National Marine Renewable Energy Centers

Sustaining and Securing National Energy Needs with Water Power

-April 26, 2011-

OCEAN RENEWABLE ENERGY COALITION
The Marine and Hydrokinetic Energy Trade Association

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Oregon State UNIVERSITY OSU

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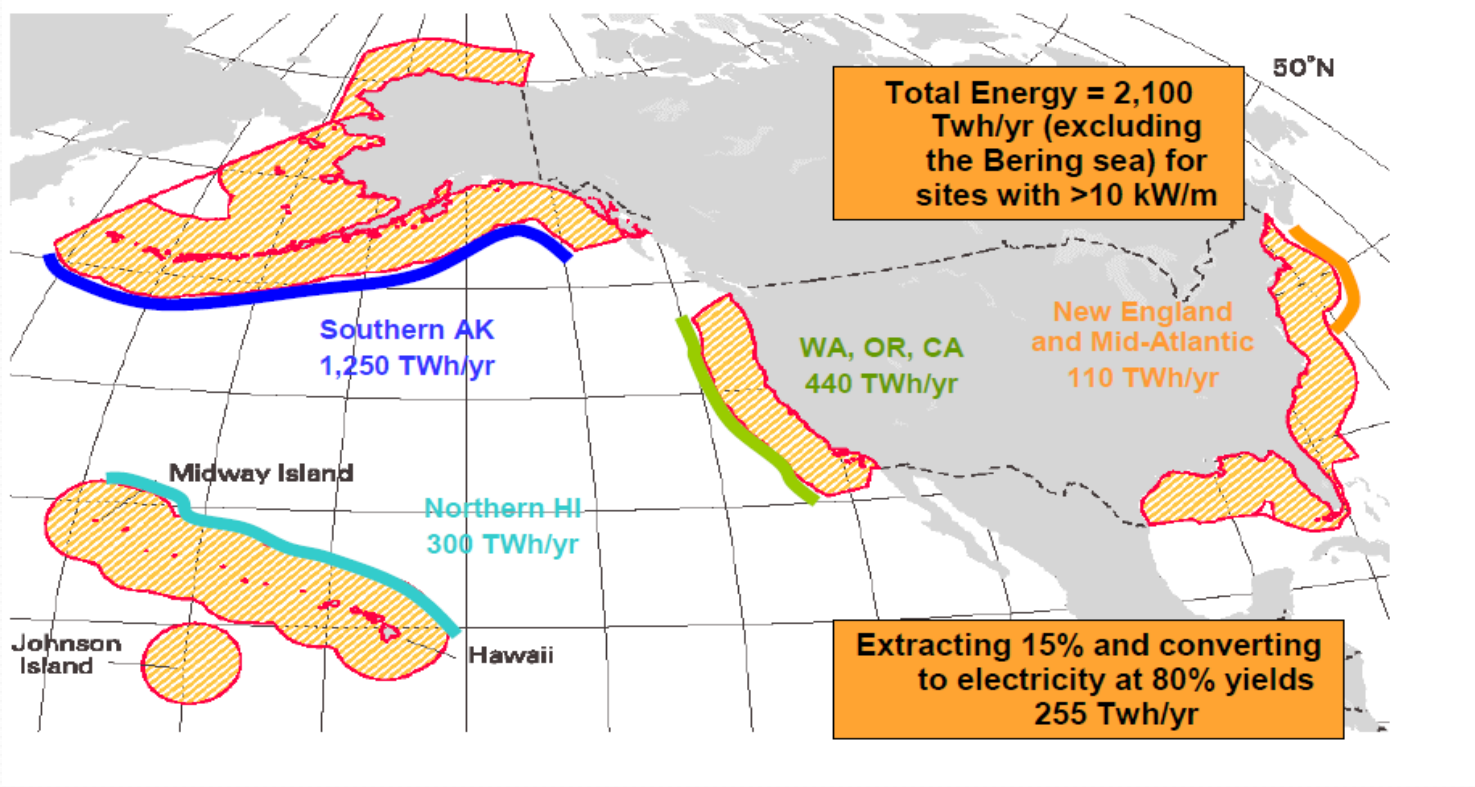
U.S. MHK Energy Potential

- EPRI estimates U.S. wave energy resource to be about 2,100 TWh/year.
- Tidal energy resource evaluated by EPRI is estimated at 114 TWh/yr with 6 TWh/yr at sites in the continental U.S. and the remaining 109 TWh/yr in Alaska.
- EPRI research suggests that ocean wave and in-stream tidal hydrokinetic energy resource energy production potential is equal to about **10% of present U.S. electricity consumption** (about 400 TWh/yr).



Testimony to U.S. Potential

"Since 1998, I have engaged in an effort to advance utility-scale power generation technology for both wave energy and ocean currents. Based on this engineering, we are targeting a cost of energy for both technologies in the range of $0.10 to $0.12/kWh by 2015, a level that should enable commercialization, provided the U.S. government implements an effective program of incentives for research, development, and deployment, that supports marine renewables more tangibly and consistently than the federal support for wind energy. Meaningful rates of deployment (several gigawatts/year) should come in the 2015-2020 timeframe in line with the forecast potential of ***23 GW by 2025****."*

–Remarks by James Dehlsen, Father of the U.S. Wind Industry, delivered to the House Committee on Science and Technology 12/3/2009

MHK Technologies

- **Wave Energy** can be captured from offshore, near shore, and shore based locations. It is driven by wind blowing over water creating waves from which energy is captured.
- **Tidal Energy** can be captured from the ebb and flow of tides, thus the tidal devices change orientation with the tide. It is driven by the gravity of the moon and sun and can be predicted efficiently (better than wind and solar technologies).
- **Current Energy** can capture the energy from moving ocean, tidal or river currents.
- **Ocean Thermal Energy Conversion (OTEC)** uses the ocean's natural thermal gradient to drive a power-producing cycle.

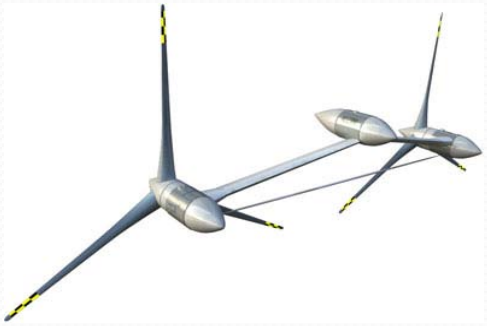
Wave Energy

Ocean Power Technologies
PowerBuoy

Tidal Energy

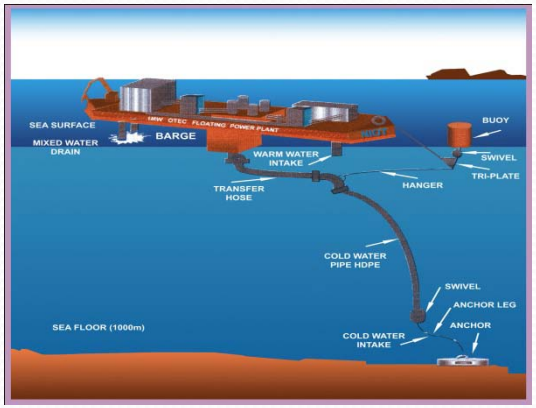
Verdant Power
Free Flow System Turbines

Current Energy



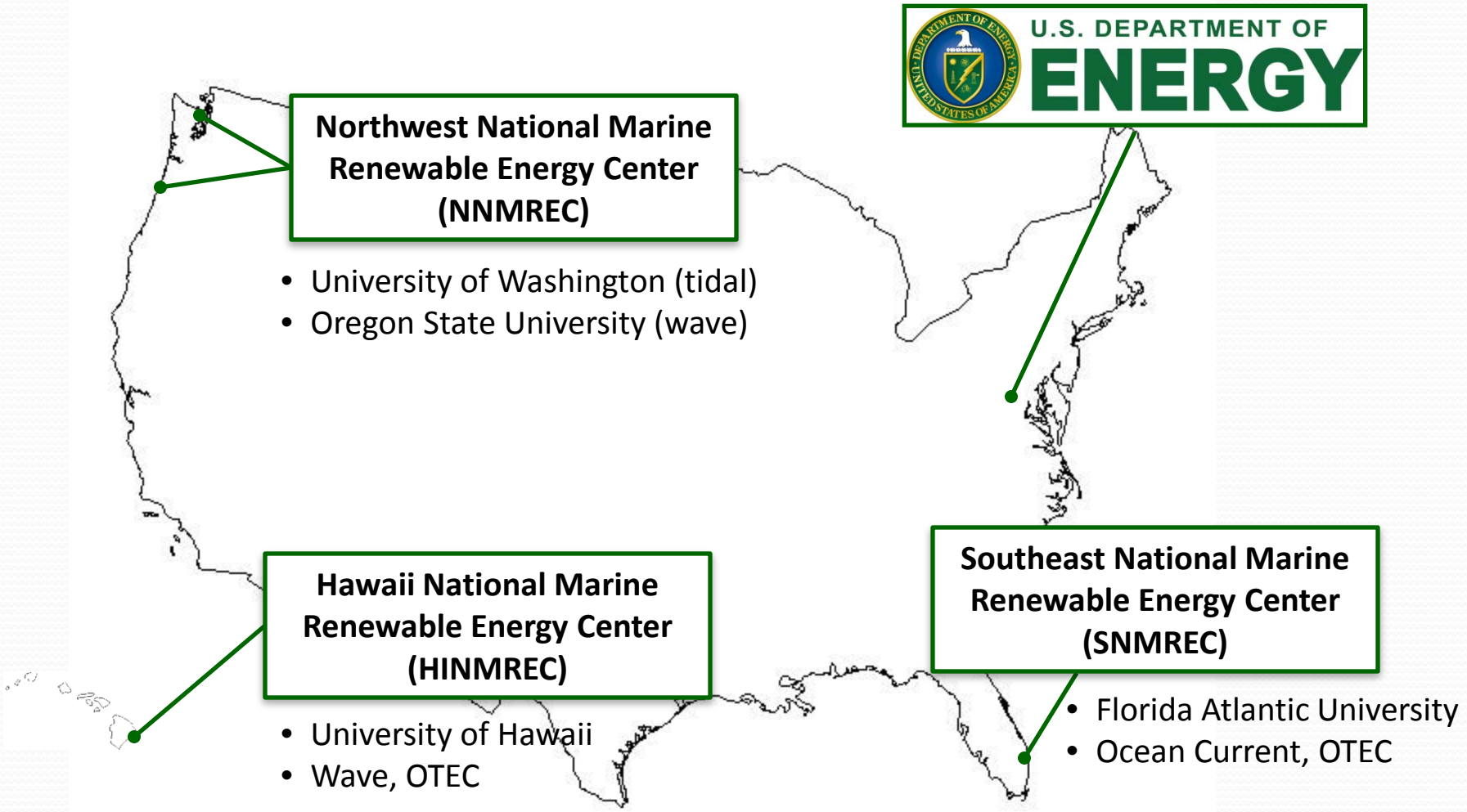
ECOMERIT - Aquantis
Gulf Stream CurrentTurbine

OTEC



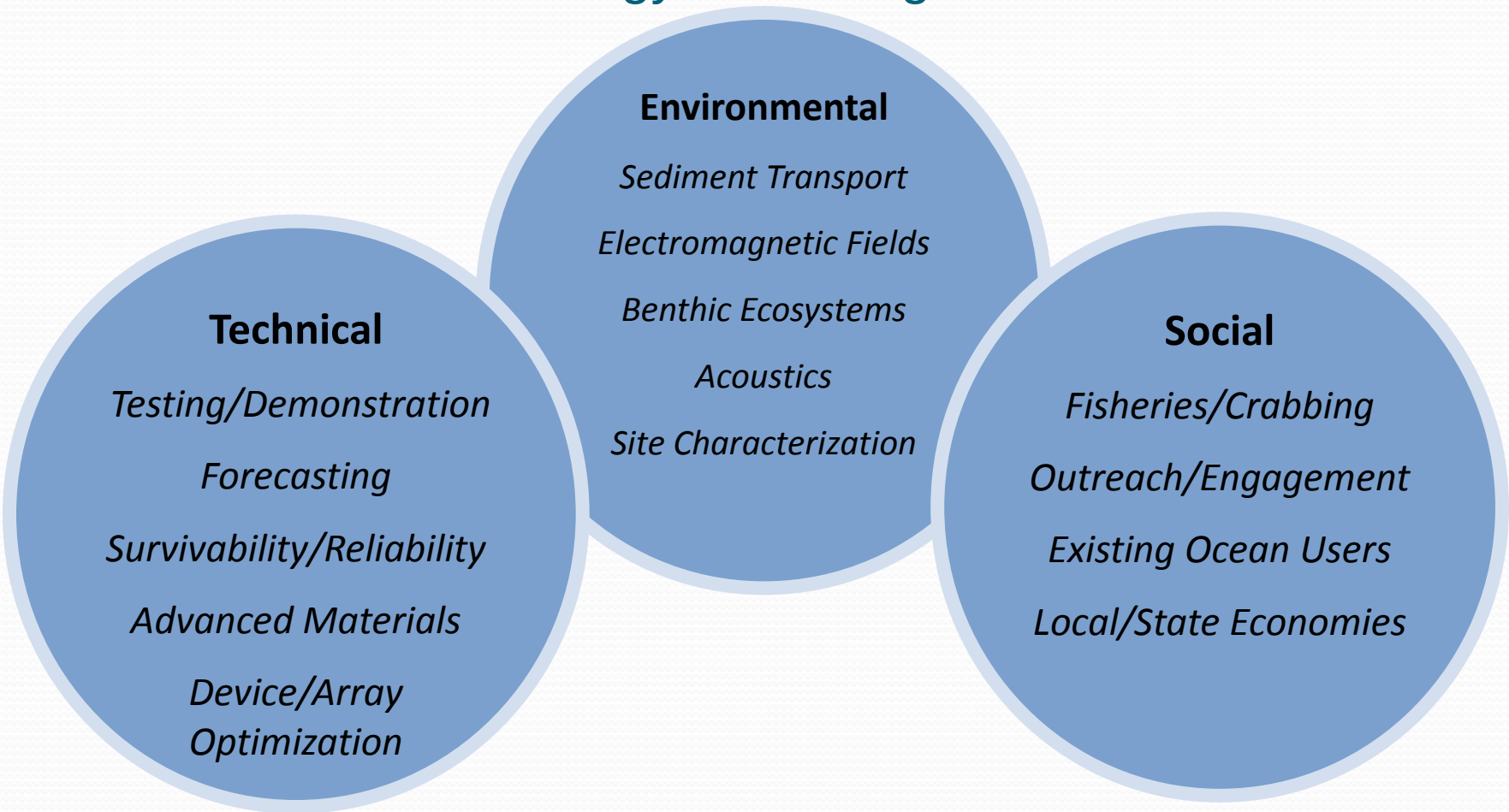
OTEC Design Model

National Marine Renewable Energy Centers



Moving the Industry Forward

MREC's focus is on the evaluation of marine renewable energy technologies



Northwest National Marine Renewable Energy Center

Robert Paasch, Director
Oregon State University

http://nnmrec.oregonstate.edu/

The Northwest National Marine Renewable Energy Center (NNMREC)

- A partnership between Oregon State University & the University of Washington funded by the U.S. Department of Energy
- Develop a full range of capabilities to support wave and tidal energy development
- Center activities are structured to:
  - Facilitate device development,
  - Inform regulatory and policy decisions,
  - Close key gaps in understanding,
  - Educate the first generation of marine renewable energy engineers and scientists.

Funding for NNMREC is provided by DOE, OSU, UW and multiple partners

OSU's Unique Capabilities – Wave Energy Research and Testing

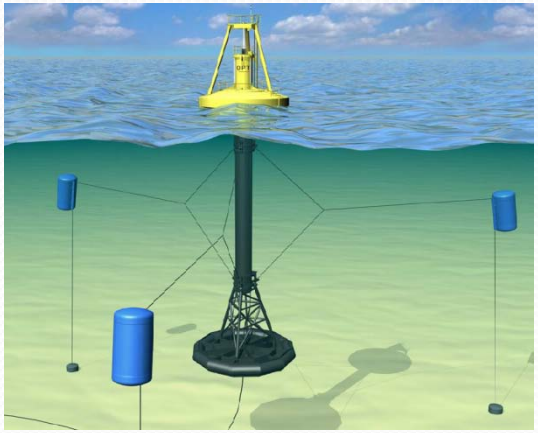
- Hatfield Marine Science Center, Newport, OR
  - Strong history, expertise in environmental studies and assessment
- Engagement of the coastal communities

- Cutting-edge research in breakthrough technologies necessary to advance the industry
- Unique wave testing facilities and permitted open-ocean testing facility (by end of 2011)

Oregon State University OSU

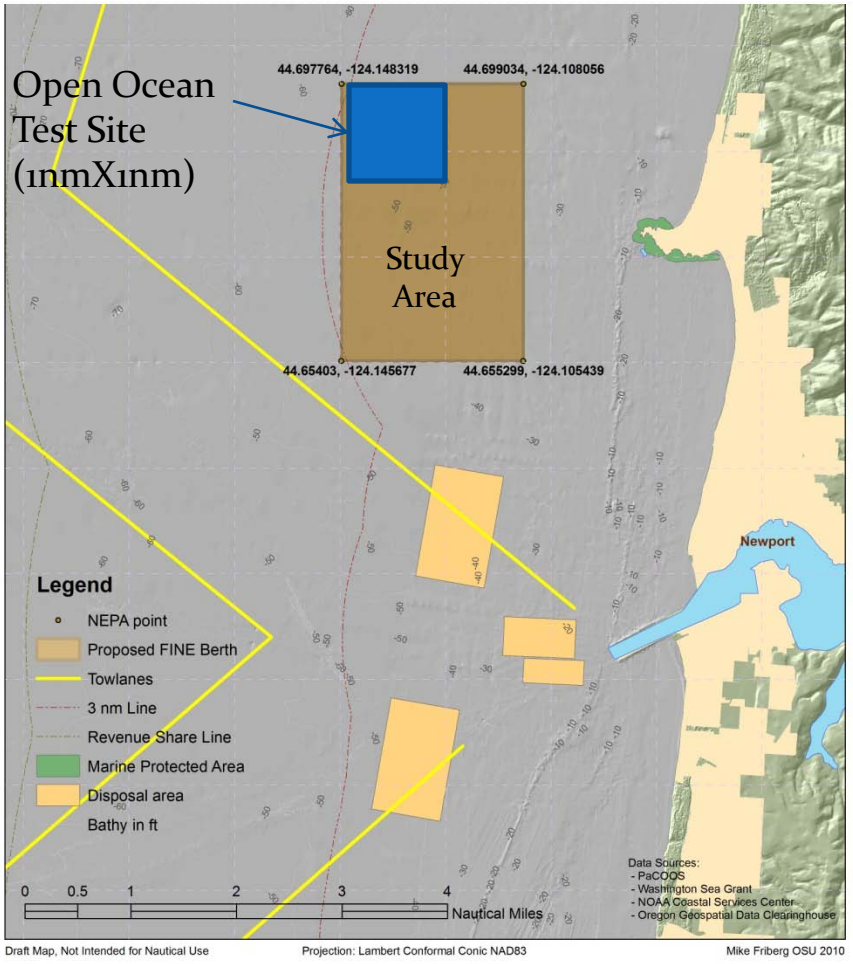
U.S. Need for Full Scale Wave Energy Test Facilities

- U.S. wave energy industry needs standardized testing to reach commercialization – the demand has been confirmed
  - Columbia Power Technologies
  - Ocean Power Technologies
  - Resolute Marine Power
  - Ecomerit (Dehlsen Associates)
  - M3 Wave Power LLC
  - Neptune Power
- Additional developers interested in Oregon
- 12 developers responded to PG&E's RFP



National Open-Ocean Wave Energy Test Facility

- Phase 1: Pre-Permitted Open-Ocean Marine Energy Test Site
- Capacity to test 150kW, or larger self-contained devices
- Operational Q4 2011
- Funded



National Open-Ocean Wave Energy Test Facility

- Phase 2: Grid Connected Test Facility
- Cable to shore allows minimum 2 WECs @ 1MW each.
- Pacific Northwest Wave Climate & Environment
- Cost to Construct: $15-$20M

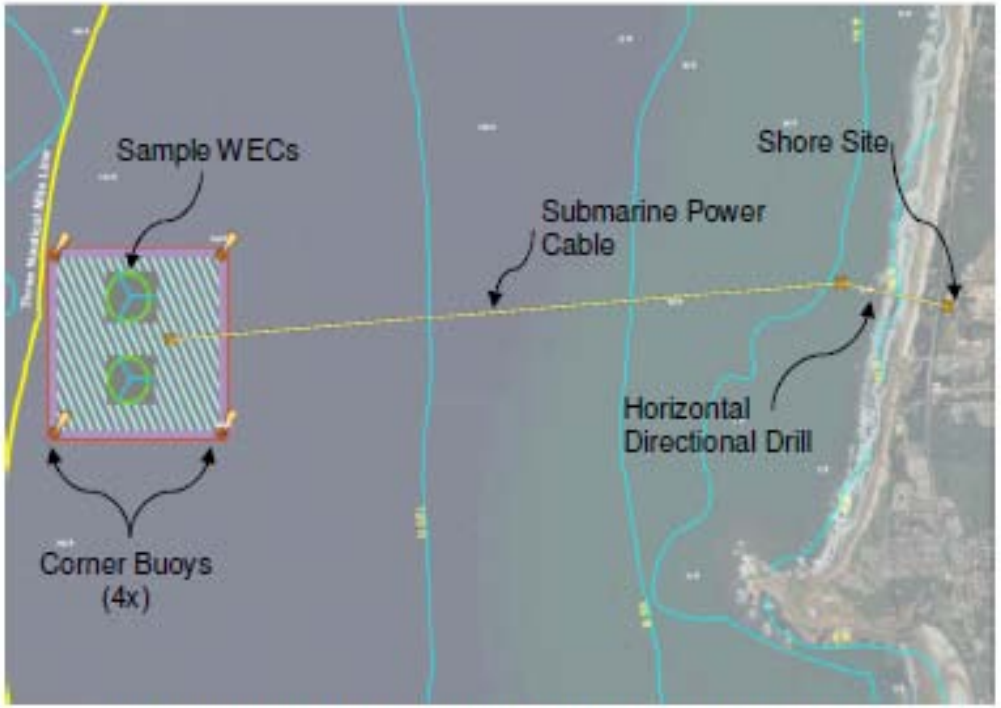


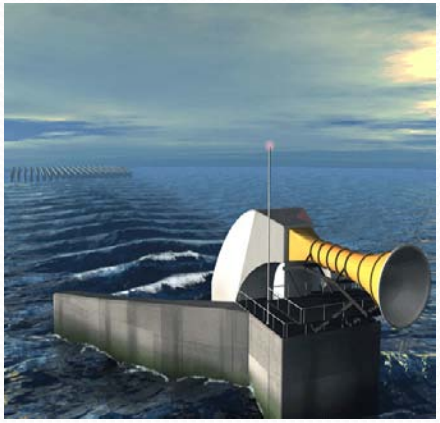
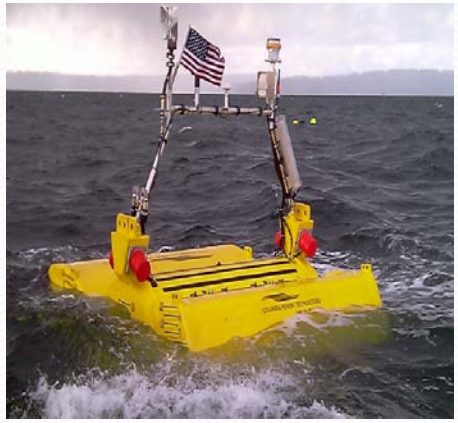
Figure 6 – Shore MOTB Concept, 1nm by 1nm Offshore Area

Oregon State University OSU

Why Oregon?

- The Oregon Coast has one of the best wave energy resources in the U.S.
- Oregon is the site of multiple proposed wave energy projects (Ocean Power Tech. Wavegen, Columbia Power Tech. Aquamarine Power).
- Portland and coastal areas have a work force trained and skilled in marine engineering and oceanography.
- Oregon has the required infrastructure and access to port facilities for wave energy device deployment.



Northwest National Marine Renewable Energy Center

Tidal Energy Test Facility

Brian Polagye
University of Washington

http://depts.washington.edu/nnmrec/

NNMREC – Tidal Energy Activities

Helping industry refine designs, optimize performance and, minimize environmental effects.

Resource and Site Assessment	System Optimization	Testing Capabilities	Environmental Monitoring
What are the conditions at tidal energy sites?	*What is the optimal design for tidal devices and arrays?*	*How can the benefits from testing be maximized?*	*How can impacts be mitigated?*

ORPC OCEAN RENEWABLE POWER COMPANY

BioSonics®

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

openhydro tidal technology

SMRU

Sound & Sea Technology engineering solutions

Sandia National Laboratories

Pacific Northwest NATIONAL LABORATORY

NREL

OAK RIDGE National Laboratory

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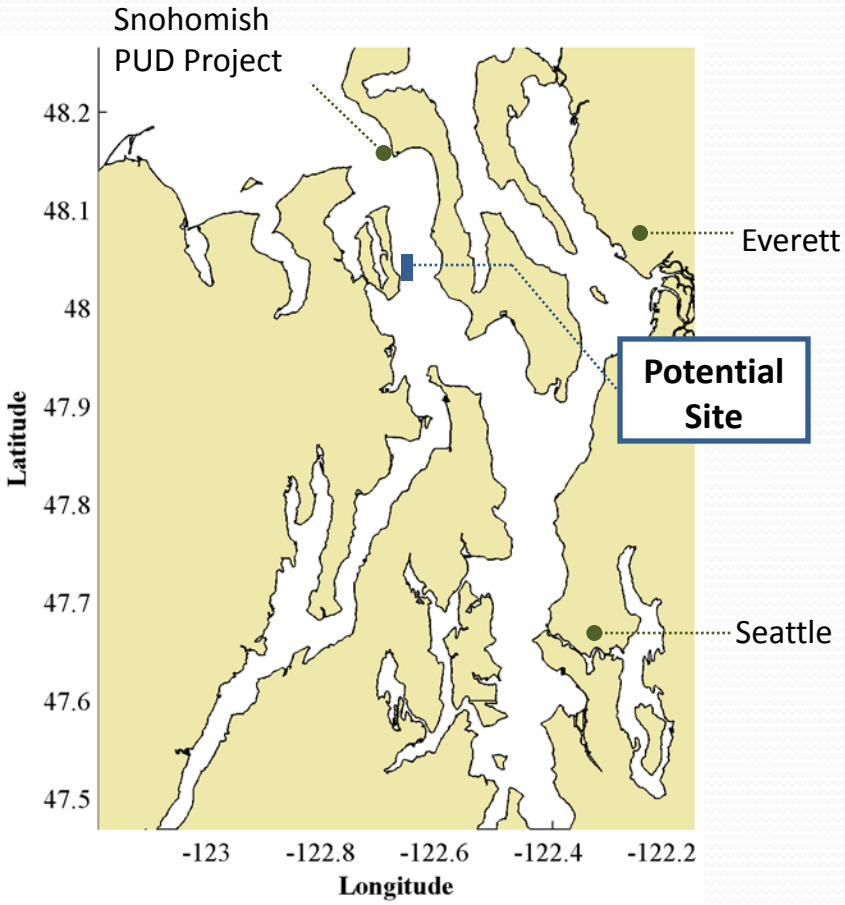
National Tidal Energy Test Facility

Provide developers with a dedicated test site and support commercial projects



- Test Facility takes on permitting and regulatory compliance, allowing developers to focus on technology innovation
- Three grid-connected berths, capable of testing a range of device scales and technical readiness levels
- Commercial-scale resource with a smooth transition from lab to field
- **Cost to construct: $15-$20 M**

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Benefits of a Tidal Energy Test Facility

- Provide a fully **instrumented and permitted platform** for testing tidal energy conversion devices.
- Provide **objective performance evaluations** of tidal energy devices in realistic conditions.
- Provide **comprehensive environmental monitoring** to study potential environmental effects of tidal energy conversion.
- **Accelerate commercialization** by reducing development cost and uncertainty.

Currently the 60+ US tidal energy developers are required to individually permit and install devices on a one-off basis

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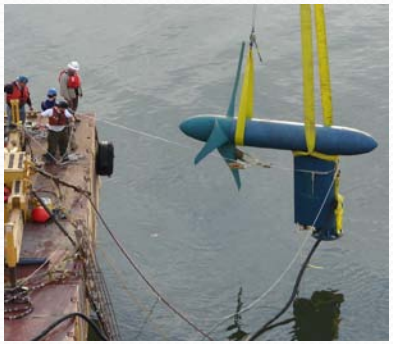
Why Puget Sound?

- Puget Sound has the best tidal energy resources in CONUS
- Puget Sound is the site of two tidal energy projects (Snohomish County PUD and Verdant Power)
  - These projects have had strong Congressional support
- The Puget Sound area has a work force trained and skilled in marine engineering, oceanography and environmental monitoring
- Puget Sound has the required infrastructure and easy access

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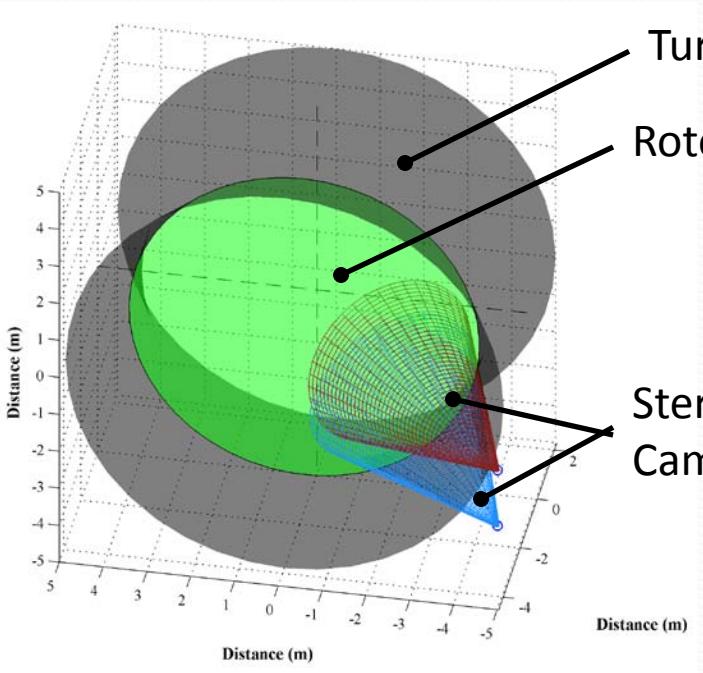
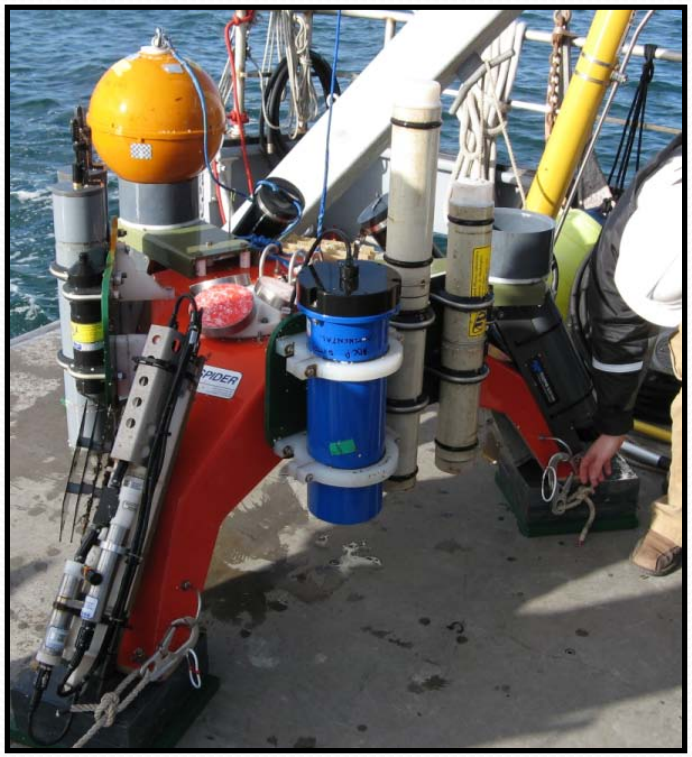
Leveraging NNMREC Capabilities

Working with industry and regulatory agencies to get projects in the water



Designing Cost-Effective Environmental Monitoring Systems

Site Characterization



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Southeast National Marine Renewable Energy Center

Camille Coley, J.D.
Florida Atlantic University

http://snmrec.fau.edu/

Southeast National Marine Renewable Energy Center

Identify and address technical, environmental, and socio-economic hurdles for competitive Marine Renewable Energy (MRE) commercial implementation

- Located in Southeast Florida near Gulf Stream (24/7 base-load renewable)
- MRE Focus Areas: **Ocean Current** and **Ocean Thermal Energy**

AQUANTIS

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

U.S. DEPARTMENT OF ENERGY

NREL

FLORIDA STATE UNIVERSITY 1851

ORPC OCEAN RENEWABLE POWER COMPANY

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

US Army Corps of Engineers

U.S. DEPARTMENT OF THE INTERIOR MARCH 3, 1849

DEPARTMENT OF THE NAVY UNITED STATES OF AMERICA

Virginia Tech

FPL

VERDANT POWER

LOCKHEED MARTIN

IOOS INTEGRATED OCEAN OBSERVING SYSTEM

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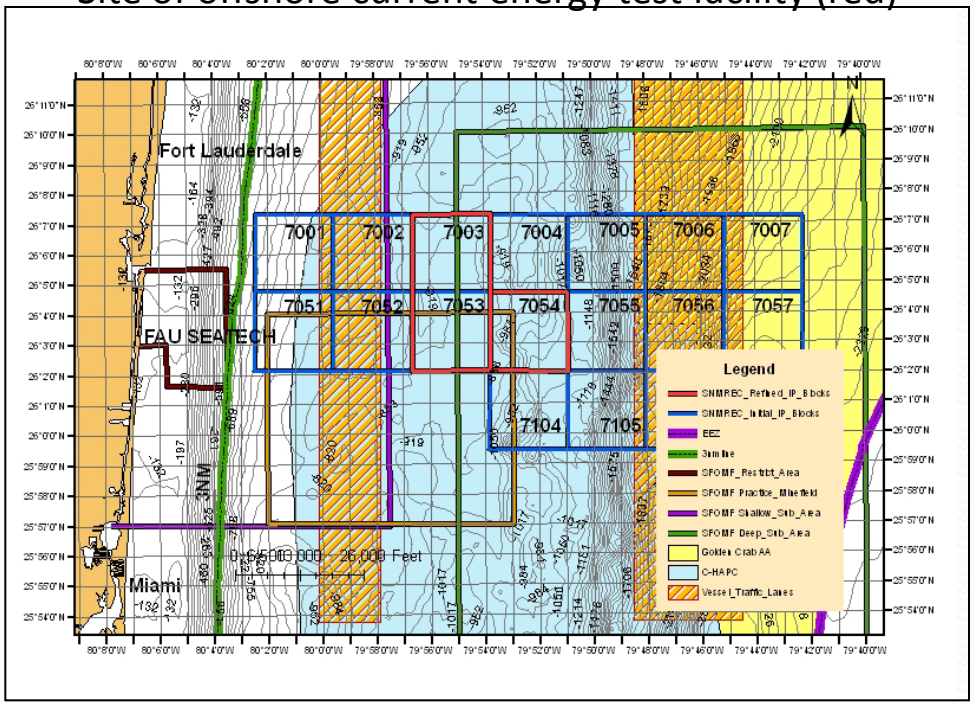
SNMREC Comprehensive System Approach

- Industry Technology Development Assistance
- Commercial Technology Testing and Optimization
- Standards Development
- Environmental Assessment
- Resource Characterization and Modeling
- Regulatory and Policy Input
- Public Outreach
- Education Programs and Workforce Training

Site of offshore current energy test facility (red)



Example: “mini” Coastal and Marine Spatial Planning effort that addresses broad spectrum of uses and external drivers

Research, Infrastructure Development, and Strategic Partnerships

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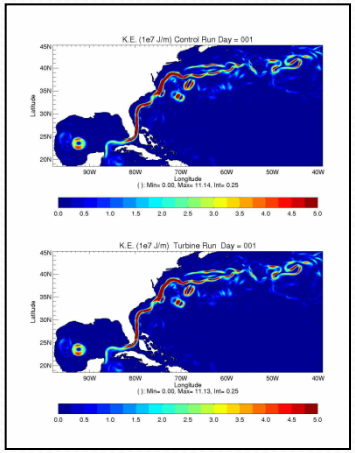
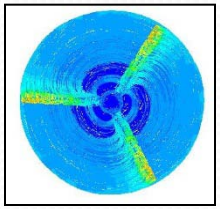
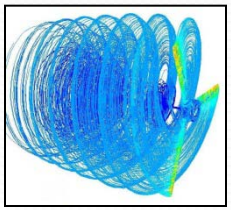
Achievements & Progress







- **Onshore test facility**
  (20kW-scale Dynamometer operating)
- **Offshore test berth buoy**
  (preliminary tow testing)
- **BOEMRE Application and Addendum**
  (1st OCS MHK lease under the Interim Policy)
- **High School Curriculum**
  (teacher workshops and developed materials)
- **Resource Measurement and Modeling**
  (ocean current and temperature profile data over 3 years)
- **Aerial Sea Turtle and Marine Mammal Surveys**
  (3 months of surveys)
- **National Public Discussions**
  (1st Industry Dialog and 1st International MRE Environmental Conference)
- **Fundamental Questions**
  (more than 3 dozen graduate-level research efforts)
- **Industry Partnerships**
  (more than two dozen agreements in place including international)

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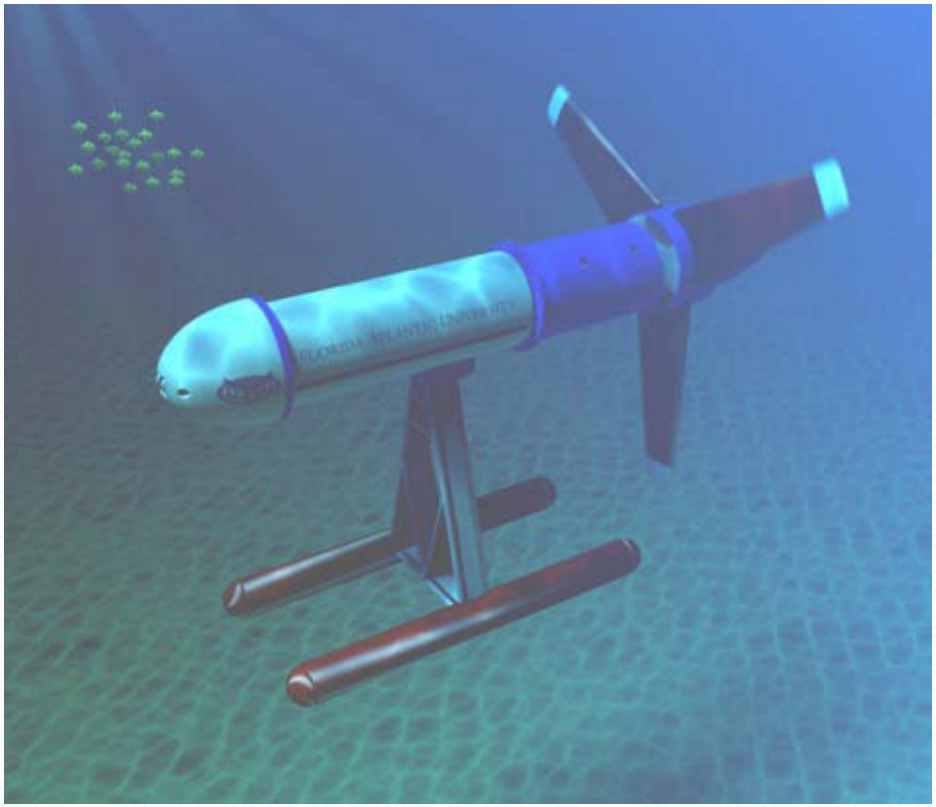
Future Programs and Needs

- **Expand commercial testing capability** for larger-scale devices and arrays, with grid-connected power to shore
- Build and maintain **a cabled scientific offshore observatory**
- Continue **gap-enabler development** like video aerial survey, intelligent sensor monitoring systems, and technology evaluation
- Expand **education and workforce training**
- Continue to provide **objective analysis, measurement, and modeling for policy-makers and industry**



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Commercial MRE Reality

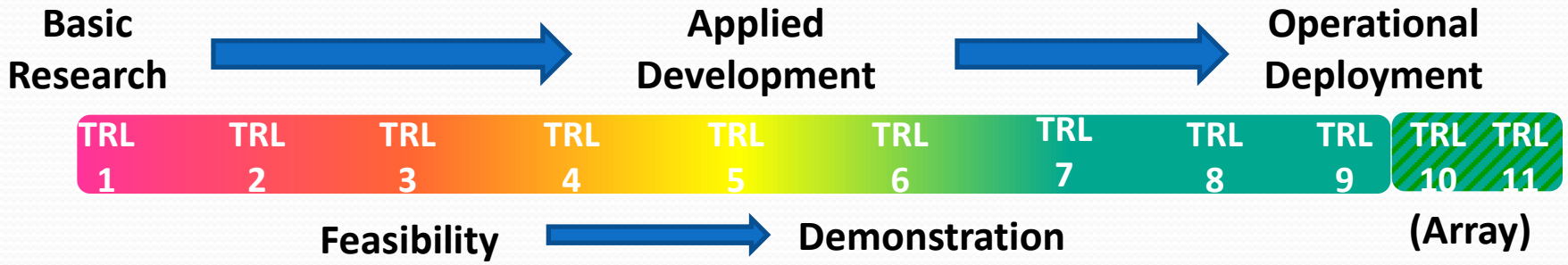
In order to anticipate and drive MRE development,
CONTINUED INVESTMENT NEEDED

Present Status:

Ocean current: TRL 1-4

Ocean thermal: TRL 4-6

Although state and federal support has been strong, in order to keep pace with industry development and energy needs, **a minimal $5M annual investment is necessary**.



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Hawaii Marine Renewable Energy Center

Dr. Richard Rocheleau
University of Hawaii

rochelea@hawaii.edu

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

Hawaii National Marine Renewable Energy Center

- **Facilitate testing and commercialization of wave energy Conversion (WEC) systems**
  - Multiple sites allow developers to test devices under a variety of environmental conditions
  - Environmental studies reduce permitting costs and delays;
  - Develop testing infrastructure and provide grid interconnection

OPT WEC Buoy

- **Leverage partnership with NAVFAC and ONR to facilitate Pre-commercial testing of Ocean Thermal Energy Conversion**
  - Environmental studies to understand impact of OTEC
  - Support developers in design, manufacturability, plant operations, licensing and permitting
- **UH modeling, analysis, and testing support industry needs**
- **U.S. Department of Energy Support:**
  - $1 million per year for 5 years with equivalent costs share provided by UH and industry partners

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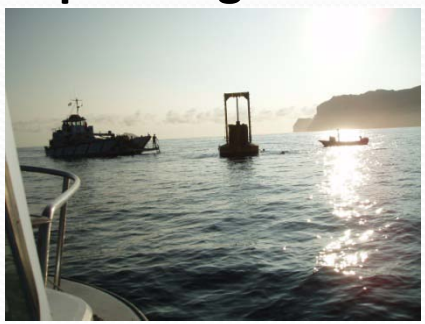
Hawaii Wave Energy Test Site

- **HI NMREC goal is to develop flexible, multi-hub wave energy test site at Marine Corps Base Hawaii**
  - Expand ongoing grid-connected testing funded by NavFAC
  - Develop pre-permitted in-water test facility with year-round access for timely deployment, maintenance, and device retrieval
  - Collaborate with NavFAC and base personnel to develop permitting and grid connected infrastructure
  - UH faculty support via wave resource models, mooring protocols, environmental studies, and design support
  - Strong interest from many developers: Ocean Power Technologies, Wavebob, BioPower Systems, Columbia Power Technologies, Natural Power Concepts, Ocean Energy, Oceanlinx, Protean Energy, Resolute Marine Energy
- **Requires funding of $6 to $9 million plus annual operating costs**

MCBH Test Site

Installation of OPT WEC



OPT WEC installed at MCBH

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Ocean Thermal Energy Conversion (OTEC)

- **Uses temperature difference between warm surface water and cold deep water (1,000m) to generate electricity with heat engine;**
- **Electricity generation and simultaneous desalinated water production has been demonstrated in Hawaii at experimental scale (~ 250kW);**
- **Economic models indicate scale of > 50 MW needed to be economically viable;**
- **Near term industry needs:**
  - Low cost manufacture and long-term testing of critical components, e.g. heat exchangers and deep water pipe systems;
  - Evaluation of potential local and global environmental impact of OTEC plants – uses large volumes of warm and cold water;
  - Deployment and testing of a pre-commercial OTEC plant (5 to 10 MW) to determine realistic costs, survivability, and environmental impact;
  - Sustained and substantial government support through pre-commercial demonstration.

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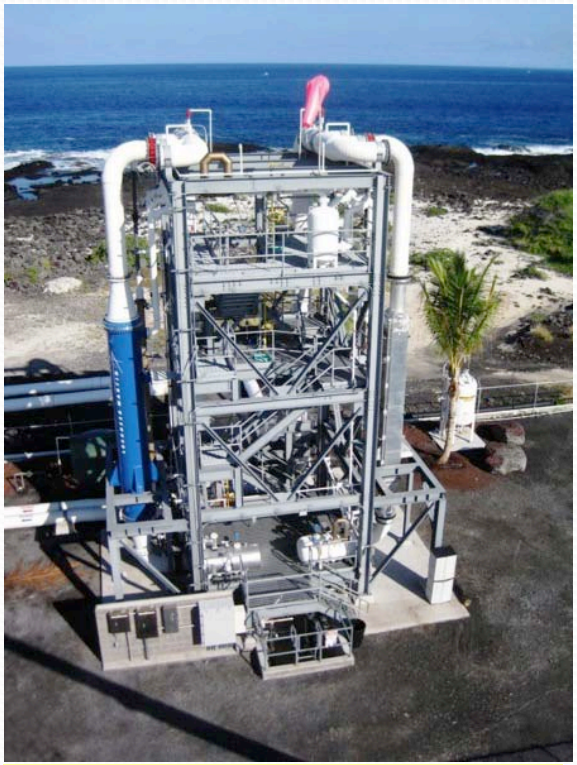
Hawaii OTEC Activities

- **UH Support**
  - ✓ Corrosion and biocorrosion studies of materials
  - ✓ Advising developers on design, manufacturability, plant operations, and licensing & permitting;
  - ✓ Modeling OTEC water intake and discharge characteristics, plant spacing, and degradation and global sustainability of resource;
  - ✓ Documenting baseline oceanographic conditions as input to EIS at potential deployment sites
- **Testing- Leveraging ONR/NavFAC funding for testing of pre-commercial heat exchangers support by Makai Ocean Engineering at NELHA (Big Island)**



Makai Ocean Engineering Heat Exchanger Test Rig at NELHA Facility

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Program Needs

Challenges

- DoE funding sufficient for analysis but not sufficient to support critical in-water testing;
- Delays with permitting and licensing jeopardizes company ability to secure financing;
- Government (USDOE) funding of technology development not coordinated with center activities to optimize government investment in the three Marine Centers;
- *USDOE NEPA Compliance Authorization* introduces costly delays in projects, e.g., one-year was required for routine Bathymetric Survey; and,
- WEC developers tend to be enthusiastic but undercapitalized – Center support valuable

Center Support (WEC and OTEC)

- Secure ~ $9M DoD/DoE funding to implement pre-permitted Wave Energy Test Site (WETS);
- $2M/year for ongoing UH center operations including test support.

Industry Support (WEC and OTEC)

- Secure multiyear government funding to develop USA WEC Industry over 5 to 10 years leading to a world market and capturing jobs and investment;
- Multi-agency funding to implement OTEC pilot demonstration.

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U.S./U.K. Wave & Tidal Energy Support

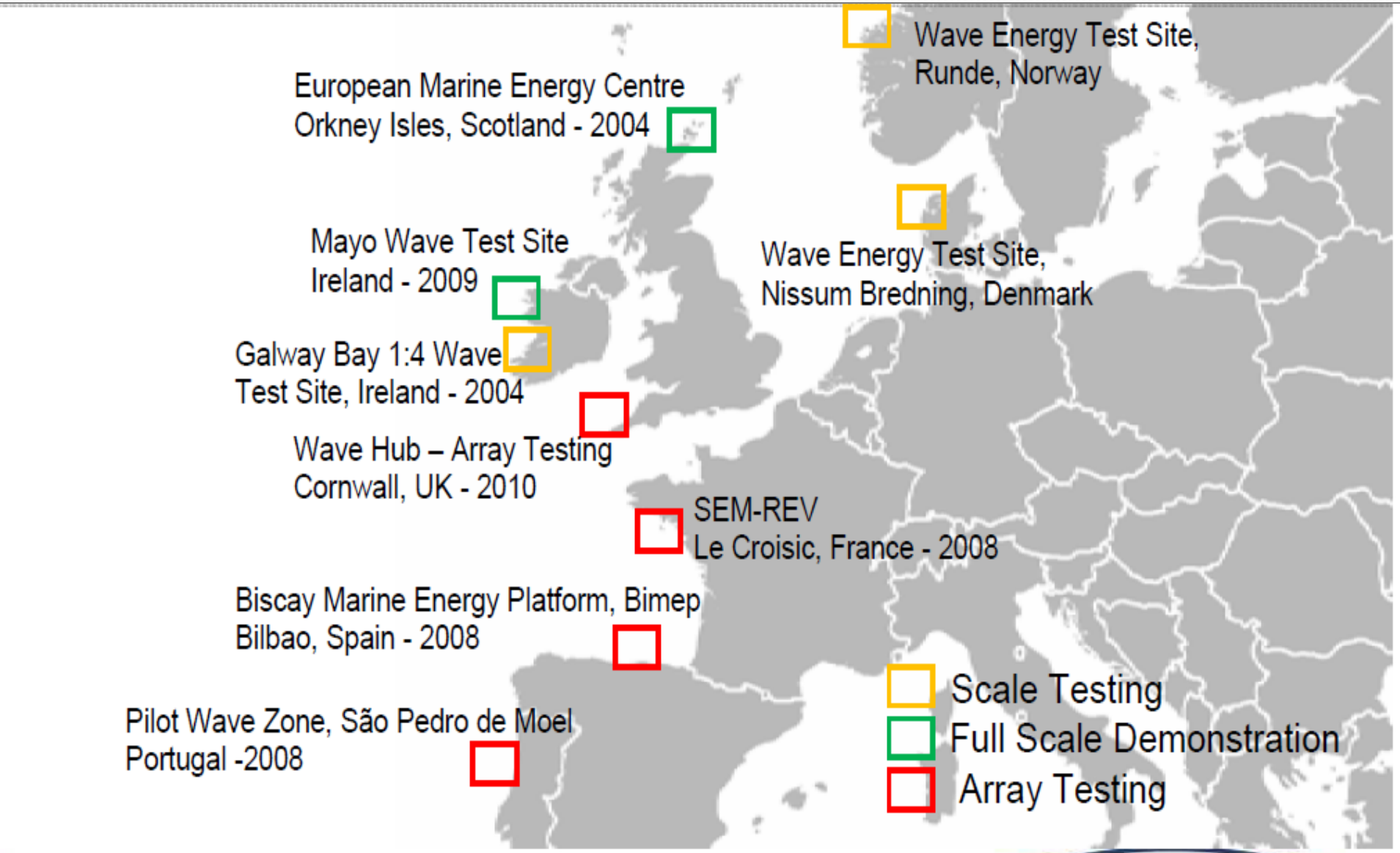
U.S. Government Support

- Govt. target of 7.5% by 2013, no ntl. target
- $82M appropriated for water power up to 2009 (includes conventional hydro)
- $50M announced for FY2010. FY11 is TBD.
- FY12 PBR is $38.5M
- Adaptive management fund to pay for environmental studies, not yet enacted
- PTC & accelerated depreciation credit – lacks parity with other renewables
- National test centers designated, no established infrastructure

U.K. Government Support

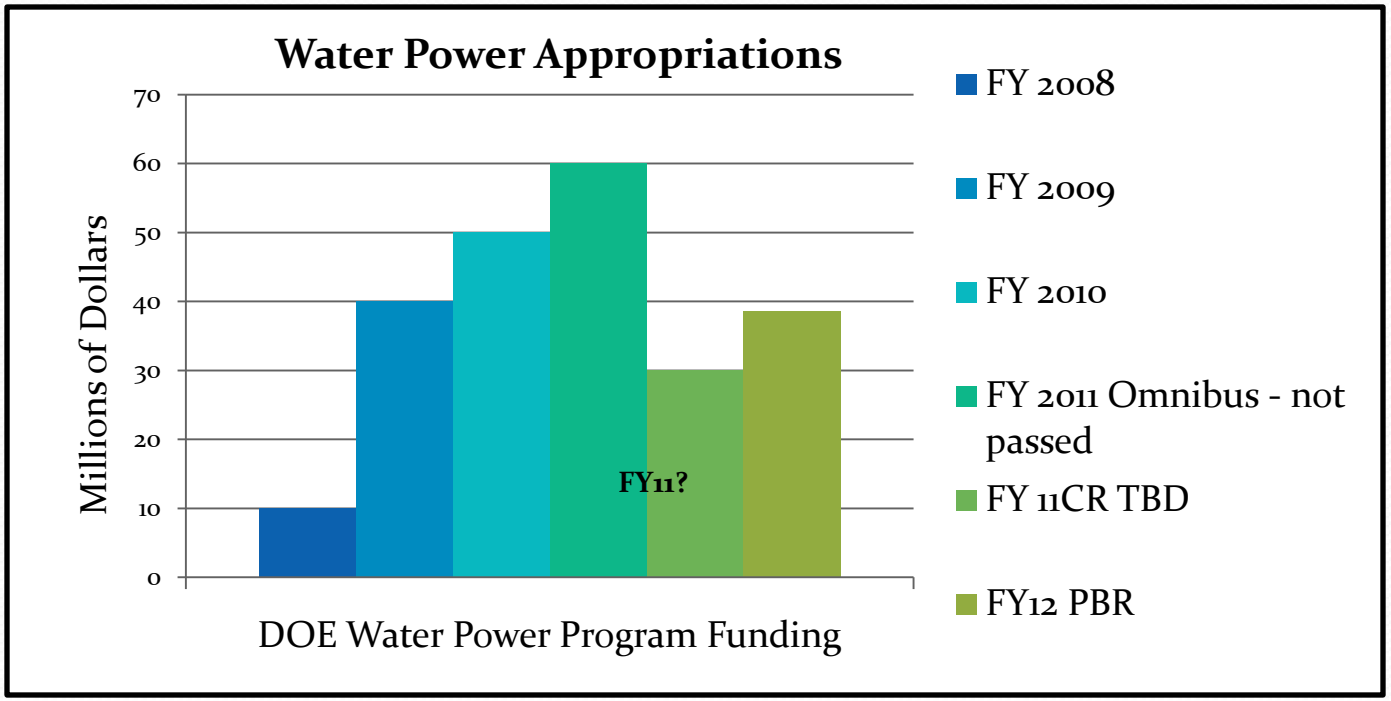
- 15% renewable energy target for 2020
- £115M invested up to 2009 ($172M)
- £48M announced b/w Mar. '09 & Mar. '10, and £60M announced for 2010
- Streamlined regulatory framework with Strategic Environmental Assessment
- Revenue Support Security (Renewable Obligation Certificates); Renewable Energy Feed-In Tariffs (REFITS)
- Two national test centers

European Marine Energy Test Sites



DOE Water Power R&D Program

- EPACT 2005 officially recognized ocean energy as a qualified renewable source.
- EISA 2007 emphasized MHK technologies.
- DOE water power activities were restarted in FY 2008.
- Includes funding for both MHK and Conventional Hydropower R&D



U.S. Policy & Funding Needs

- National MHK deployment and timeline roadmap
- Streamlined framework for siting and permitting
- Increased DOE funding to $100M for FY2012
- Investment Incentives
- Continue to support DOE-authorized Marine and Hydrokinetic Technology test centers