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Ocean Energy Technology Development


Wave Technology

US Ocean Energy RD&D Status:

- Energy Policy Act Implications
- Wind & Hydropower Program Activities
- Technology & Policy Concerns
- Pathway Forward


In-Stream Tidal Technology

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NREL/PR-500-40461 • October 2006

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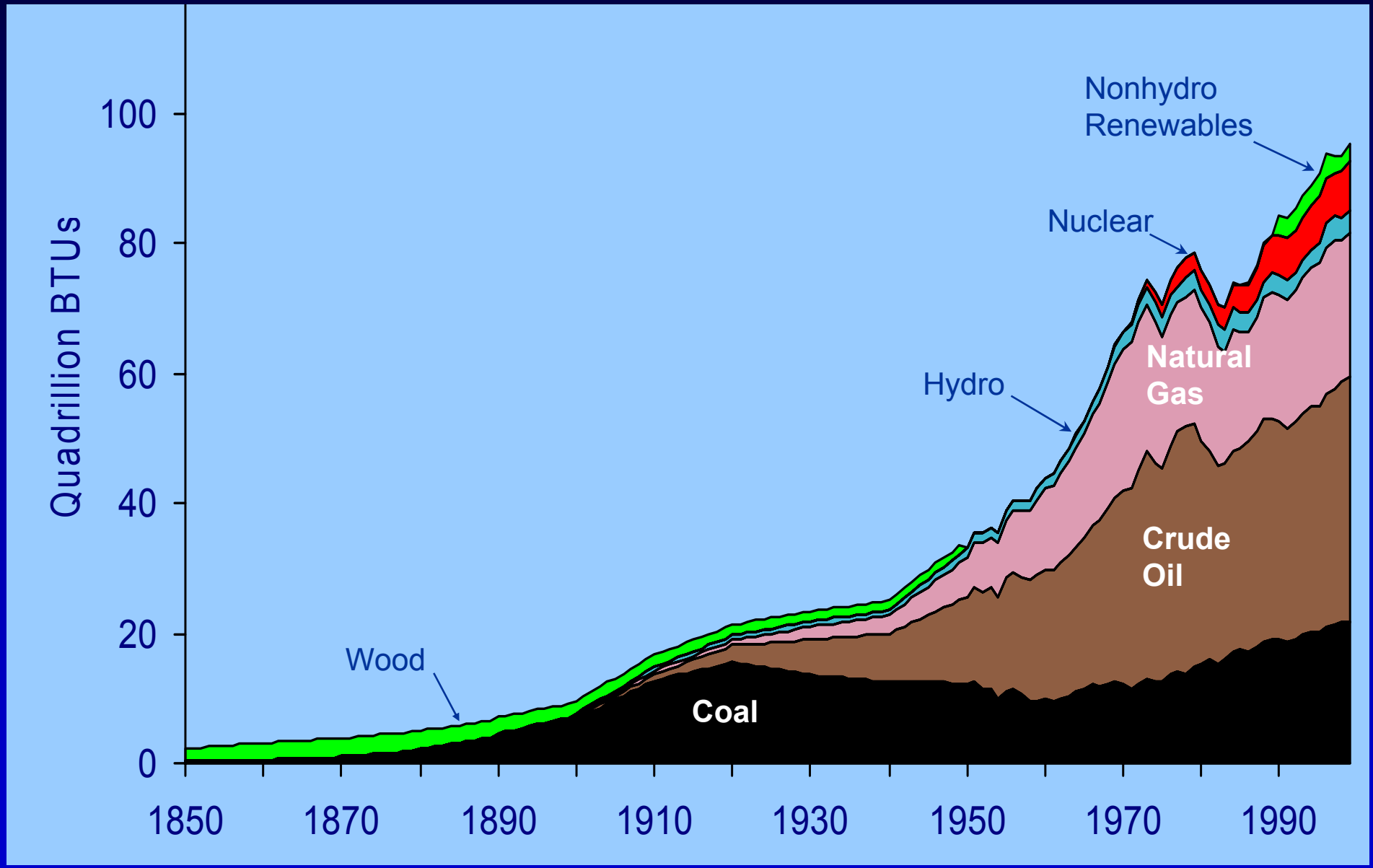
The U.S. Energy Picture by Source - 1850-1999



Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables. 1997-1999, Annual Energy Review 1999, Table F1b.

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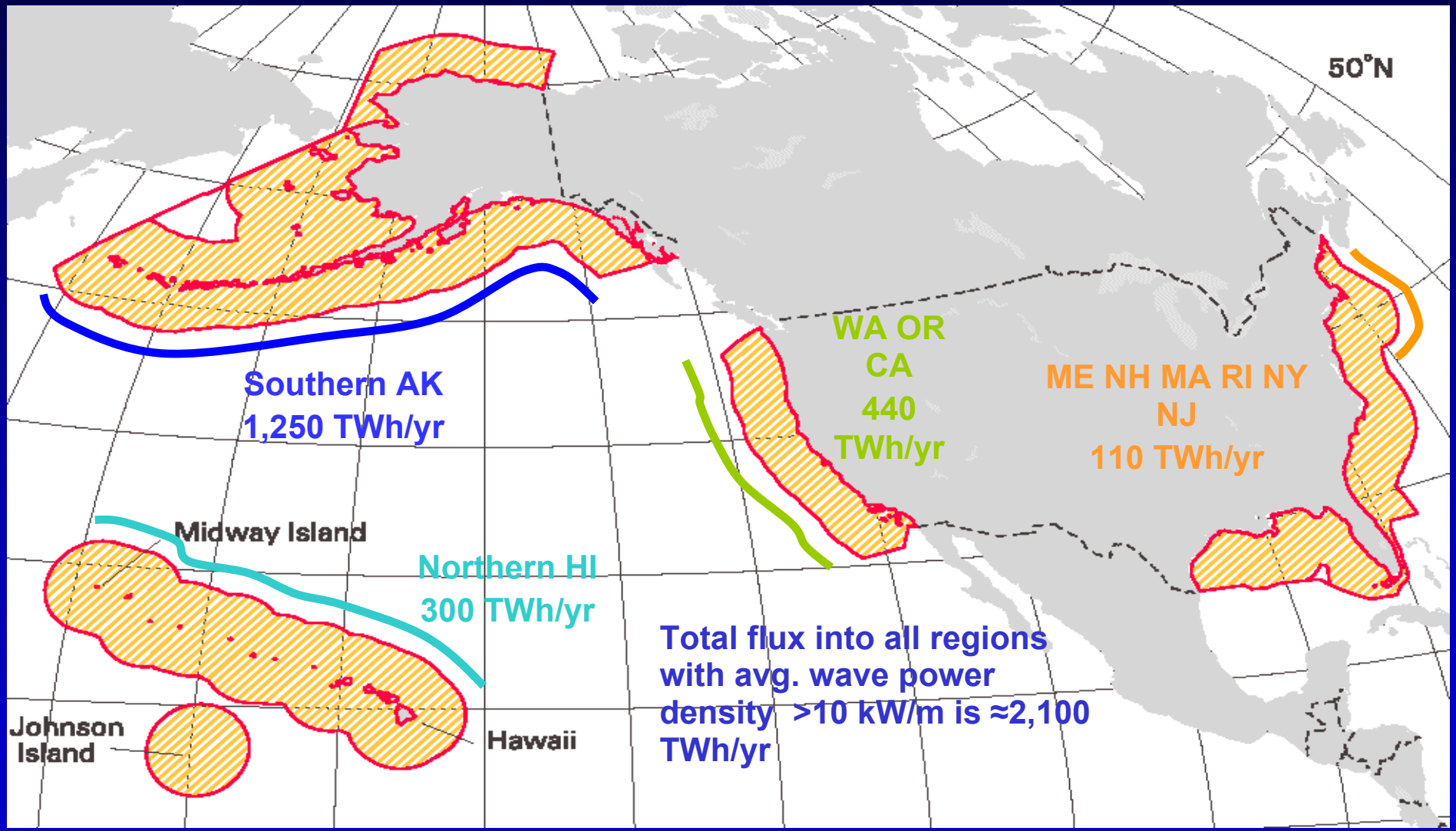
Ocean Wave Resource Location



Harnessing 20% of offshore wave energy resource at 50% efficiency would be comparable to all US conventional hydro generation in 2003.

Ocean Renewable Energy Resource Summary

North America Ocean Renewable Energy Resource

	Total Capacity [2] (GW)	Extraction Potential (GW)	Total Energy Potential (TWh/y)	US Electrical Demand [2] (%)
Wind Onshore		8,000 [5]	70,080	2,500
Wind Offshore		6,000 [5]	52,560	1,875
Wave [6]	240	< 240 [8]	2,100	75.0
Tidal [1]	30	7.5 [3]	65.7	2.3
Ocean Current [1]	25	2.5 [4]	21.9	0.8

1 *International Journal of Energy*, Vol. 4, No. 5, 1979
2 Total Resource Capacity without exclusions
3 25 % maximum extraction potential
4 10% maximum extraction potential
5 NREL GIS Calculations; Includes Standard Exclusion Assumptions
6 EPRI; Single Energy Flux Line
7 FY 2003 US Electrical Consumption 2,803 TW-h/y; IEA
8 Without Exclusions

Energy Policy Act of 2005

EPAct 2005 Authorizations Pertaining to Ocean Energies R&D:

Section 931: RENEWABLE ENERGY
(a) (2) (E) MISCELLANEOUS PROJECTS

"The [DOE] Secretary shall conduct research, development, Demonstration, and commercial application programs for :"

(i) ocean energy, including wave energy

(iv) kinetic hydro turbines

Other EPAct 2005 Provisions Relating to Ocean Energy

Section 388: ALTERNATE RELATED ENERGY USES ON THE CONTINENTAL SHELF

(a) Amendment to Outer Continental Shelf Lands Act - Section 8 of the Outer Continental Shelf Lands Act (43 U.S.C. 1337) is amended by adding at the end the following:

(p) Leases, Easements, or Rights-of-way for Energy and Related Purposes

(1) IN GENERAL- The [DOI] Secretary, in consultation with the Secretary of the Department in which the Coast Guard is operating and other relevant departments and agencies of the Federal Government, may grant a lease, easement, or right-of-way on the outer Continental Shelf for activities not otherwise authorized in this Act , the Deepwater Port Act of 1974 (33 U.S.C. 1501 et seq.), the Ocean Thermal Energy Conversion Act of 1980 (42 U.S.C. 9101 et seq.), or other applicable law, if those activities

(C) produce or support production, transportation, or transmission of energy from sources other than oil and gas

Other EPAct 2005 Provisions Relating to Ocean Energy

Section 388: ALTERNATE RELATED ENERGY USES ON THE CONTINENTAL SHELF

(b) Coordinated OCS Mapping Initiative-

(1) IN GENERAL- The Secretary of the Interior, in cooperation with the Secretary of Commerce, the Commandant of the Coast Guard, and the Secretary of Defense, shall establish an interagency comprehensive digital mapping initiative for the outer Continental Shelf to assist in decision making relating to the siting of activities under subsection (p) of section 8 of the Outer Continental Shelf Lands Act (43 U.S.C. 1337) (as added by subsection (a)).

Specified EPAct 2005 Federal Agency Roles

- **DOE/EERE**
  - Ocean Energy, Wave & Hydro Kinetic Technology Development
- **Minerals Management Service**
  - EPAct Aug 2005 Designated Lead Agency To Permit Nonextractive Energy Facilities (including wave in OCS);
  - Engage In Siting Activities In Collaboration With DOD
- **Corps of Engineers**
  - Navigation Obstructions In Federal Waterways (Sec 10 Permit)
  - Water Quality & Approval of Most Transmission Lines
- **Federal Energy Regulatory Commission**
  - Approval of Power Supply Contracts;
  - Defined Powerhouse Under Federal Powers Act 2003 For Wave & Tidal
- **National Oceanic & Atmospheric Administration**
  - Siting in and Around Protected Areas (Marine Sanctuaries)
  - Specific Legislation for OTEC (Not Active);

Stakeholder Projects & Coalitions

State/City Agencies (9)

Maine Tech Initiative
Mass Tech Collaborative
New Brunswick Ministry
Nova Scotia Ministry
Alaska Energy Authority
Washington CTED
Oregon DOE
San Francisco & Oakland CA

Institutes (8)

Bedford Oceanography
Alexandria Research
Virginia Tech
University of Washington
Oregon State University
University of Massachusetts
Massachusetts Institute of Technology

Federal (2)

U.S. DOE & NREL

Technology Companies (30)

Wave & Tidal Power Developers

EPRI Wave & Tidal Commercial Demonstration Projects

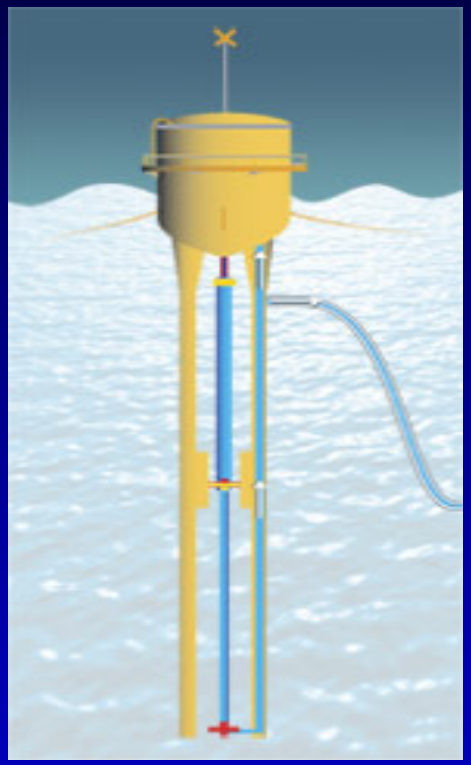
- Feasibility of demonstration projects in North America
- Examines technology viability, site locations & deployment economics
- Accelerate commercialization of the technology
- Facilitate public/private partnerships between coastal states, state agencies, utilities, device develops, interested third parties, and the DOE
- Wave & tidal report completed; (www.epri.com/oceanenergy)

Utilities (19)

Bangor Hydro Central
Maine Power
National Grid
NSTAR
NB Power
NS Power
Chugach
Tacoma Power
Puget Sound Energy
Seattle City and Light
Snohomish PUD
Bonneville Power
Central Lincoln PUD
Douglas Electric Co-op
Portland General
PacifiCorp
PG&E
HECO and KIUC

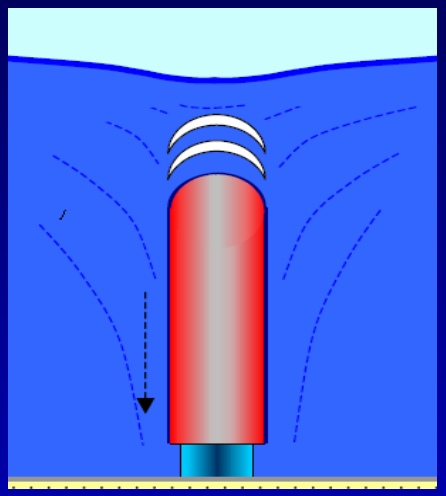
Point Absorber Technology Examples

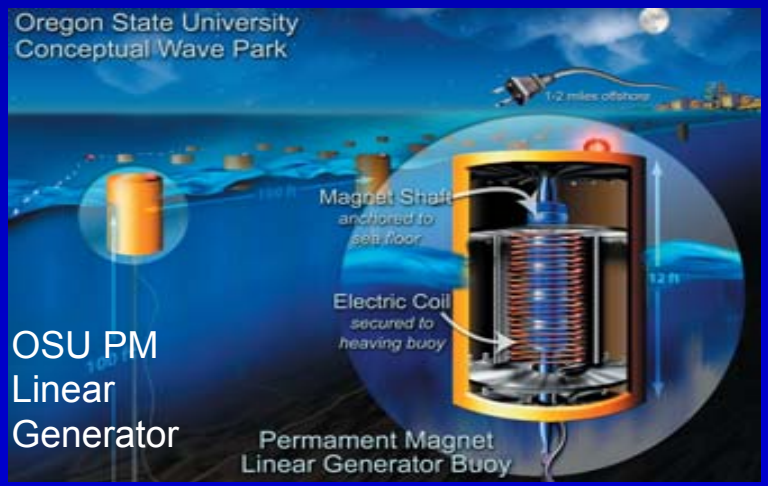
Aquabuoy; AquaEnergy - Makah Bay, WA



OPT

PowerBuoy; Ocean Power Technology Oahu, Hawai





OSU PM Linear Generator

Archimedes Wave Swing MK I - Portugal

North America Wave Energy Projects "Coast to Coast"

	HI, Oahu Kaneohe	WA Makah Bay	RI Point Judith	CA, San Francisco	OR Gardiner
Developer	Ocean Power Tech	AquaEnergy	Energetech	SFPUC	Oregon State University
Development Stage	Deployed June 04	Permitting since 2002	Permitting since Feb 2005	Seeking funding for permitting	Seeking funding for permitting
Device	Power Buoy™	Aqua BuOY™	OWC	Pelamis (tentative)	TBD
Size	Single buoy 40 kW	4 buoys 1 MW	Single OWC 500 kW	Single Unit 750 kW	TBD
Water Depth/ Distance from Shore	30 m 1 km	50 m 6 km	2 m 2 km	30 m 15 km	TBD

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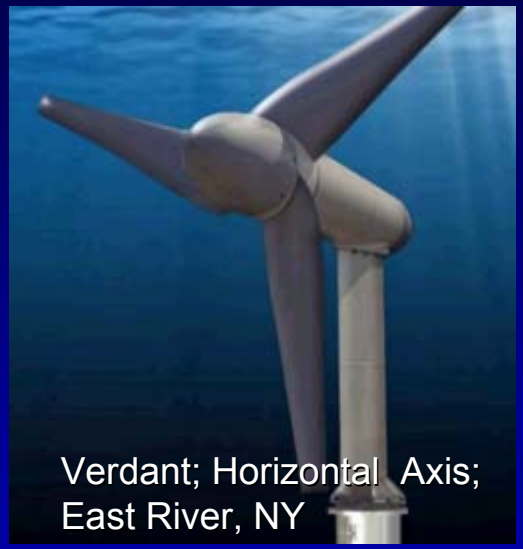
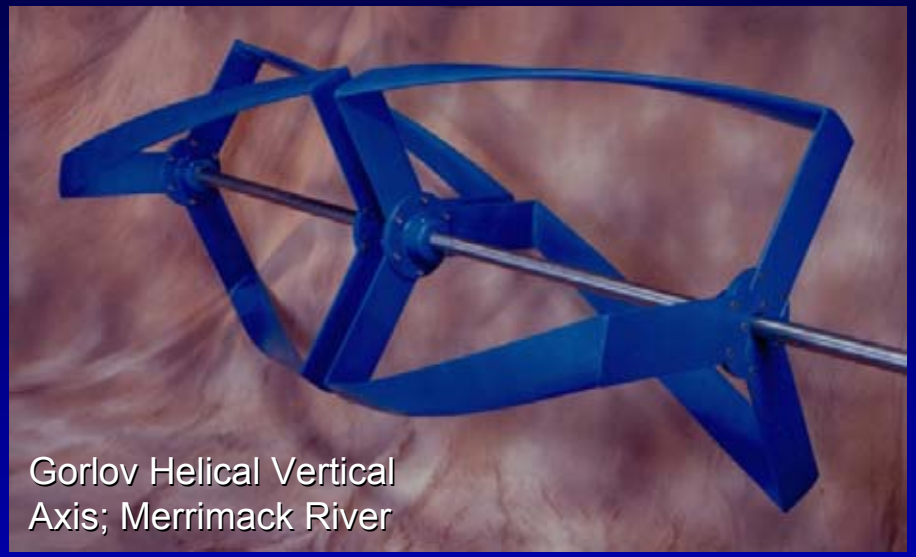
In-Stream Tidal Technology Examples


Verdant; Horizontal Axis; East River, NY


Gorlov Helical Vertical Axis; Merrimack River


Hydro; Open Center Turbine; Gulf Stream


Lunar Energy, Rotech Tidal Turbine

Underwater Electric Kite; Merrimack River


MCT SeaFlow Experimental Test

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North America Tidal Energy Projects "Coast to Coast"

	MA Amesbury	NY NY, East River	BC Race Rocks	CA, SF	DE Indian River Inlet	WA Tacoma
Developer	Verdant	Verdant	Clean Currents	SFPUC Marin	UEK	Tacoma Power
Development Stage	2 Month Test Complete	Construction	NA	Formative	Permitting	Application in process
Device	Vertical axis	Horizontal axis	NA	TBD	Horizontal axis	TBD
Size	1 m X 2.5 m 1 unit	5 m diameter 6 units	NA	TBD	3 m diameter 25 units	TBD
Power (kW) at Max Speed (m/s)	0.8 kW @ 1.5 m/s	34 kW @ 2.1 m/s	NA	TBD	400 kW @ 3 m/s	TBD

OREC Corporate Members

Ocean Renewable Energy Coalition (OREC)

- Newly formed trade association to promote commercialization of offshore renewables
- Helped secure benefits for ocean in EPAct
- Continues to promote ocean industry through future action – but needs industry and public support
- www.oceanrenewable.com

OREC Membership

- Battery Ventures
- Devine Tarbell Associates
- Ocean Power Delivery
- Ocean Power Technologies
- Ocean Renewable Power Company
- Ocean Wave Energy Company
- Open Hydro
- Oregon Ironworks
- Millbank Tweed Hadley & McCloy, LLP
- Reluminati
- RenewableEnergyAccess.com
- Science Applications International Corporation (SAIC)
- The Stella Group
- Verdant Power

Ocean Activities Supported by Wind & Hydro Program


IEA ExCO Meeting Brussels - 2005 IEA


Pelamis under tow to EMEC

- Formal IEA-OES ExCO Membership in 2005
  - Jim Ahlgrimm (DOE) - Delegate
  - Mike Robinson (NREL) - Alternate
- DOE Participant in EPRI Ocean Collaborative
  - Ocean Wave Demonstration Project Report (Complete 2005)
  - Ocean Tidal Demonstration Project Report (Complete 2006)
- Hydro Kinetic Workshop (October 2005)
- FY 2008 First Ocean Power Funding Opportunity

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What are the Hardware Developers Asking For?

European Marine Energy Center
Orkney, Scotland

Four individual test berths

- **Substation and the grid isolator**
- **Observation point**
- **Meteorological station**
- **Operational at the end of 2003**

http://www.emec.org.uk/index.html.

DOE Hydro-Kinetic Meeting
October 2005

- **Leadership in a national ocean energy program**
- **Federal government to support wave & tidal RD&D**
- **Pilot feasibility demonstration projects**
- **R&D at universities**
- **Operate a national offshore ocean energy test facility**
- **Development of standards**
- **Leading the streamlining of permitting processes**
- **Studying provisions for incentives and subsidies**

Development, Legislative and Policy Environment

- **Rush to development**
  - Project before policies
- **Each state/project is unique**
  - Hardware, deployment, interconnect & environmental impact
- **Regulatory requirements are in flux**
  - State & Federal mandates are being established "real time" without coordination
- **Numerous agencies with resource management responsibility involved for NEPA compliance and approval**
- **Significant barriers to timely & cost-effective demonstration projects exist**
- **Everyone is a pioneer and in learning mode**

Environmental Issues And Concerns

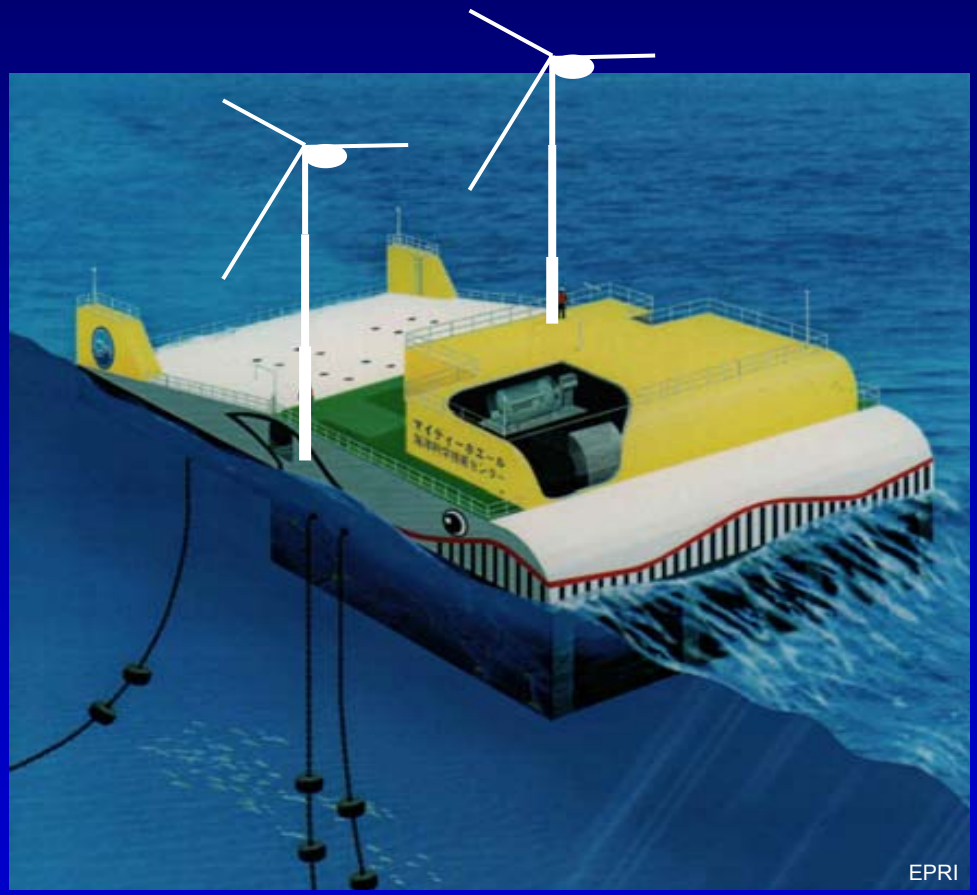
- **Withdrawal of wave energy**
  - Near-shore effects on sedimentary processes, biological communities, competing uses for wave resources
- **Interactions with marine life and seabirds**
  - Marine organism intake, fish aggregation, whale migration, hauling out of sea lions and seals, colonization by birds, marine growth on submerged surfaces, scouring of sea bottom by mooring catenaries
- **Atmospheric and oceanic emissions**
  - Working fluid spills & leaks, anti-fouling hull coating, underwater noise, atmospheric noise
- **Visual appearance**
  - Visual intrusion on seascape, mandatory navigation hazard warnings, extent of required marking
- **Conflicts with other uses of sea space**
  - Marine protected areas, commercial shipping & fishing, military

Initial Strategic Steps

- **Ocean Energy Technology Characterization Program;**
  - Assess & down select technology options & validate resource potential;
- **Collaborate with MMS to Define & Streamline Permitting Process**
  - Advanced notice for leasing & rights of way for OCS; clarify FERC license requirements for prototypes & demonstration projects; establish sliding scale for NEPA compliance & stakeholder involvement; consider a programmatic EIS for ocean technology deployment on a region by region basis; develop an intuitional archive for applicable environmental permitting documents
- **Educate Federal & State Regulators**
  - Address state & Federal permitting requirements; document environmental & technology risks
- **Consider Establishing an Ocean Renewable Energy Testing Facility Based on Technology Assessment**
  - Validate technology selections & assess environmental impacts

Technology Path Forward

Small Wind-OWC Wave Platform



Ocean Power Program:

- Work with various Federal, state & local government agencies to address technology, permitting & environmental impact issues – WPA
- Comprehensive R&D program to evaluate technologies; establish public/private development partnerships; support innovation through university research
- Support field test & demonstration projects; national testing site?
- Actively address environmental impact issues up front
- Leverage synergistic activities with other technologies & agencies
- Long-term success depends on risk mitigation to attract investment!

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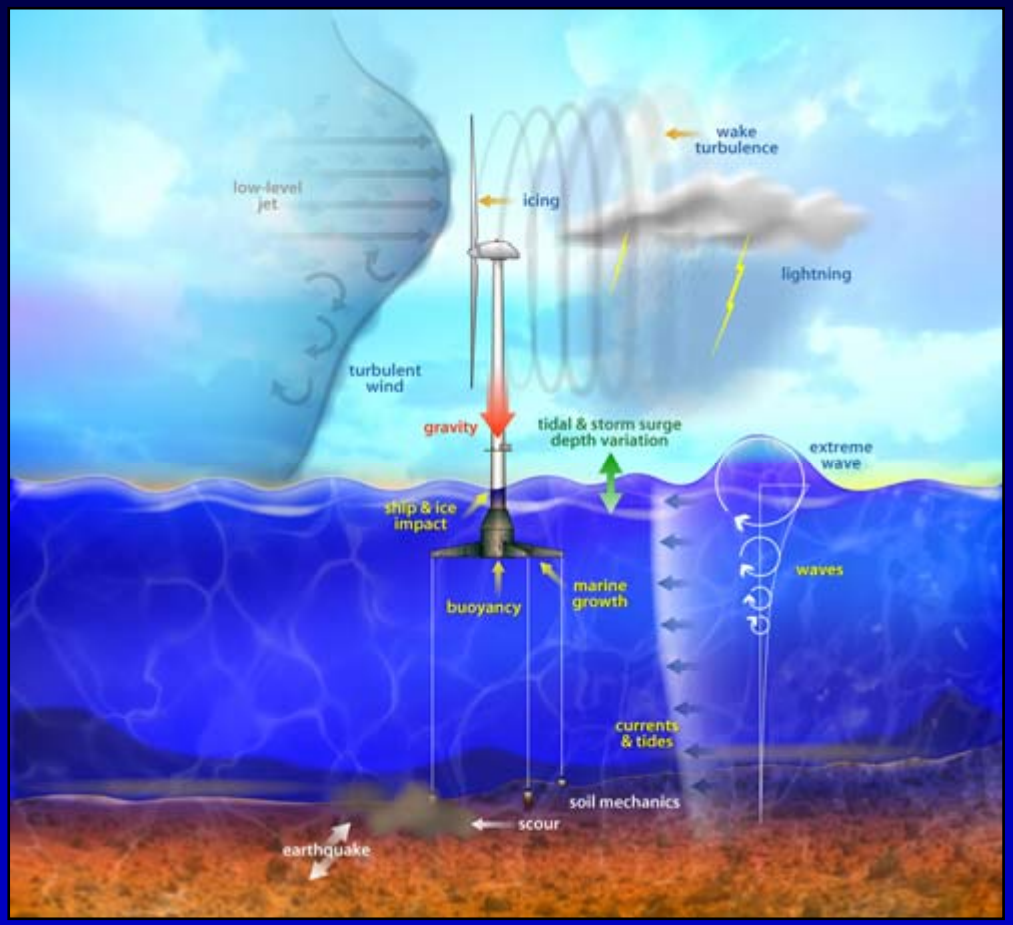
Offshore Wind/ Wave Synergy



- Common engineering & design considerations
- Maximize grid interconnect potential through dual technologies
- Improve intermittency & total energy output
- Increase system reliability & reduce maintenance

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EPRI is building a coalition of developers, universities and other stakeholders to explore the wind/wave development potential

Conclusion

Is there a compelling case for investing in ocean energy RD&D ?

- Are the tidal & wave resources sufficient to justify a federal investment?
- What device type and size is best?
- What capacity factor is optimum?
- Will the installed cost of wave and tidal energy achieve their potential of being less expensive than wind energy?
- Will the O&M costs be as high as predicted?
- Are the performance and cost estimates accurate?
- What is the reliability, maintainability, and availability?
- What are the effects on marine life and the coastline?
- What is its ability to survive storms?
- What is its ability to operate over a 20-year or so life?