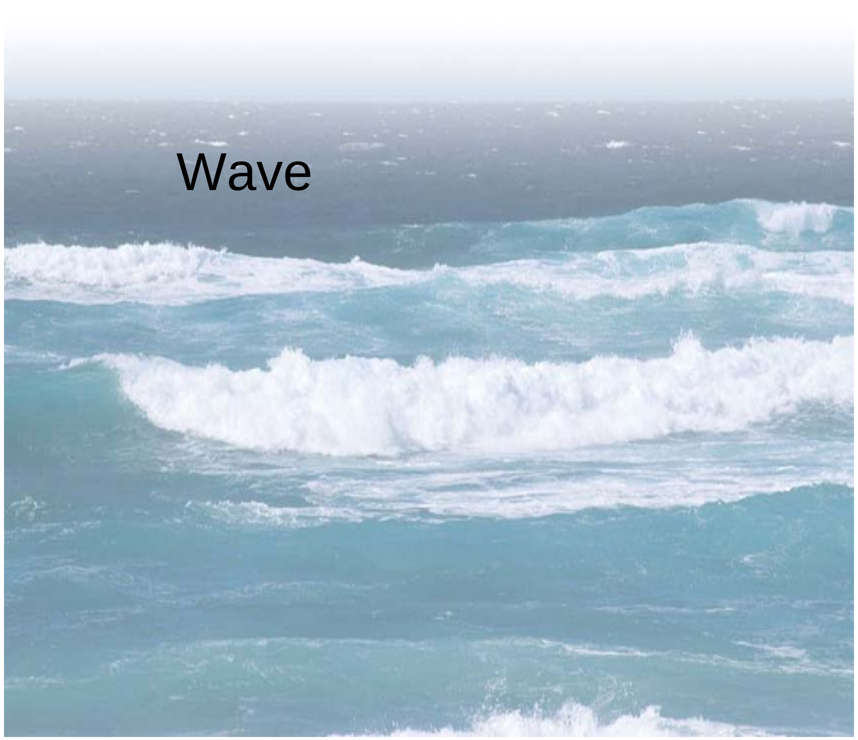
Overview of EPRI Ocean Energy Program and its Future



DOE HydroKinetic Workshop

October 28, 2005

Presented by: Roger Bedard /EPRI

Outline

- Introduction / Participants
- EPRI Wave North American Collaborative Project
- EPRI In-Stream Tidal North American Collaborative Project
- Ongoing US Wave and In Stream Tidal Energy Demonstration Projects
- 2006 EPRI Initiative – Hybrid Offshore Wind-Wave Energy Conversion

EPRI Ocean Energy Feasibility Assessments

- **Motivation**
  - A diversity of energy sources is the foundation of a reliable electrical system
  - North America has significant wave and tidal in-stream energy resources
  - Technologies able to harness these resources are becoming available
- **Objective**
  - Feasibility demonstration in North America
  - Accelerate sustainable commercialization of the technology
- **Approach**
  - Facilitate public/private collaborative partnership between coastal states, involving state agencies, utilities, device develops, interested third-parties, and the DOE

The Big Picture

- US Total Electricity Consumption = 3.7 TWh/yr

  (source EIA)

- US primary energy required = 11.2 TWh/yr

  (assumes 33% energy conversion efficiency)

- Total Annual US Wave Energy Resource = 2.1 TWh/yr

  (calculated by EPRI)

- Extractable energy is less but significant

FUEL TYPE	
Coal	50%
Nuclear	20%
Natural Gas	18%
Hydroelectric	7%
Fuel Oil	2%
Biomass	2%
Geothermal	1%
Wind	<1/2%
PV	<1/20%

Benefits of Ocean Energy

- Diversify energy sources to improve energy security,
- Job creation and local economic development
- Zero emission and with low environmental impact and Minimizes aesthetic issues
- Economics look attractive (at significant scale)
- Reduces dependence on foreign energy supplies

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Three Projects

Completed
In-progress
Future

Offshore Wave Energy Conversion (OWEC)

- **Phase 1 Project Definition Study** — 2004
- **Phase 1.5 Pre-Implementation Planning** — 2005
- **Phase 2 Design, Permitting, & Financing** — 2006
- **Phase 3 Construction** — 2007
- **Phase 4 Operation & Evaluation** — 2008

Tidal In-Stream Energy Conversion (TISEC)

- **Phase 1 Project Definition Study** — 2005
- **Phase 2 Design, Permitting, & Financing** — 2006
- **Phase 3 Construction** — 2007
- **Phase 4 Operation & Evaluation** — 2009

Hybrid Offshore Wind-Wave Energy Conversion (HOW-WEC)

- **Phase 1 Project Definition Study** — 2006

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Participants (Funders – cash and in-kind)

Technology Companies (30)

Wave & Tidal Power Developers

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

Federal (2)

U.S. DOE
NREL

Institutes

Bedford Oceanography
Alexandria Research

EPRI PROJECT

EPRI
EPRI Solutions
M. Previsic
Devine Tarbell
NREL
Va Tech
Univ of WA
OSU
UMASS
MIT

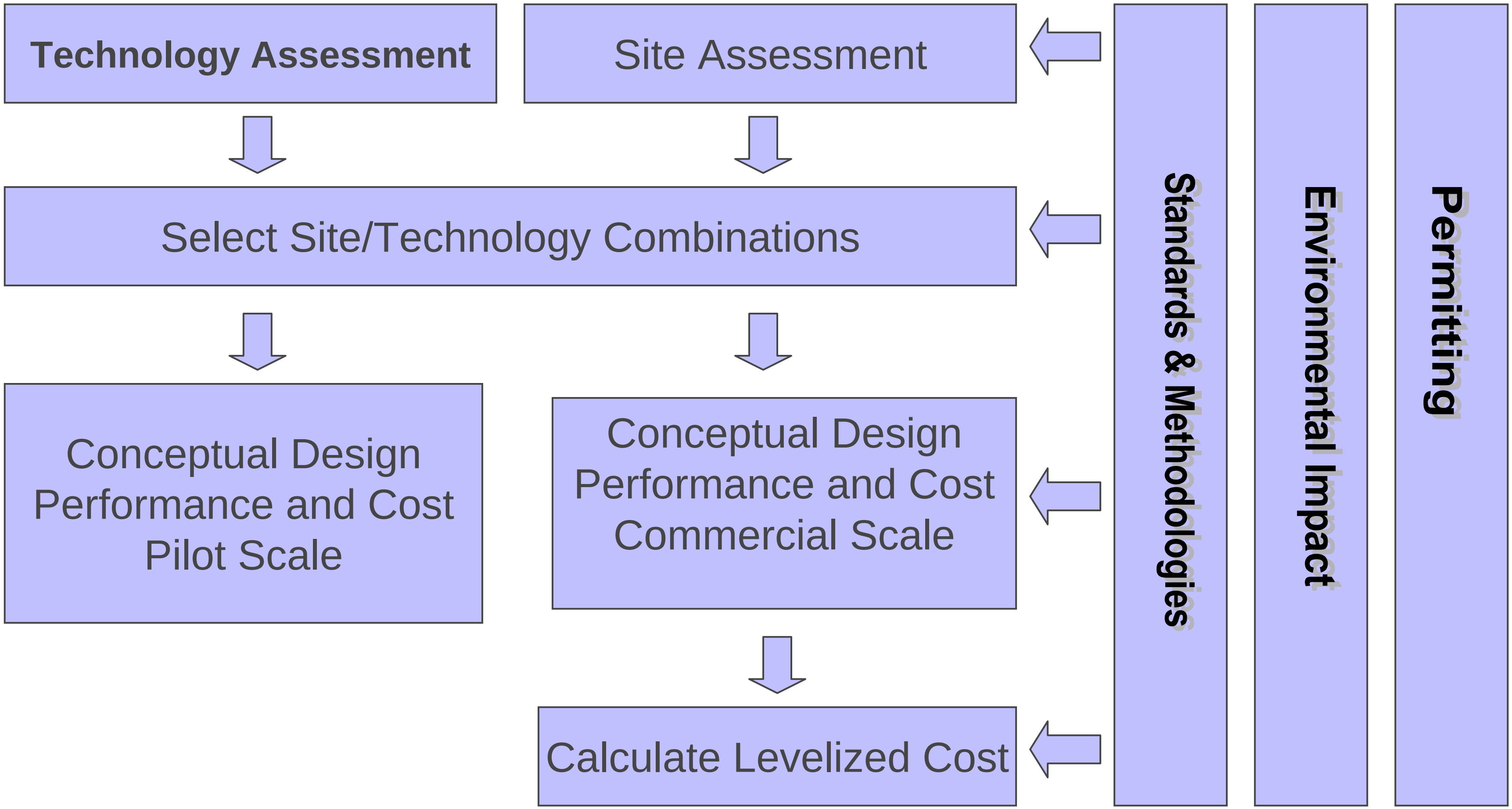
Utilities (19)

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

Resource Comparison

	Solar CSP	Wind	Wave	Tidal Current
Development Status	Early Commercial	Commercial	Pre-Commercial	Pre-Commercial
Source	Sun	Uneven solar heating	Wind blowing over water	Gravity of moon & sun
Annual Average Power Density	200-300 watts/m^2 (southern & western US)	400-600 watts/m^2 (US Great Plains)	20-25 kW/m (US West Coast) 5-15 kW/m (US East Coast)	5-10 kW/m^2 (Alaska, Bay of Fundy) 1-2 kW/m^2 (Seattle, SF)
Intermittency	Day-night; clouds, haze, and humidity	Atmospheric fronts and storms (local winds only)	Sea (local winds) and swell (from distant storms)	Diurnal and semi-diurnal (advancing ~50 min./day)
Predictability	Minutes	Hours	Days	Centuries

Project Definition Phase



Wave Project

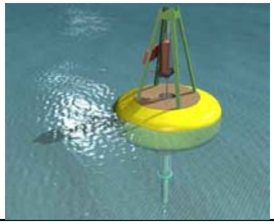
OBJECTIVES

Demonstrate the feasibility of wave power to provide efficient, reliable, environmentally friendly and cost-effective electrical energy

Create a push towards the development of a sustainable commercial market for this technology.

WHY

Wave Energy is an energy resource that is too important to overlook



Phase	Duration	Key Assumptions	Cost	Funding
Phase I – Project Definition Study (including site and device selection) Phase 1.5	1 Year 1 Year	Evaluate 5 Site-Device options Two site-device options	Phase I $240K Phase I.5 - OR - $40K	EPRI State Energy Agencies/Trusts Utilities DOE & Others
Phase II – Design, Permitting and Financing	12 – 18 Months	Design 1 Site – Device option	$500-800K	Private owner or collaborative financing
Phase III – Construction	12 -18 Months	500 KW Plant	$1,500 2,5000K	Private Owner or Collaborative financing
Phase IV -Operation	2 Years	Plant O&M costs	$100-250K	Private Owner or collaborative
Phase IV – Evaluation	2 Years	Additional cost due to RD&D	$100-250K	50% DOE 50% EPRI
Total	**5 1/2 - 7 Yrs**		**$2.5 –4.1 M**	

FUNDERS

✓**Hawaii** –HECO & KIUC (in-kind)

✓**Washington State** –Snohomish PUD and Seattle City Light (In-kind)

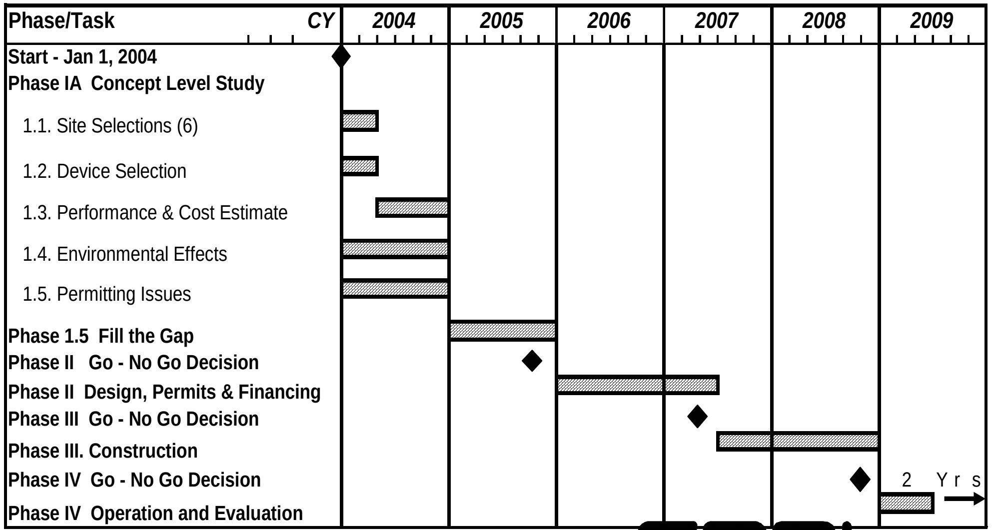
✓**Oregon** – Bonneville Power, Central Lincoln PUD, PGE and Pacificorp

✓**California** – SF PUC and City of Oakland, PG&E (In-kind)

✓**Maine** – MTI, CMP (In-kind) and Bangor Hydro Electric (In-kind)

✓**Massachusetts** - MassTech

✓**DOE/NREL (**Cash and In-kind) and **EPRI –** SS&T



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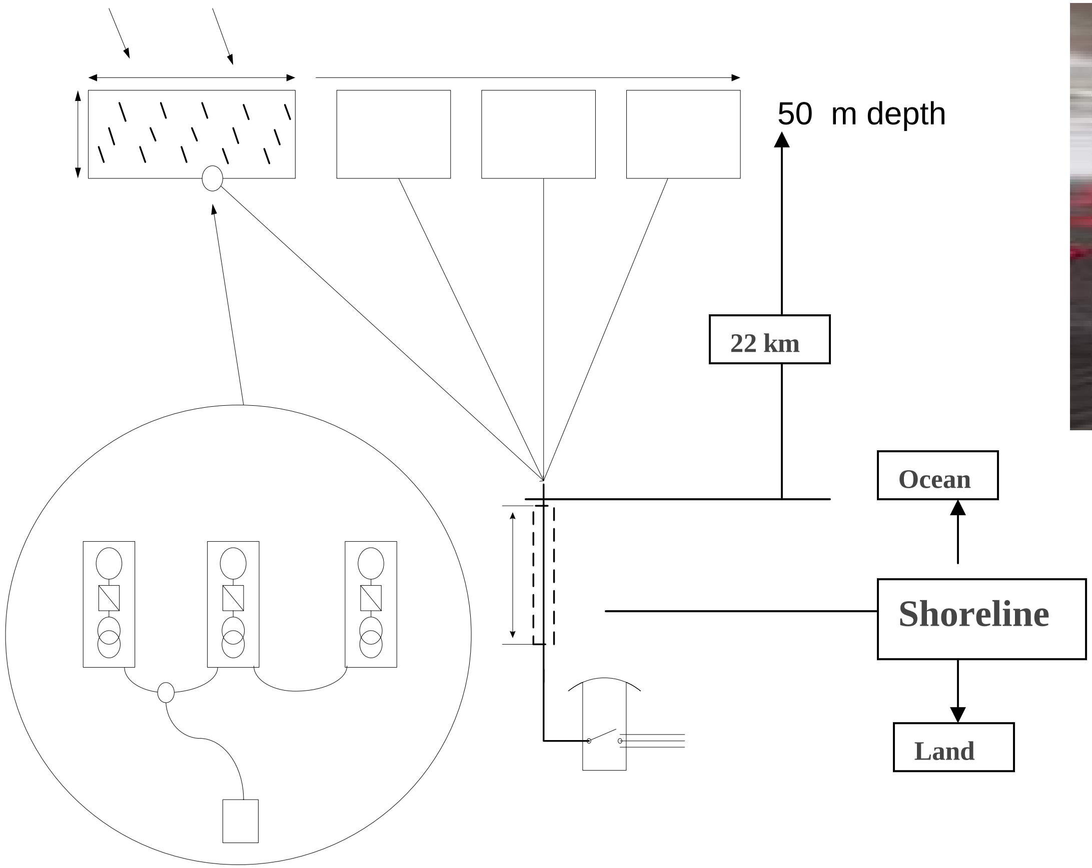
2004 Wave Project Achievements

- Developed standardized methodologies for estimating power production and performing economic assessments
- Surveyed, characterized potential North American Wave Farm sites
- Surveyed, characterized, and assessed energy conversion technology available for developers worldwide
- Established 5 Conceptual Designs for Pilot and Commercial Sized Plants
- Performed an independent cost and economic assessment for the commercial scale plants
- 2004 studies made a compelling case for investing in wave energy technology.

Commercial Wave Power Plant

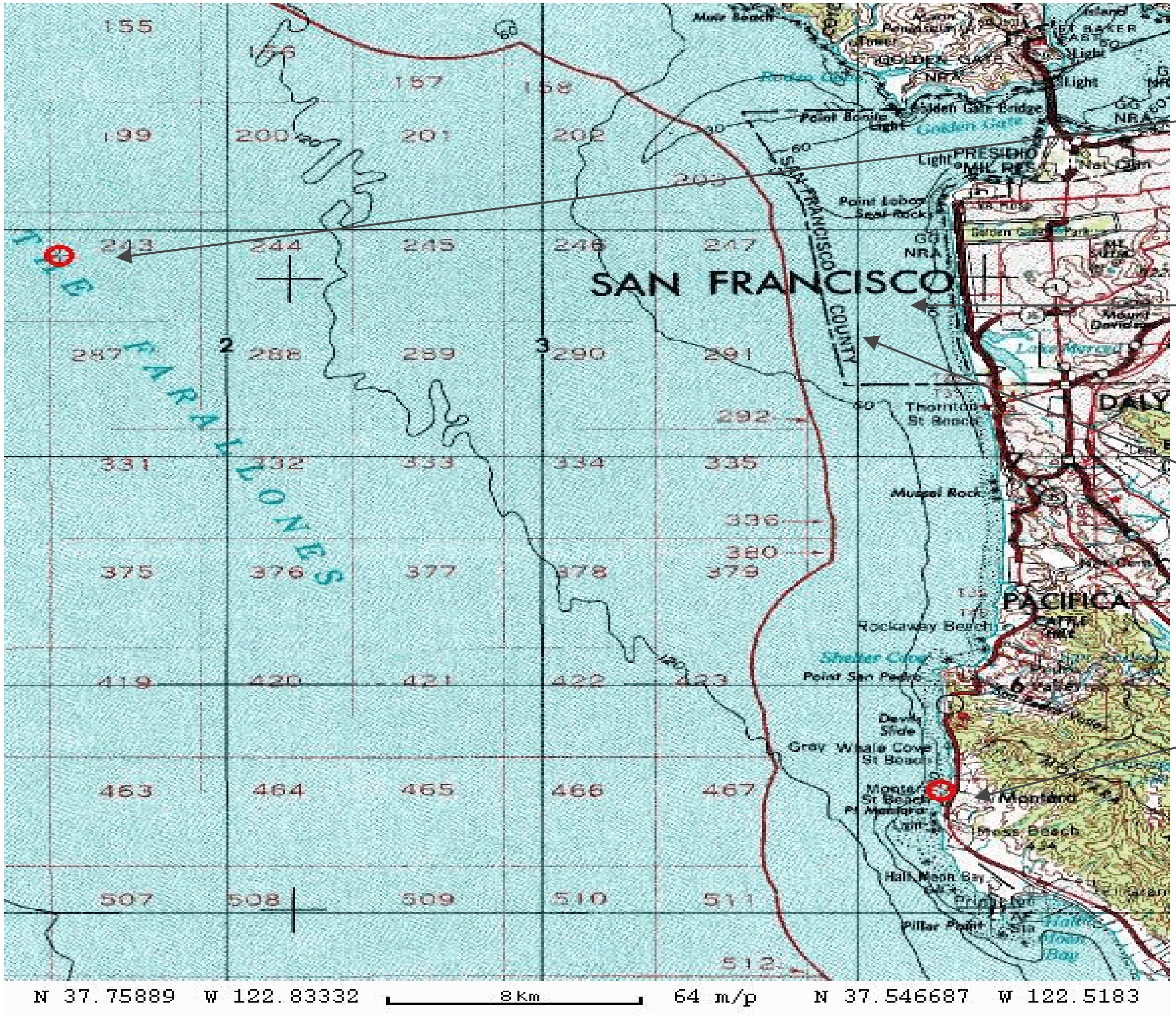
Ocean Beach, SF Ca – 300,000 MWh/yr – 106.5 MW Rating – 213 Pelamis Devices each rated at 500 kW



Avg. Annual Power = 34,2000 kW
No. of Homes Powered = 34,200

Wave Direction

San Francisco Site Map



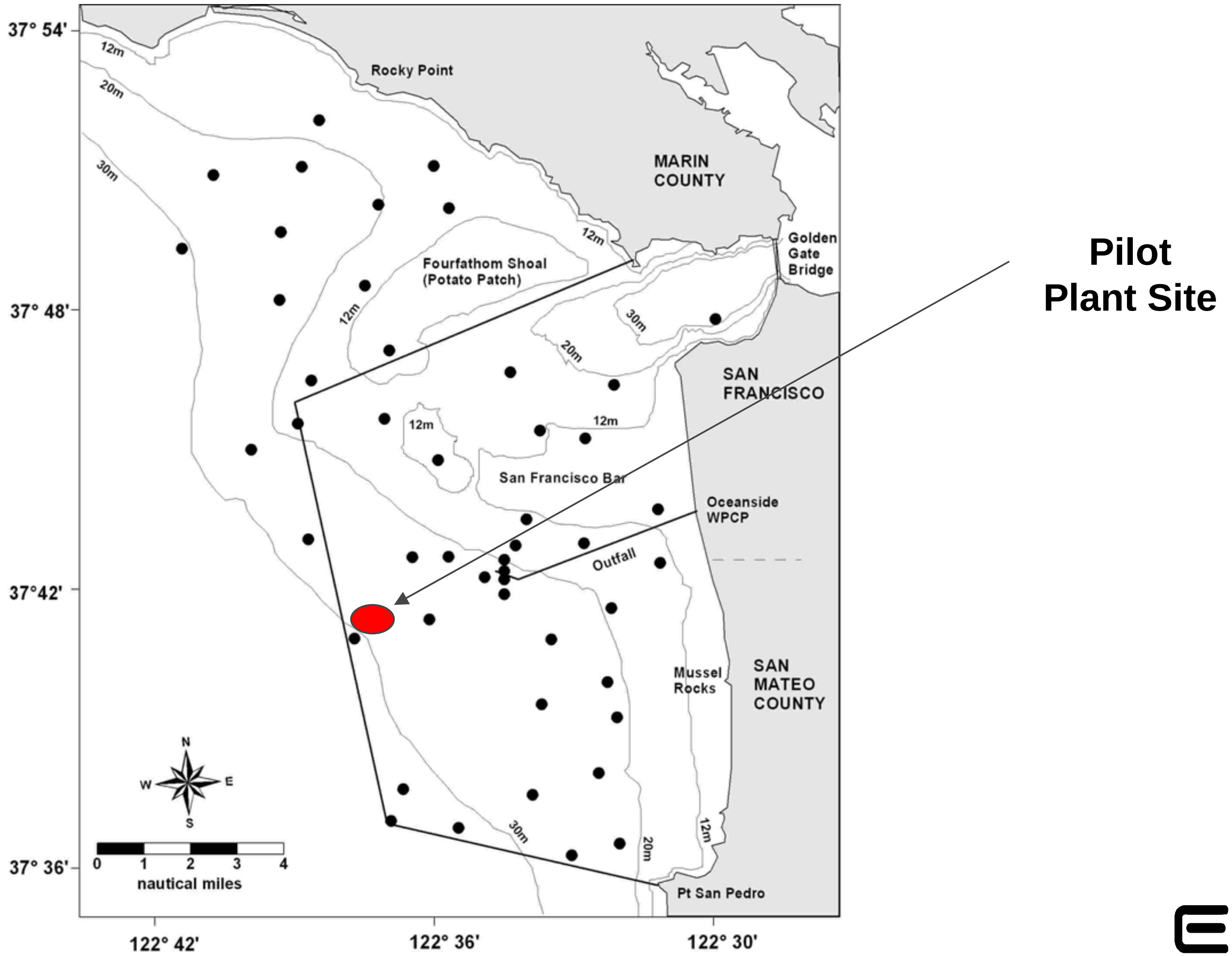
Com'l Plant Site and NDBC 46026

Wastewater Outfall

Pilot Plant Site

CDIP 0062

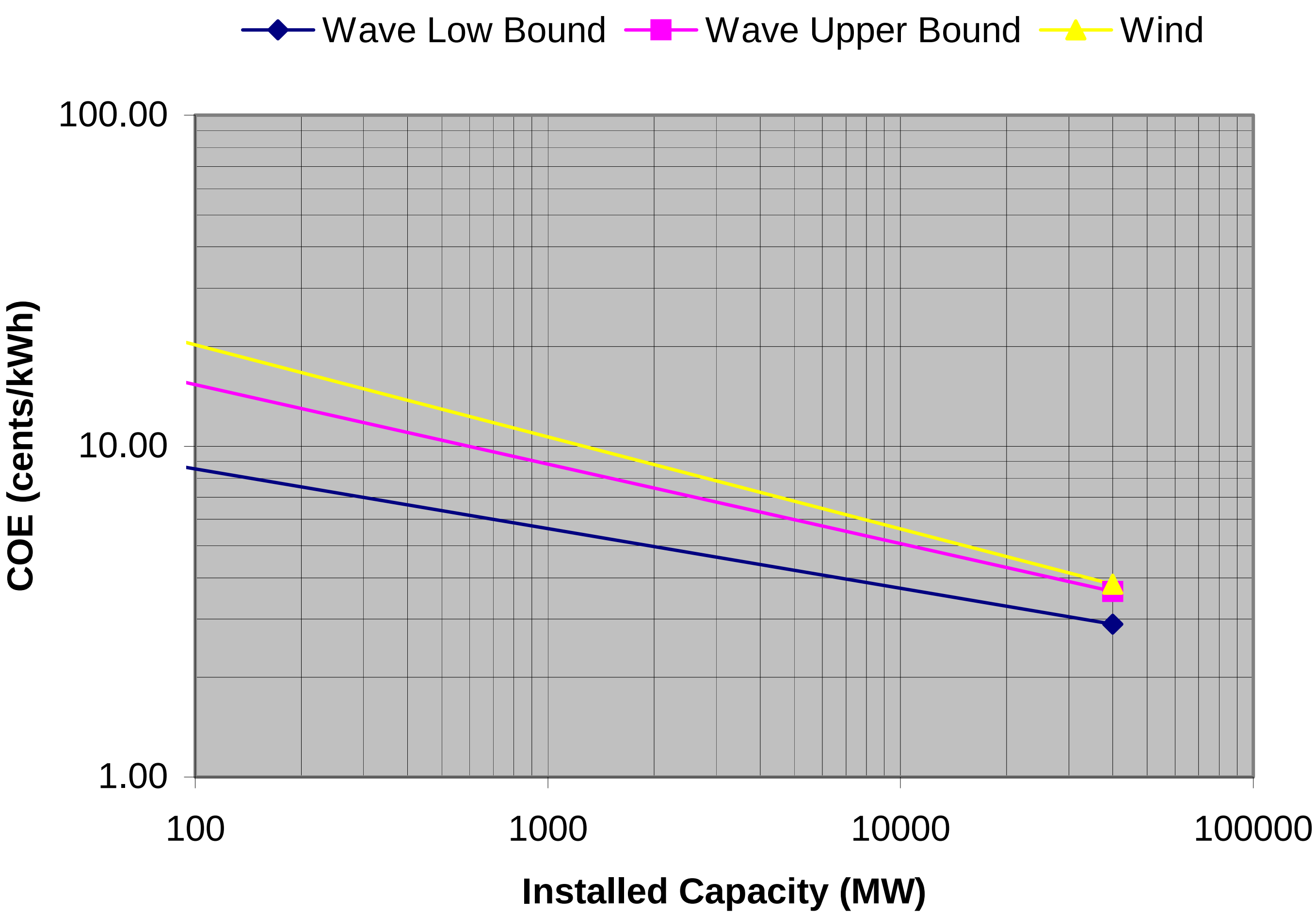
SF Exclusion Zone showing Environmental Monitoring Stations and Pilot Plant Site



Hunter's Point Naval Shipyard

SF has ample marine engineering infrastructure

Learning Curves – Ocean Beach SF CA – Pelamis Wave Energy vs Generic Wind Energy (2004$ - Assumptions per EPRI Report 006 – SF)



Wind

Installed $700/kW

2.2 cents/kWh

and

O&M 1.9 cents/kWh

Non Economic Benefits

- Given proper siting, converting wave energy to electricity is one of the most environmentally benign ways to generate electricity
- Wave energy offers a way to minimize Aesthetic Issues
- Because wave energy is more predictable that direct solar insolation and wind, there is a higher probability that it may be dispatchable

EPRI

Conclusions – Techno Economic Forecasts EPRI Report 009-WP-US Mar 2005

- Northern California and Hawaii have both excellent wave climate, coastal infrastructure and high electricity prices
- Oregon has excellent wave climate and coastal infrastructure, but low electricity prices
- Washington has excellent wave climate, but poor coastal infrastructure and low electricity prices
- Massachusetts has good wave climate in the winter, but poor in the summer, high electricity prices and a REC market
- Maine has a poor wave climate – a good wind site is forecasted to be techno economically favorable to wave energy for the state of Maine

Conclusions EPRI Report 009-WP-US Mar 2005

- There is a compelling case for investing in wave energy RD&D to answer many application questions such as:
  - What device type and size is best?
  - What capacity factor is optimum?
  - Will the installed cost of wave energy achieve its potential of being less expensive than wind energy?
  - Will the O&M costs of wave 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?

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Recommendations – Needed Actions EPRI Report 009-WP-US Mar 2005

- Encourage pilot feasibility demonstration projects
- Encourage R&D at Universities
- Encourage the Federal Government to Support RD&D
  - Leadership for a national ocean energy program
  - Operate a national offshore ocean energy test facility
  - Development of standards
  - Joining the IEA Ocean Energy Program
  - Leading the streamlining of permitting processes
  - Studying provisions for incentives and subsidies
  - Ensuring that the public receives a fair return from the use of ocean energy resource
  - Ensuring that development rights are allocated through a fair and transparent process taking into account state, local and public concerns

North America Wave Energy Projects

	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	SF Seeking funding for permitting	OSU Seeking funding for permitting
Device	Power Buoy™	Aqua BuOY™	OWC	Pelamis (tentative)	TBD
Size	Single buoy 40 kW Buildout to 1 MW	4 buoys 1 MW	Single OWC 500kW	Single Unit 750 kW Buildout to Com'l Plant	TBD - RD&D Center
Water Depth/ Distance from Shore	30 m 1 km	50 m 6 km	2 m 2 km	30 m 15 km	TBD

EPRI North American Tidal Flow Power Feasibility Demonstration Project

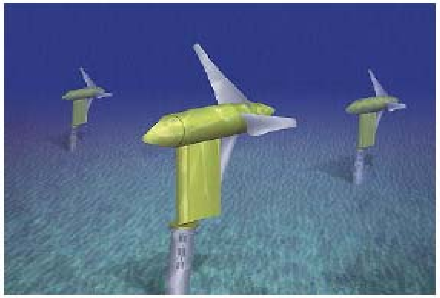
OBJECTIVES

Demonstrate the feasibility of tidal flow power to provide efficient, reliable, environmentally friendly and cost-effective electrical energy

Create a push towards the development of a sustainable commercial market for this technology.

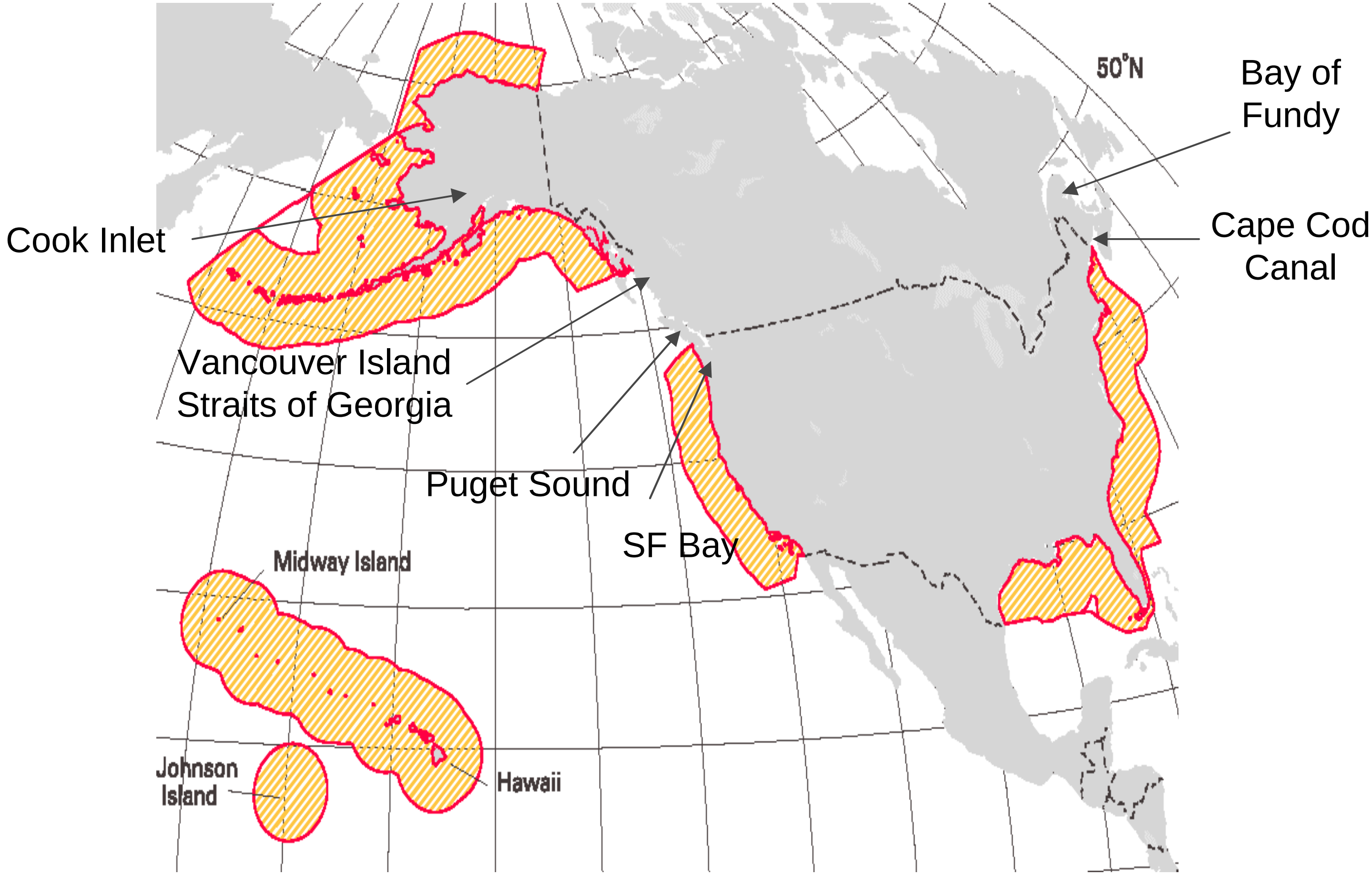
WHY

Tidal Flow Energy is an energy resource that is too important to overlook



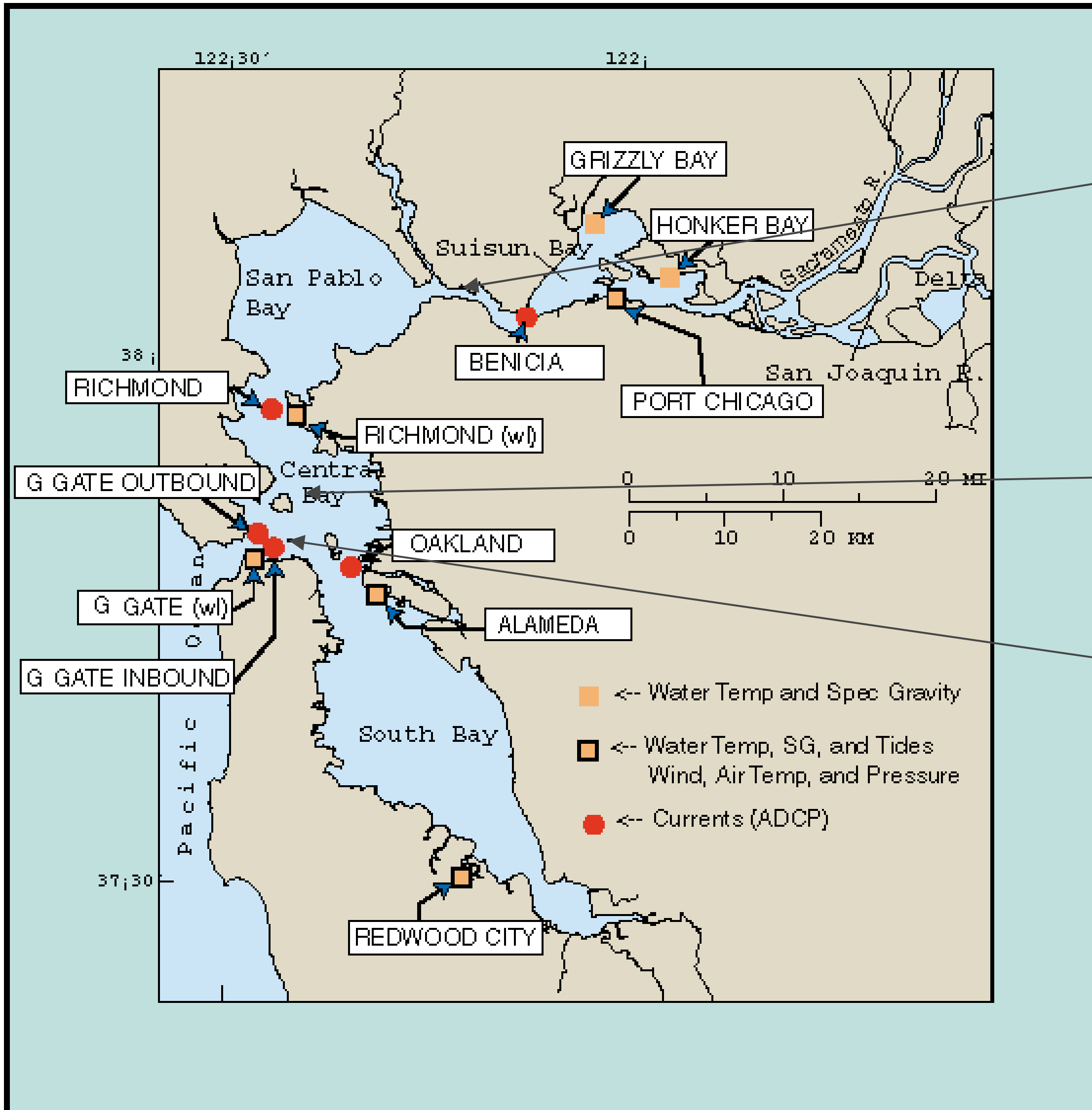
Phase	Duration	Key Assumptions	Cash Cost	Expected Cash Funding
Phase I – Scoping or Project Feasibility Definition Study	1 Year	Five site survey and characterizations; Device survey and characterization; Eight system level design, performance analysis, cost estimate and economic assessment; environmental, regulatory and permitting issues	$350K With Prob Factor + $150K In – kind Cont	Full $60K Maine $50K Mass $60K Washington $60K New Brunsw $60K Nova Scotia $10K DOE Design Only $40K San Fran $40K Alaska
Phase II – System Design	12-18 Months	System Design, permitting and financing - 1 Site – Device	$500-1,000 K	Private Owner or collaborative
Phase III - Construction	12 - 18 Months	1,500 MWe per year Plant (500 kW at 40% capacity factor)	$1,500 - 2,700 K	Private Owner or collaborative
Phase IV - Operation	1-2 Years	Plant O&M costs	$100-250K	Private Owner or collaborative financing
Phase IV - Evaluation	1-2 Years	Additional cost due to RD&D needs	$100-250K	50% DOE 50% EPRI
Total	**5 - 7 Yrs**		**$3-5 M**	

Major No. American Tidal Flow Resources



EPRI

San Francisco Bay Tidal Sites



Carquinez Straits

MFC=2.1 kts

MEC = 2.2 kts

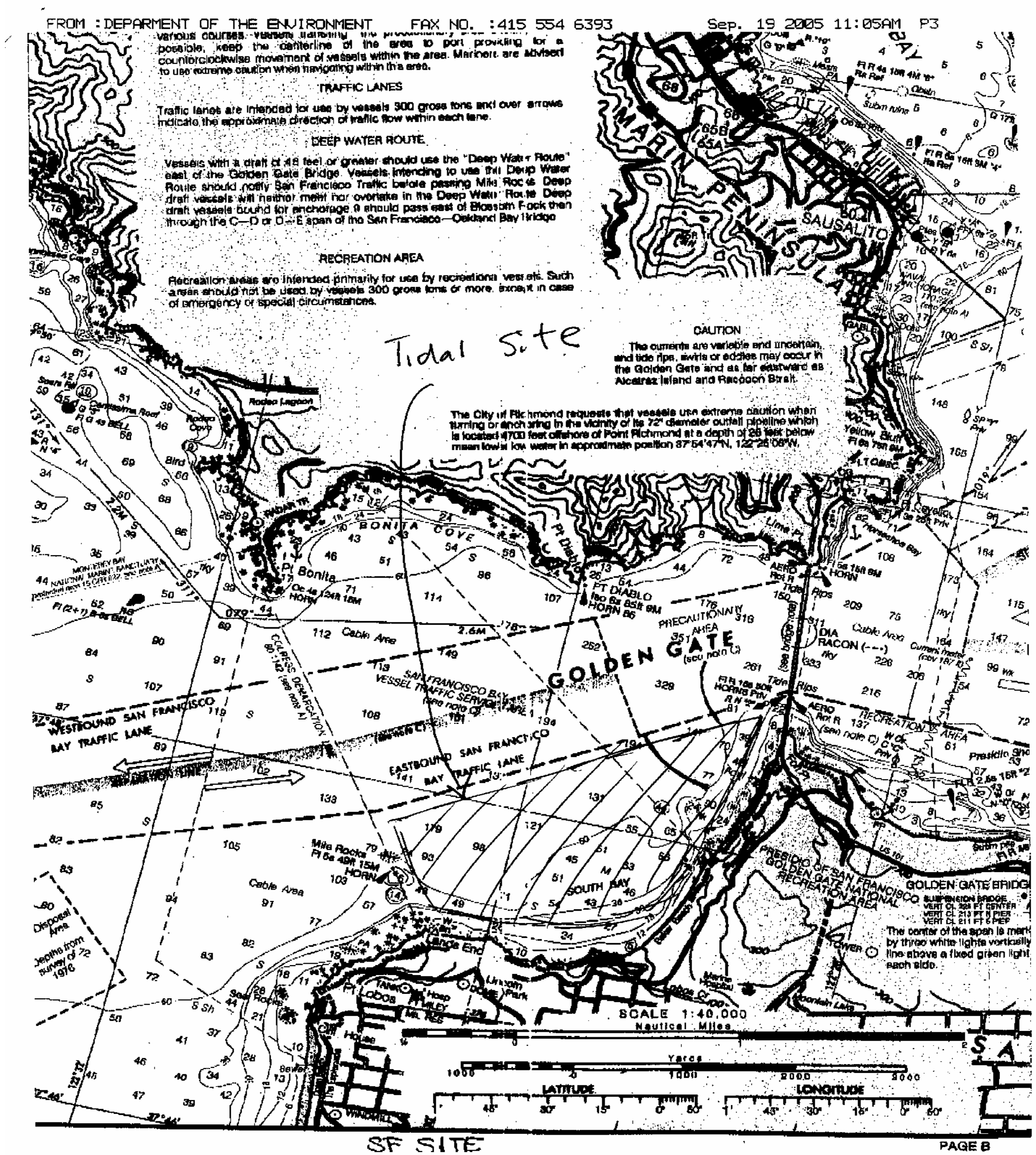
Raccoon Pass

Golden Gate

MFC = 2.9 kts

MEC = 3.4 kts

Selected Site (for EPRI Design, Performance, Cost and Economic Feasibility Study)



2005-2006 Tidal Project

- Design, Performance, and Cost – Demonstration and Commercial Scale Plants Due for Completion in Feb 2006
  - AK – Cook Inlet, Knik Arm with MCT, Lunar or Verdant
  - WA – Tacoma Narrows with MCT Device
  - SF – Golden Gate Entrance – Verdant
  - ME – Eastport Western Passage with MCT, Lunar or Verdant
  - MA, NB and NS – To be decided

- Economic Assessment and Comparisons, Conclusions and Recommendations due for Completion Mar 2006

North America Tidal Energy Projects

	MA Amesbury	NY NY, East River	BC Race Rocks	CA, SF Golden Gate	DE Indian River Inlet	WA Tacoma Narrows
Developer	Verdant	Verdant	Clean Currents	SFPUC	UEK	Tacoma Power
Development Stage	2 Month Test Complete	Construction	NA	Formative	Permitting	Tacoma Power Filed for permit with FERC
Device	Vertical axis	Horizontal axis	NA	TBD	Horizontal axis	TBD
Size	1m 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 @ 1.5m/s	34 kW @ 2.1 m/s	NA	TBD	400 kW @ 3 m/s	TBD

2006 Hybrid Wind-Wave Initiative

Present day offshore wind plants are in shallow water close to shore

Deeper water further offshore wind plants are less visually intrusive

Cost of near shore wind systems are greater than onshore and cost of far offshore wind system are greater than near shore

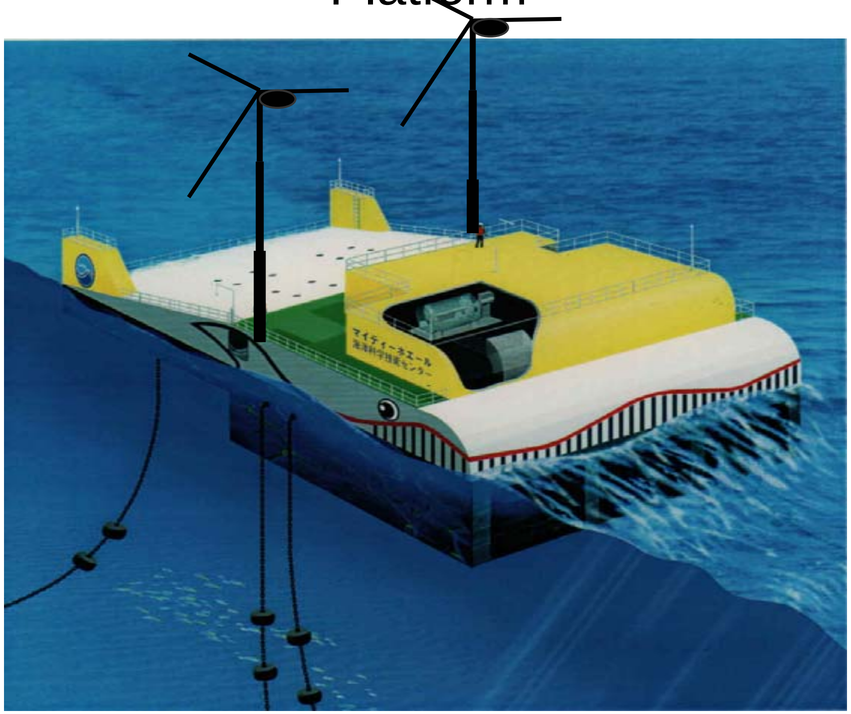
Offshore wave is an emerging technology with 1st commercial sale (25 MW plant) in 2005 in Portugal announced by OPD of the UK

Hybridization of the two technologies is expected to produce lowest COE and soonest commercialization, however, advancements needed in floating platforms and operation and maintenance technologies.

Over the horizon Hybrid Wind Wave Machines off the Cape Cod Coast

Hybrid Wind-Wave Energy Conversion Concepts

Small Wind-OWC Wave Platform



Large Wind - Wave Integrated Platform

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2006 Hybrid Wind-Wave Initiative (cont)

OBJECTIVES

Study the feasibility of deep water (>30m) over the horizon offshore hybrid wind-wave energy conversion technology to provide efficient, reliable, environmentally friendly and cost-effective electrical energy and to push towards the development of a sustainable commercial market for this technology.

WHY

Take advantage of synergies of an offshore hybrid wind-wave plant to reduce the cost of electricity and reduce the intermittency for ease of grid integration increase the reliability of ocean power.

WHO

EPRI has put together a world class team consisting of contractors, the DOE NREL and Universities including VA Tech, OSU, MIT and UMASS and wind, wave and platform vendors.

Task	Duration
1. Site Survey and Characterization (wave and wind energy resources and geophysical properties)	First 6 Months
2. Subsystem Survey and Characterization (wind and wave machines, platforms, moorings and cabling or alternate fuel production)	First 6 Months
3. System Level Design, Performance, Cost and Economics	Middle 6 Months
4. Trade Off Studies and Optimization for Minimum COE	Last 6 Months
5. Environmental Impact Issues and Avoidance/Mitigation and Regulatory Issues	Same 18 Months Semi annual reporting

EPRI

Summary

EPRI Ocean Energy Program is for the Public Benefit

All Technical Work Totally Transparent

All Reports Available:

Project Reports - www.epri.com/oceanenergy/

Monthly Progress Reports - rbedard@epri.com