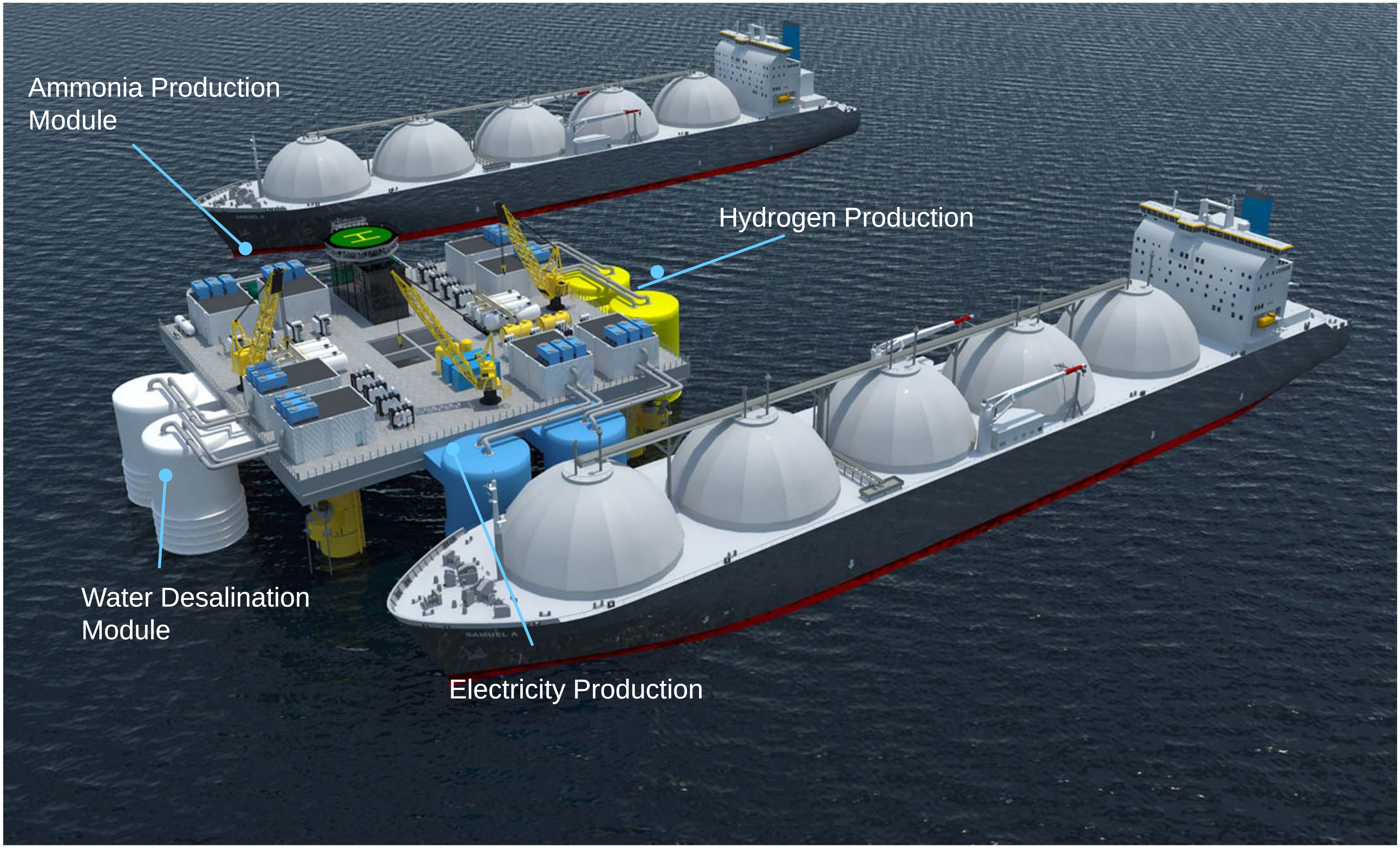


		2.5 MW	10 MW	100 MW
Warm seawater	Tonne/sec	15.8	46	430
	m^3 / sec	15.3	44.7	420
	gallon/min	*243 k*	*710 k*	*6.7 million*
Temperature	°C	25.7	25.7	25.7
	°F	*78.3*	*78.3*	*78.3*
Intake area	m^2	102	298	2800
Cold seawater	Tonne/sec	10.5	36.7	329
	m^3 / sec	10.2	35.7	320
	gallon/min	*162 k*	*565 k*	*5.1 million*
Temperature	°C	4.1	4.1	4.1
	°F	*39.4*	*39.4*	*39.4*
Cold water pipe ID	m	2.3 m HDPE	4 m FRP	10 m FRP
Discharge water	°C	17.1	16.1	16.3
	°F	*62.7*	*61.0*	*61.4*
Parameters to attain plume depth > 130 m		1 x 114m deep @ 1.1 m/s Model simulates 100 MW.	2 x 70 m deep @ 1 m/s 120 - 140 m. 127m avg.	4 x 70 m deep @ 1.9 m/s 8 x 95 m deep @ 1.9 m/s

10 MW Semi-Sub Platform



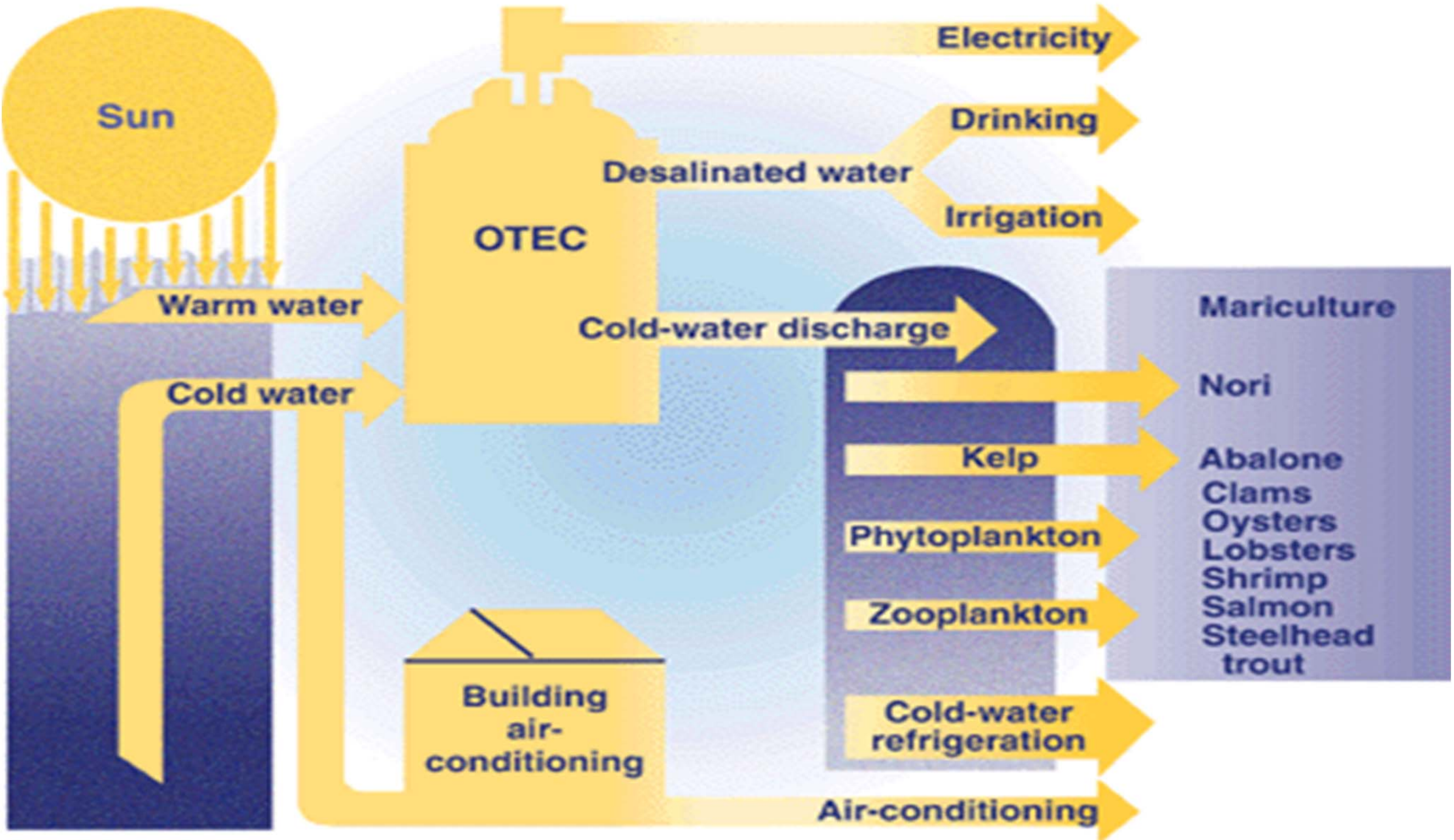
Multi-product Commercial OTEC Plant



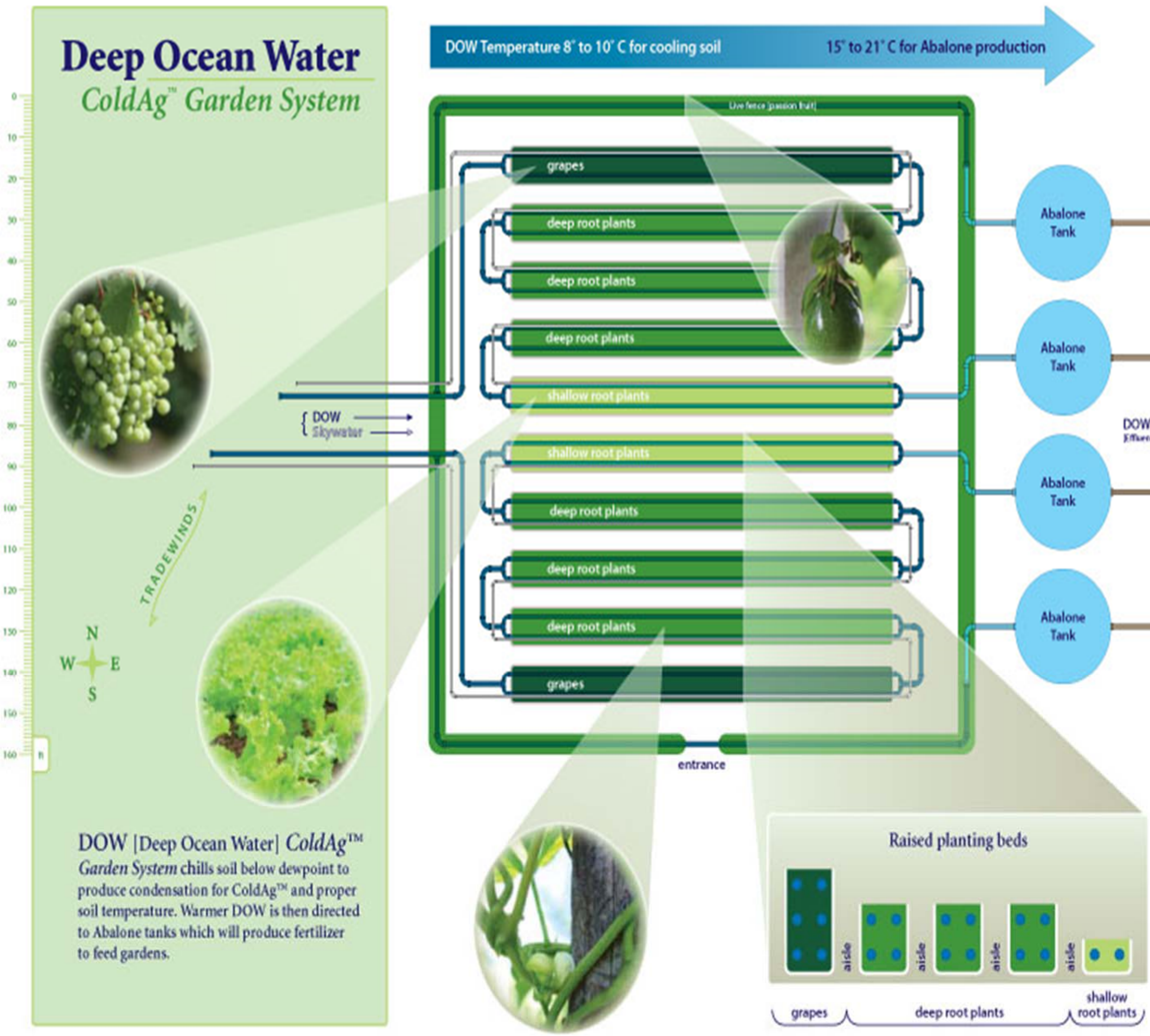
OTEC – Where Are We Now

- MARTINIQUE – DCNS/France (10 MW)
- CHINA / LOCKHEED MARTIN - TAIWAN (10 MW)
- PHILLIPPINES (10 MW)
- INDONESIA (10 MW)
- SMALL R/D – BLUERISE / LA REUNION / NELHA / JAPAN / KOREA

Seawater Systems Schematic

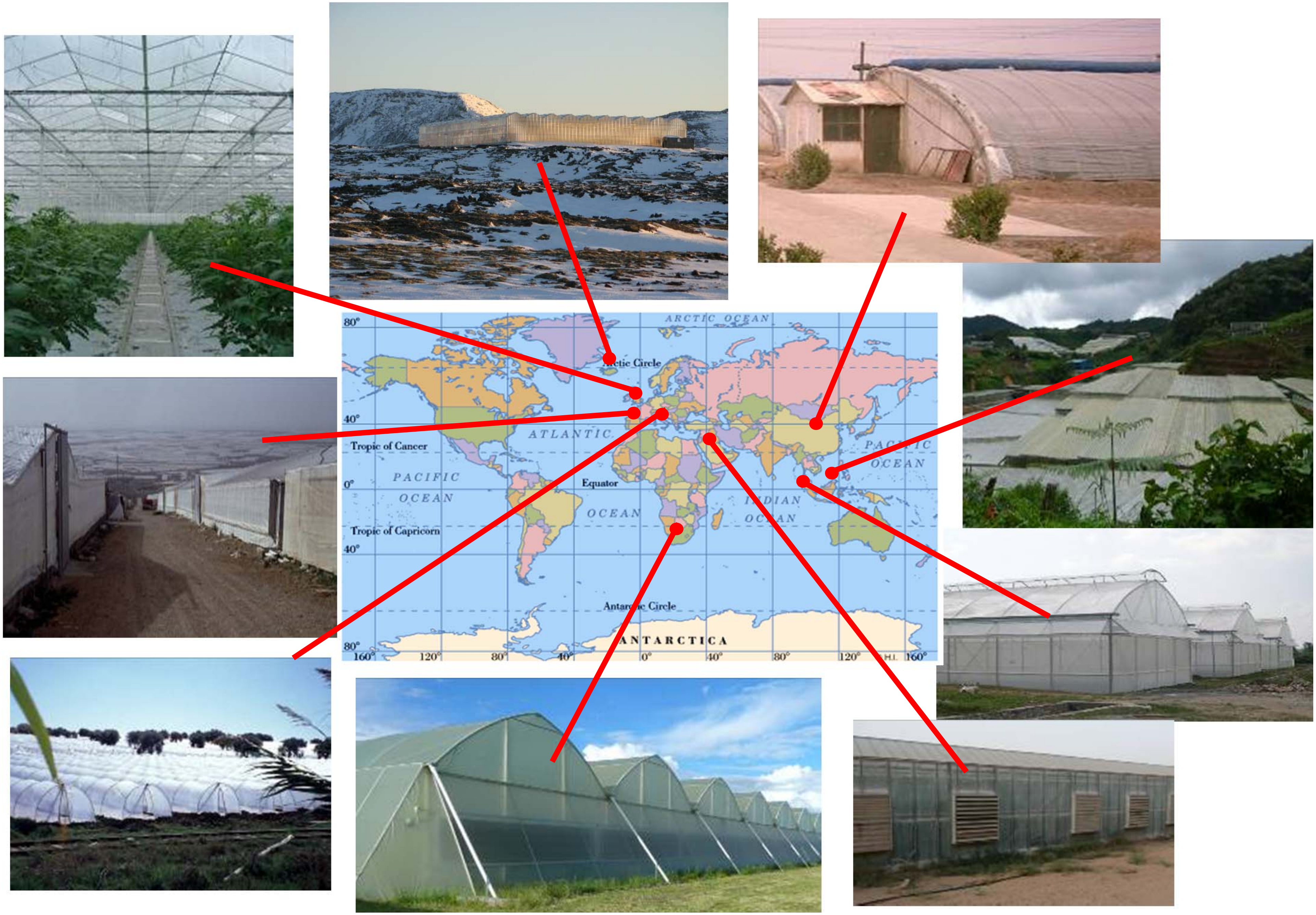


Deep Ocean Water Garden



Climate Controlled Greenhouses using DOW

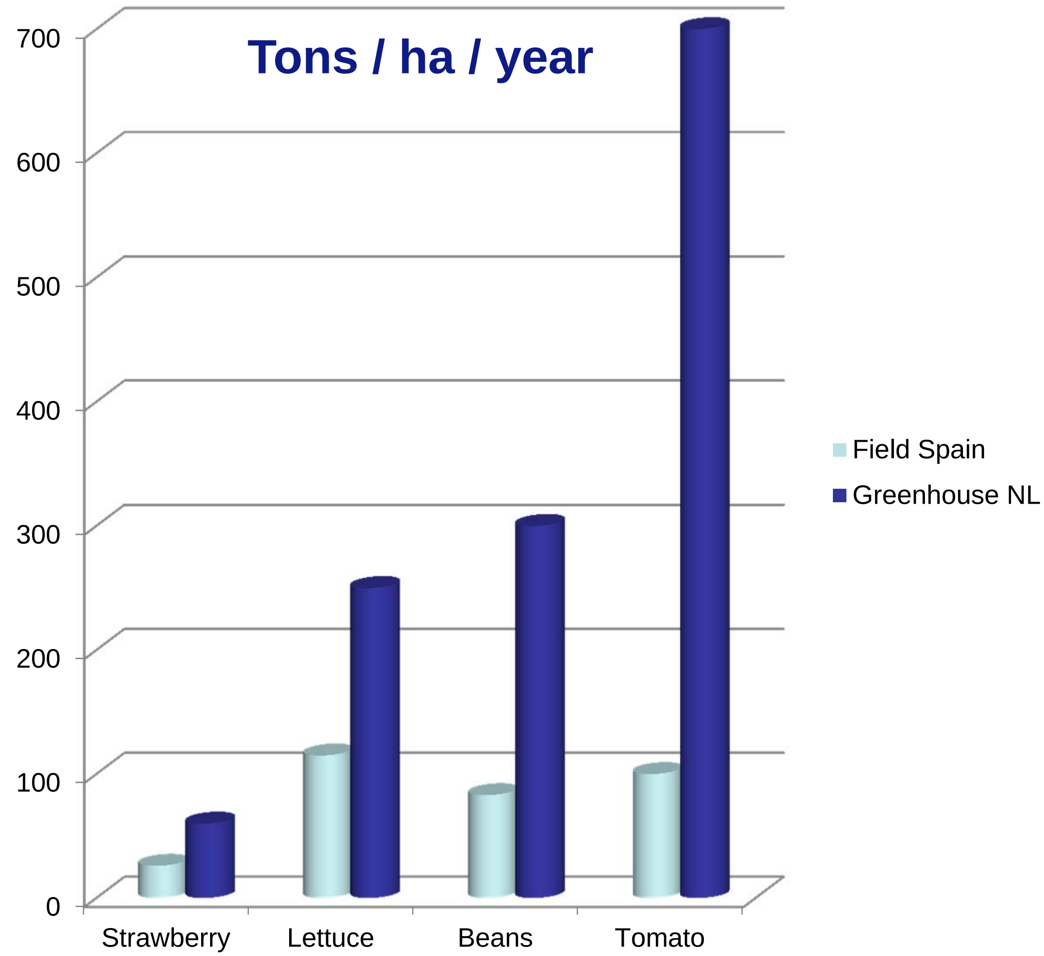
Green Houses are Adaptable to any Region



Greenhouse Performance is Superior to Outdoor Field Production

2–5 times higher yield than field grown, for crops from the same climatic zone

10–20 times higher yield for Mediterranean crops grown in cooler zones



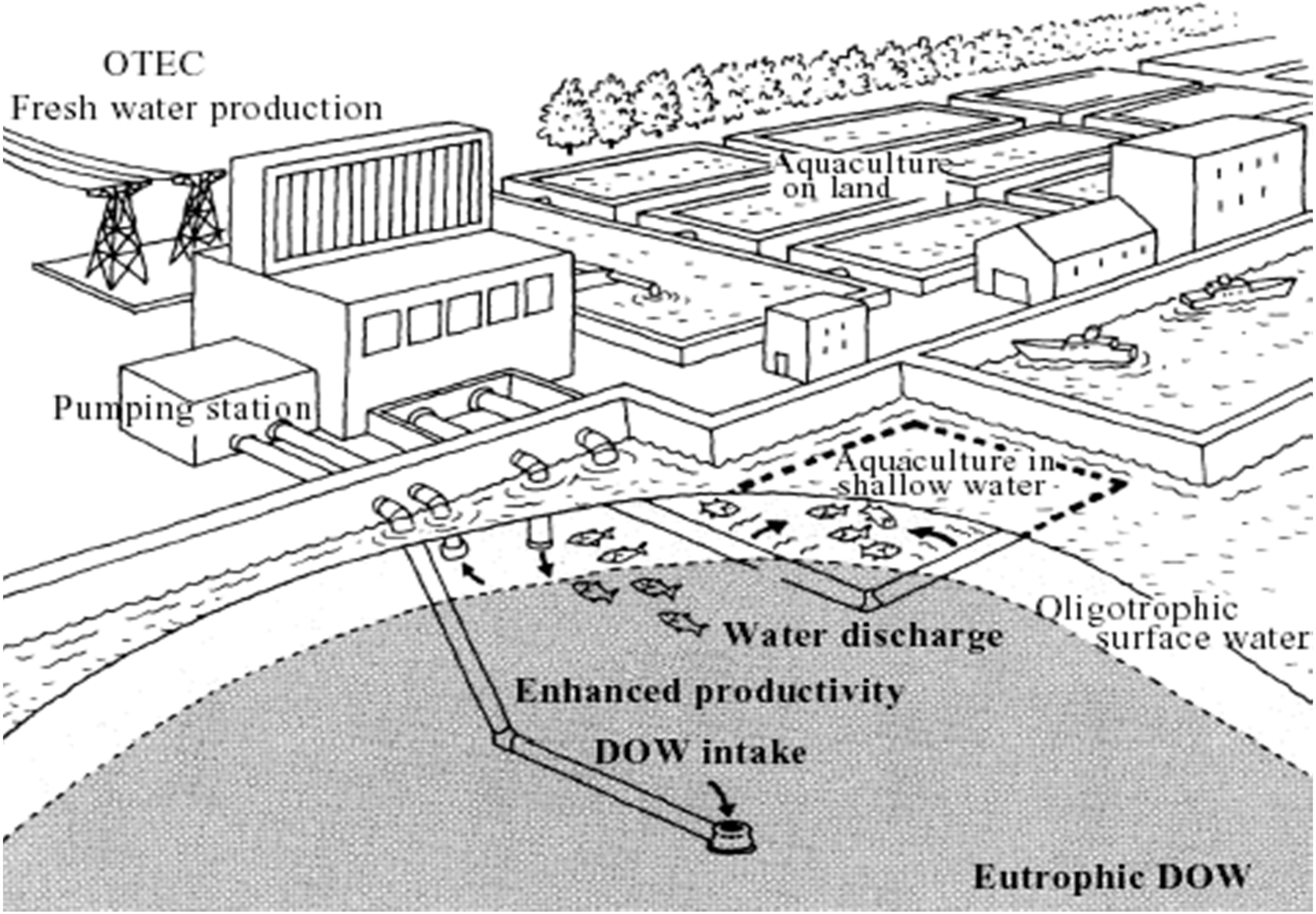
SECONDARY USES
OF
DEEP OCEAN WATER

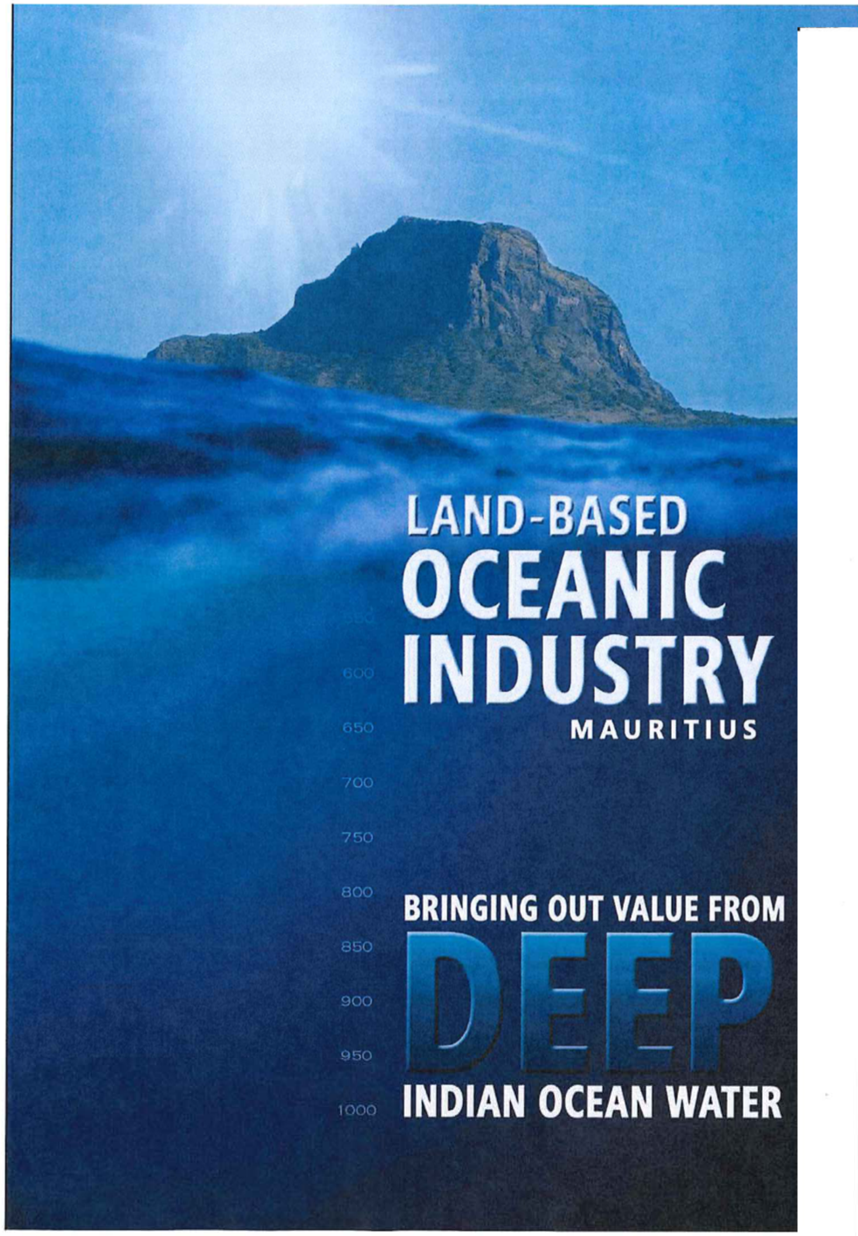
ECO-PARKS

(Niche Market Products)

Locations Interested or Operating NELHA Type "EcoParks"

- Republic of Mauritius
- Humboldt, California
- Reunion Island
- Martinique
- Japan
- Taiwan
- Korea
- China
- Curacao


OTEC
Fresh water production
Aquaculture on land
Pumping station
Aquaculture in shallow water
Oligotrophic surface water
Water discharge
Enhanced productivity
DOW intake
Eutrophic DOW



The proposed Land-based Oceanic Industry Complex is to be built on the southern coast of Mauritius.

A Unique Concept

Deep Ocean Water Application Research Center

Introduction

[Establishment of DOWARC (2001~2005)]

- Purpose: R&D of multi-purpose use of DOW
- Capability: 2,000ton/day of 300m/500m DOW
- Construction Period: '04.8 ~'05.12
- Location: 245-7 Oho-ri, Jukwang-myeon, GW
- Facility : SWAC, OTEC & NF-RO test etc.

[DOWARC Building & Facility]

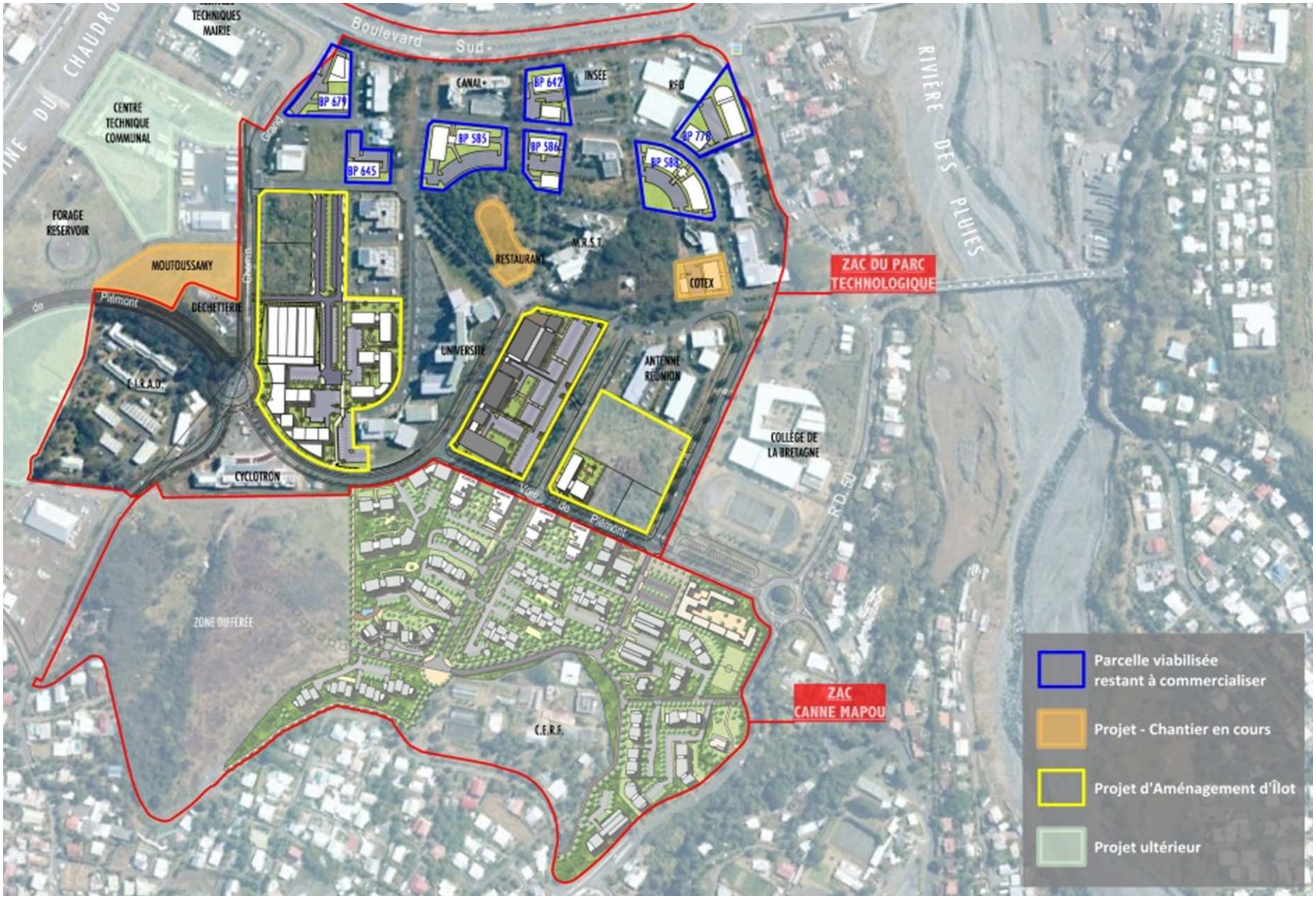
- Area 7,500m^2, Building 2,310m^2
- HQ Bd, SWE Bd, DESAL Bd, Aqua/Agri-CULT Bd, Exhibit. Hall

經濟部

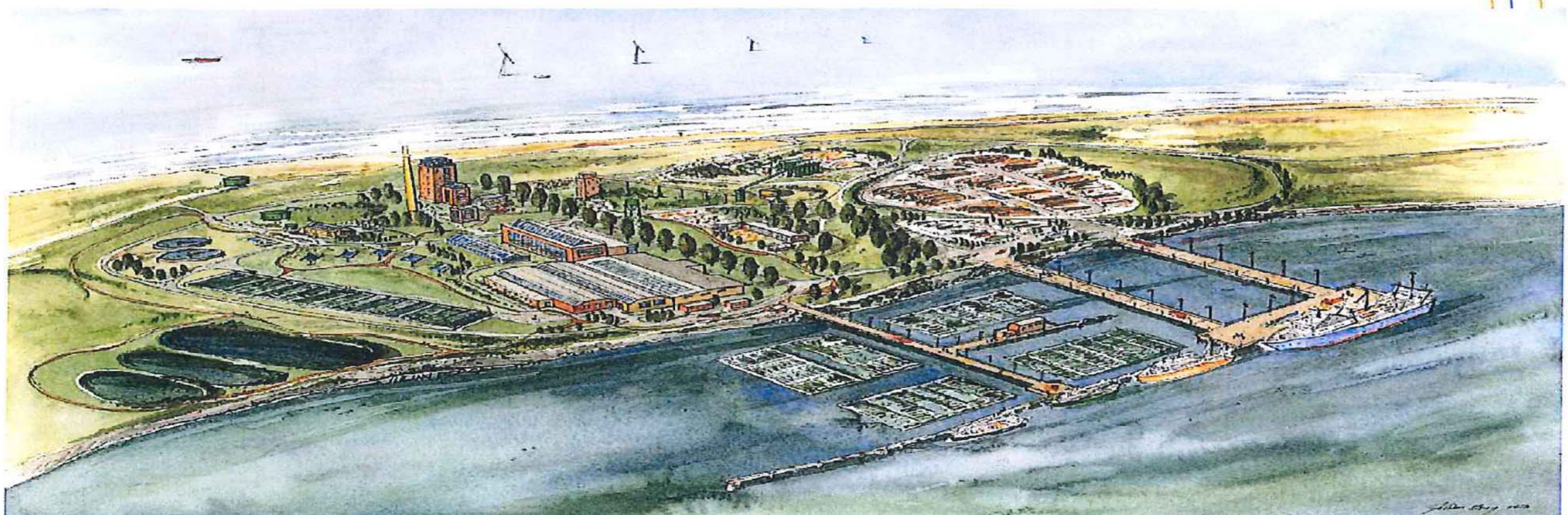
Deep Sea Water Development & Utilization in Taiwan

WRA, MOEA

ECOPARK PROPOSED FOR LA REUNION



The National Marine Research and Innovation Park



"If we want to make the best products, we also have to invest in the best ideas . . . Now is not the time to gut these job-creating investments in science and innovation. Now is the time to reach a level of research and development not seen since the height of the Space Race."
—President Barack Obama, State of the Union, February 2013

Humboldt Bay Harbor Recreation and Conservation District
Eureka, California

HUMBOLDT STATE UNIVERSITY Arcata, California

Conceptual Plan 1.1, March 2013

Most Promising Prospective EcoPark Industries

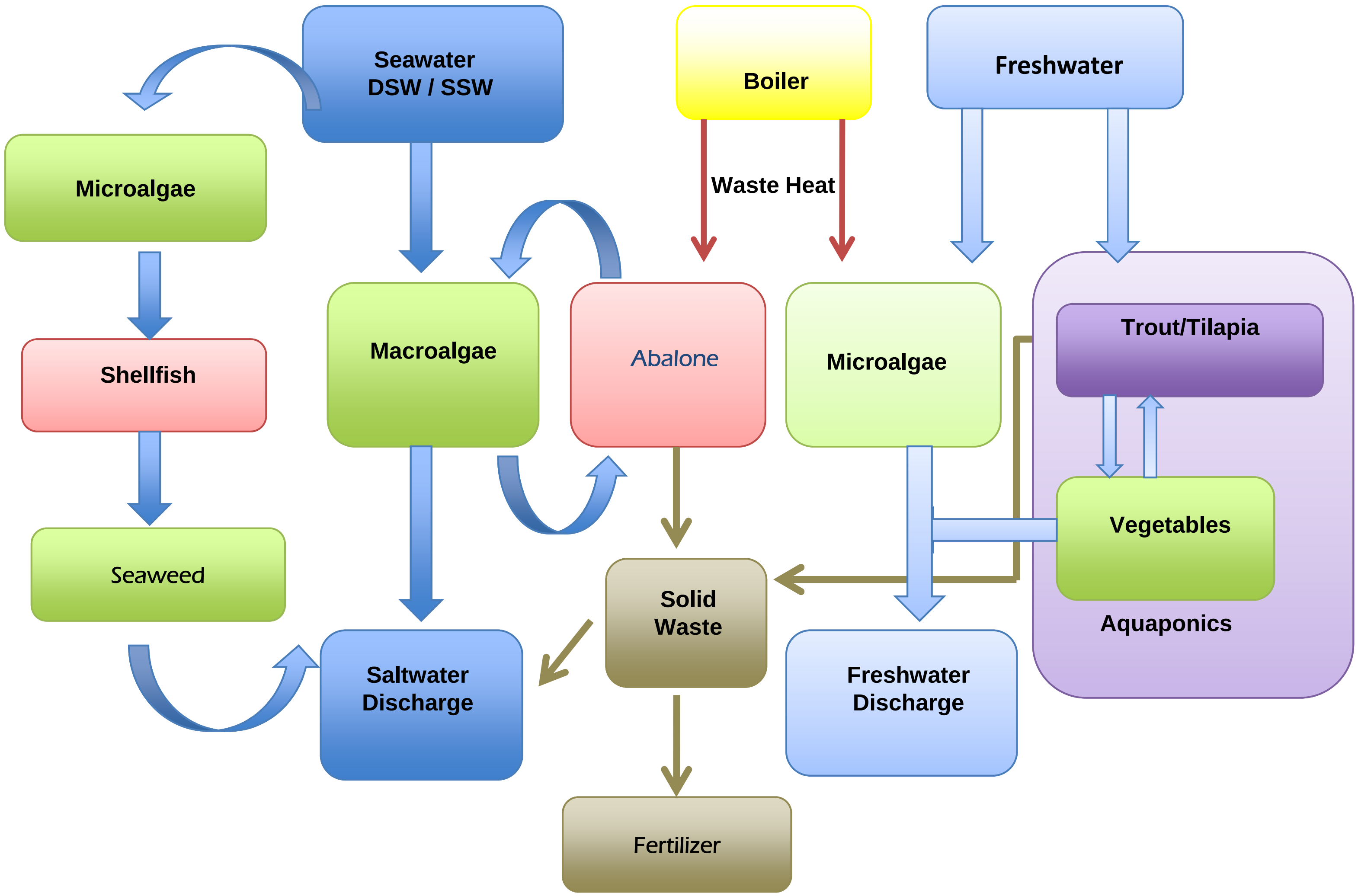
(Same as for DOW + SOW)

- SWAC
- SPACE COOLING / COLD STORAGE
- CLIMATE CONTROLED AGRICULTURE
- AQUACULTURE
- DESALINATION
- OTEC R&D (OTEC will be an Offshore Industry)

Complimentary EcoPark Prospects

- Waste to Energy / Reuse / Recycling (Heat Resource)
- Renewable Energy (Wind / Solar / Energy Storage)
- Cosmetics / Neutraceuticals
- Specialty Salts & Brine (Nigare)
- Spa / Health Centers / Thelasotherapy
- Visitor's Center / Aquarium / Restaurant
- Marine Science & Education Center
- Production of Biofuels / Energy Storage Devices
- Production of Electric Vehicles
- Precious Mineral Extraction

Cascading Eco-Systems Approach



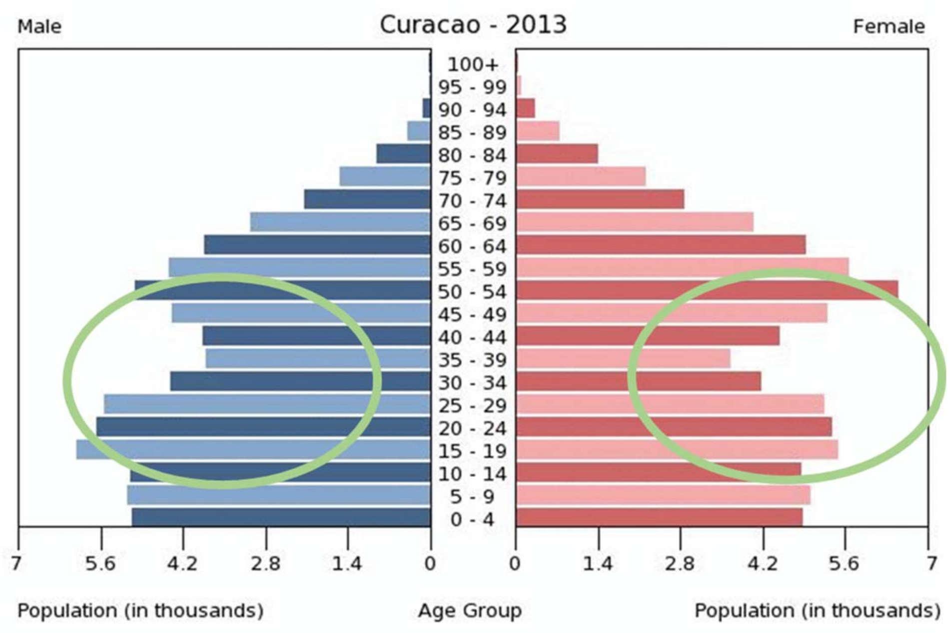
Island Nation Challenges

- Keep Electricity Costs Economical
- Reduce Dependence on Foreign Oil
- Maintain Reliability / Sustainability
- Manage Community and Environmental **Impact**




Island Nations Are Typically Economic "Brain Drains" for the Youth?

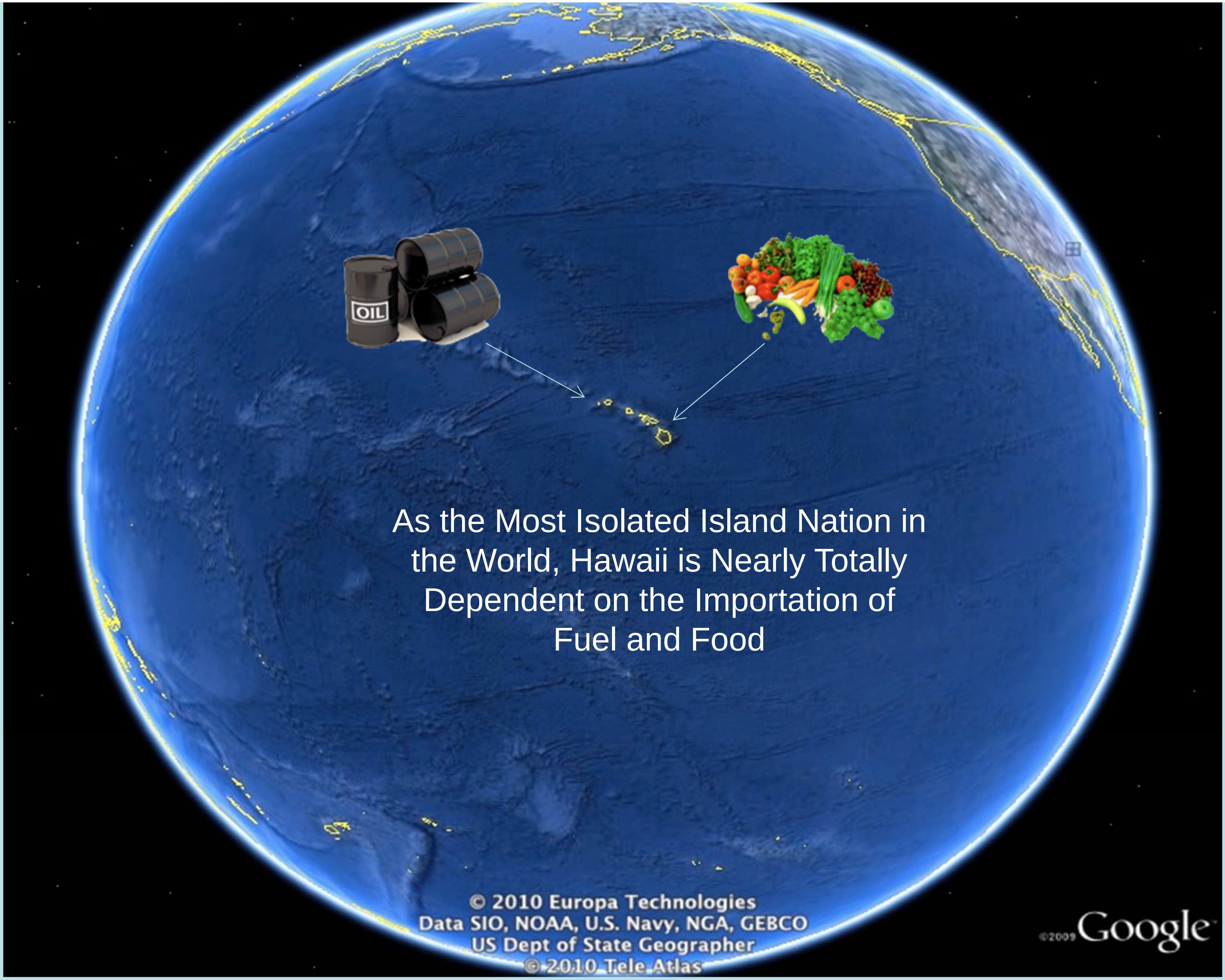
- Curacao - 13% Unemployment Sept/October 2013



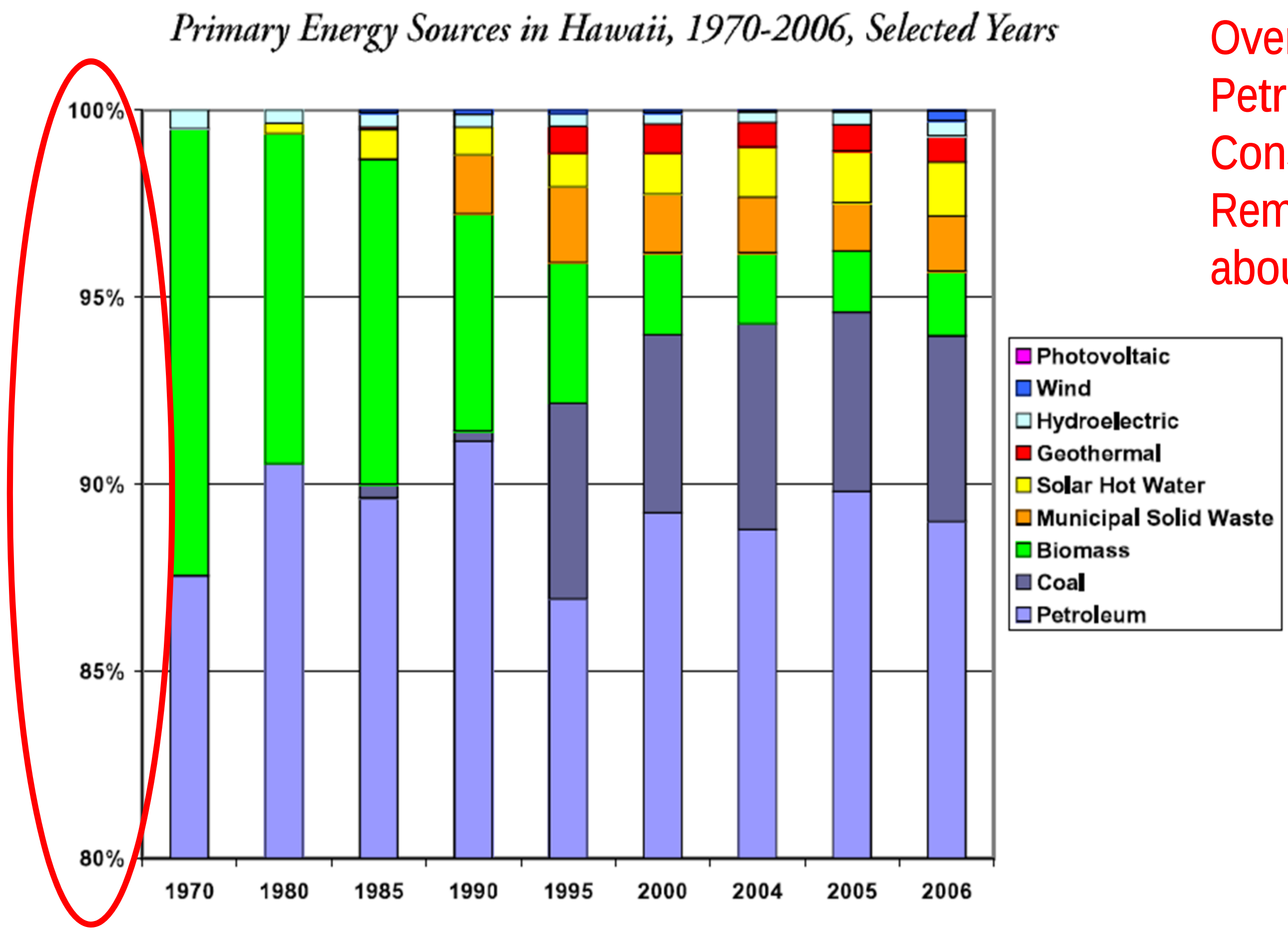
2.09 children born/woman (2013 est.)

DOW EcoParks Can Create Positive Changes For Island Economies

- Turn the Economic Brain Drain into a Brain Gain
- Creates New High Quality Job Opportunities
- Diversifies the Economy
- Creates Export Opportunities
- Provides Outside Investment Opportunities
- New Resources become Available to Produce Food, Improve Health Care and Energy Security
- Improves the Quality of Tourism


OIL
As the Most Isolated Island Nation in
the World, Hawaii is Nearly Totally
Dependent on the Importation of
Fuel and Food
© 2010 Europa Technologies
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
© 2010 Tele Atlas
Google

Hawaii's Historic Dependence on Fossil Fuels



Over 36 Years, Petroleum Consumption Remains at about 89%

$8.6 Billion Dollars is Spent Each Year in Hawaii to Import Foreign Oil

We simply must balance our demand for energy with our rapidly shrinking resources. By acting now we can control our future instead of letting the future control us" – Jimmy Carter (1979)

Hawaii's Clean Energy Initiative

The Goal of the Hawaii Clean Energy Initiative is to meet 70% of our Energy Needs by 2030

40% Renewables

30% Conservation

“Negawatt”

The Cheapest Watt of Energy is the One Never Used

- Conservation Initiatives are the Low Hanging Fruit – Easiest to Accomplish

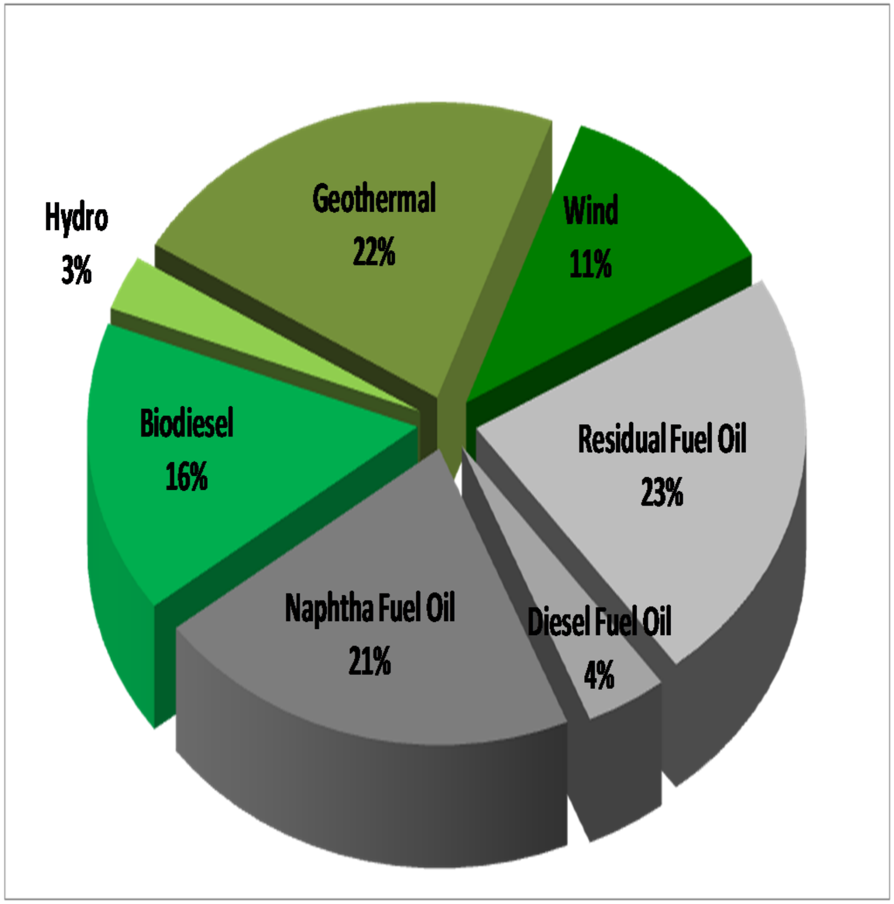
- Fastest-growing U.S. Energy Source (~2.5 - 3.5% / yr.)

- The U.S. Department of Energy estimates that Increasing Energy Efficiency throughout the economy could Cut National Energy use by 20% in 2020

- These Policies could Dramatically Lower U.S. Carbon Dioxide Emissions while Saving Consumers and Business $500 billion net during by 2020

There is Strength and Security in Diversity

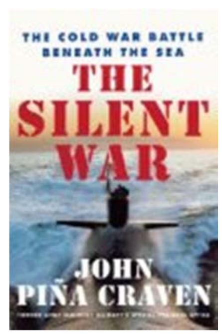
- Hawaii Island leads the State and Nation in Renewable Energy Use
- To Reach our Energy Goals, we Must Use a Diverse Mixture of Renewable Resources
- We cannot Rely on Just One Solution



Innovation is the Enemy of the Status Quo and it is only the Next Generation that can see Opportunities of Tomorrow and Apply Them Today

…..We are doing a lot of things all wrong

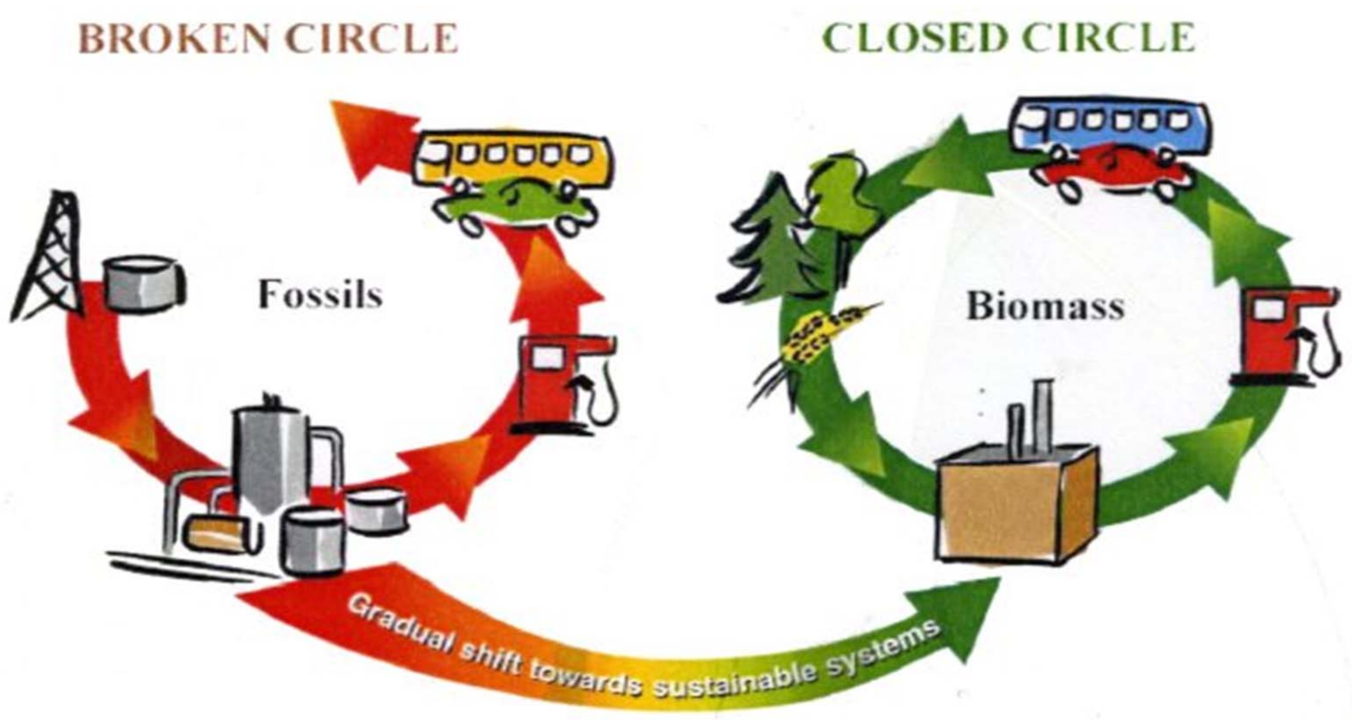
…..Sustainability is the key



Dr. John P. Craven

Founding Father of NELHA

WE MUST CONTINUE TO BREAK THE CIRCLE OF FOSSIL FUEL ADDICTION AND CLOSE THE CYCLE OF SUSTAINABLE RENEWABLES

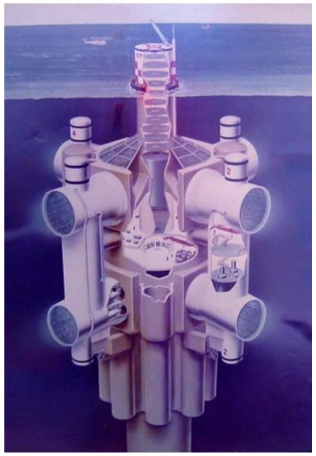


IN THE BALLGAME OF LIFE
MOTHER NATURE ALWAYS BATS LAST

SUMMARY

NELHA and its Tenants Contribute:

- New Products for Today
- New Technologies for Tomorrow
- New Employment Opportunities
- Economic Diversification for Hawaii



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