Maritime Renewable Technologies Business Concepts Brief

Presented to the
Emerging Technology Advisory Committee
by Neil Rondorf, SAIC

October 18, 2005

Why Marine Renewables

- Huge exploitable natural resource
  - offshore wind energy
  - wave energy
  - tidal-in-stream energy
- No major drawbacks to resource harvesting
  - environmental impact is minimal
  - production costs are becoming more competitive
- Technologies are beginning to mature, optimal time to become involved

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Why Important For Virginia

- A number of engineering challenges remain with marine renewable energy generation, Virginia can be a leader in solving these issues
- Driver of new R&D spending in state to infuse Virginia's economy with new technology base
- Brings together leading marine energy technology developers and local engineering firms
- Could lead to new businesses providing ancillary equipment or services

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Compelling Reasons

- Recent Energy Bill has ocean energy language
- Hurricane Katrina's impact on oil production
- Need for energy security:
  - Mid-east oil dependency
  - Creation of high-tech jobs
  - Carbon fuel alternatives
  - Fuel Cell industry needs hydrogen production
- Virginia is actively seeking to bring technology Research and Development to the state
- Ocean observatories can mitigate environmental concerns and ensure responsible development

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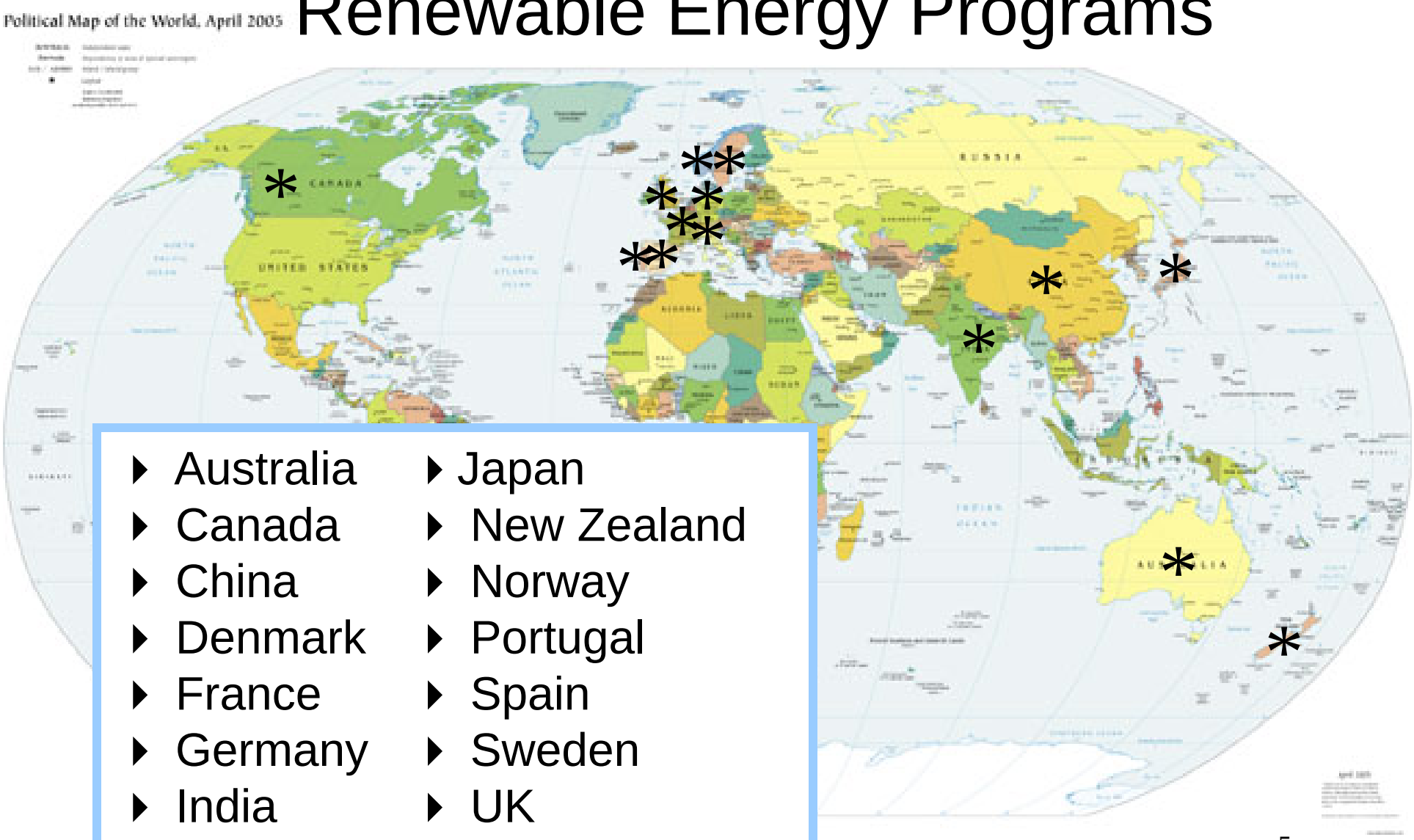
Countries with Offshore Renewable Energy Programs



- Australia
- Canada
- China
- Denmark
- France
- Germany
- India
- Japan
- New Zealand
- Norway
- Portugal
- Spain
- Sweden
- UK

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States with Offshore Renewable Energy Interests

- Alaska
- California
- Connecticut
- Hawai'i
- Maryland
- Massachusetts
- Maine
- New Jersey
- New York
- Oregon
- Rhode Island
- Washington

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Renewable Ocean Technologies

Alternative energies from the ocean is a long standing idea. What has changed?

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Renewable Ocean Technologies

Alternative energies from the ocean is a long standing idea.
What has changed?

- European Renewable Energy Obligations are in force.
- European renewable wind energy systems are in production.
- European wave energy systems are beyond prototype and pilot.

  and
- Canadian Renewable Portfolio Standards are phasing into force.
- Canadian alternative energies are an emerging industry.

  and
- US Energy Bill (2005) directly addresses ocean energy.
- US Production Tax Credits generate a profit motive.
- US Renewable Portfolio Standards are economic drivers.

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Renewable Ocean Technologies

- Shore-based wind farms are viable around the world
- Offshore wind farms in Europe are creating high-tech jobs and new tourist trade. Denmark formulated a regional government-led strategic plan that maintains the environment while harvesting it's renewable resources – sustainable and cost effective
- Offshore wave and current pilot projects in Europe are progressing and the technology has advanced to the implementation stage.

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Costs Of Electricity (COE)

GENERATING TECHNOLOGY	COE cents / kW hour
Nat Gas	5
Coal	4 - 5
Nuclear	4
Solar Photovoltaic	20
Solar Thermal	8
Wind	3 - 7
Wave: General Wave: OPT buoy, Hawaii	9 – 11 * 7 – 10 *
Tidal-in-Stream	7 - 9

* Levelized cost of wave-generated electricity is less than wind-generated electricity at any equal cumulative production volume under all cost estimating assumptions for the wave plant

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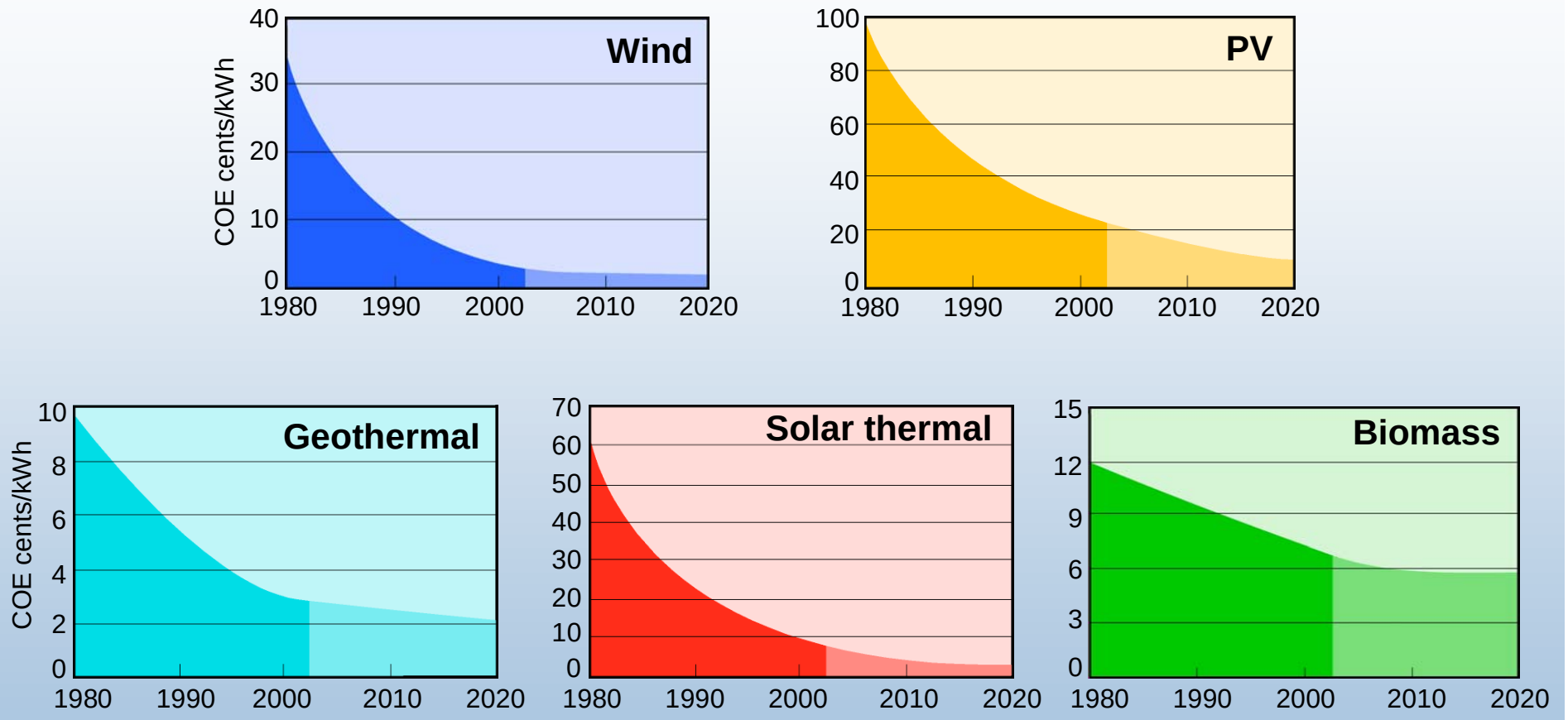
Renewable Energy Cost Trends

Levelized cents/kWh in constant $2000[1]



Source: NREL Energy Analysis Office (www.nrel.gov/analysis/docs/cost_curves_2002.ppt)
[1]These graphs are reflections of historical cost trends NOT precise annual historical data.
Updated: October 2002

EAO Energy Analysis Office
Understanding Energy Issues

NREL National Renewable Energy Laboratory

Ocean Renewable Systems

In Europe, industry-academic consortiums work in conjunction with government to develop and test the technologies, and then to promote its usage.

In Oregon, the State DOE, Oregon State University, Bonneville Power Administration, Utilities and EPRI formed a wave energy coalition.

In Virginia, collaboration among the established industries and academic institutions of the Hampton Roads area, with the support of the government of Virginia, could create a center to incubate and develop the offshore renewable technology industry.

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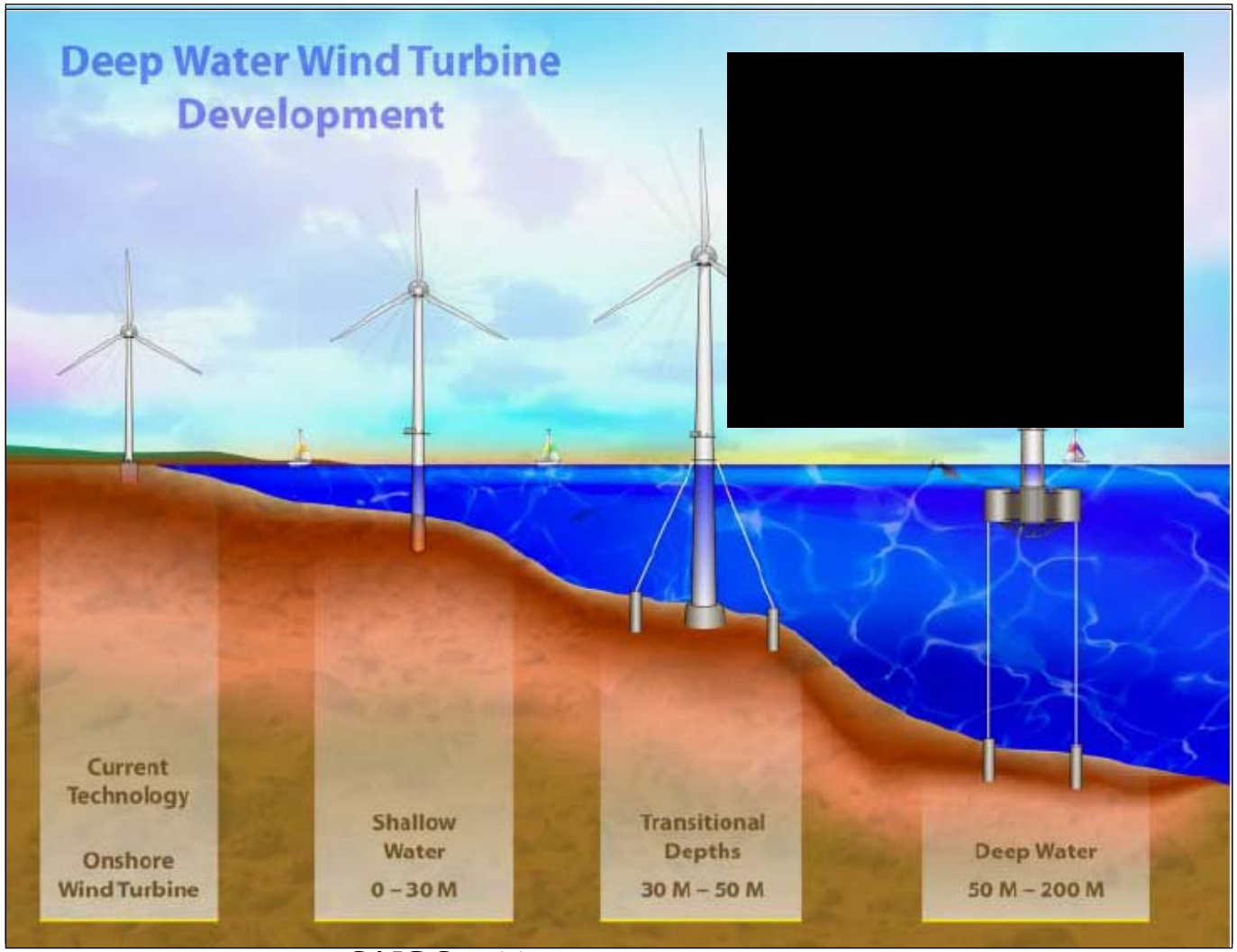
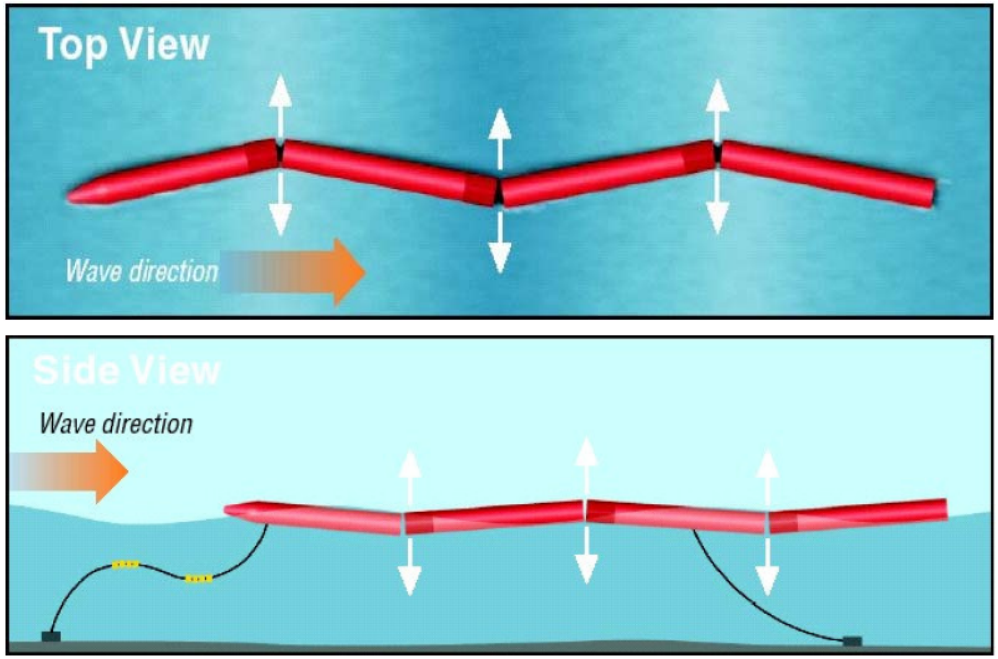
Ocean Renewable Systems

- Wind



Pelamis Device

The Pelamis is a freely floating hinged contour device. The four sections move relative to each other and this motion is converted at each hinge point to electricity by a digitally controlled hydraulic power converter system.



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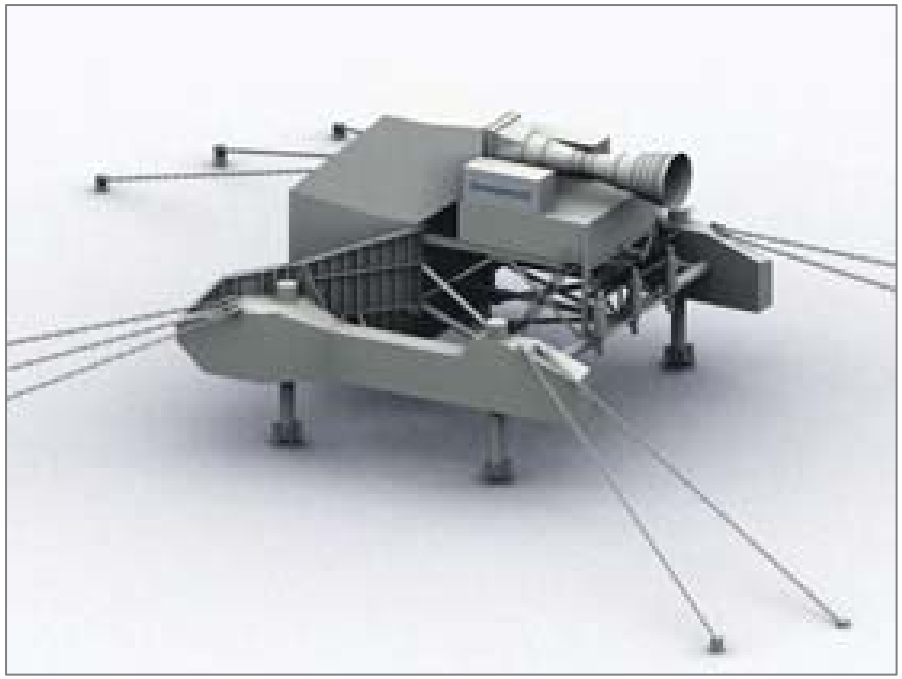
Ocean Renewable Systems

- Wave



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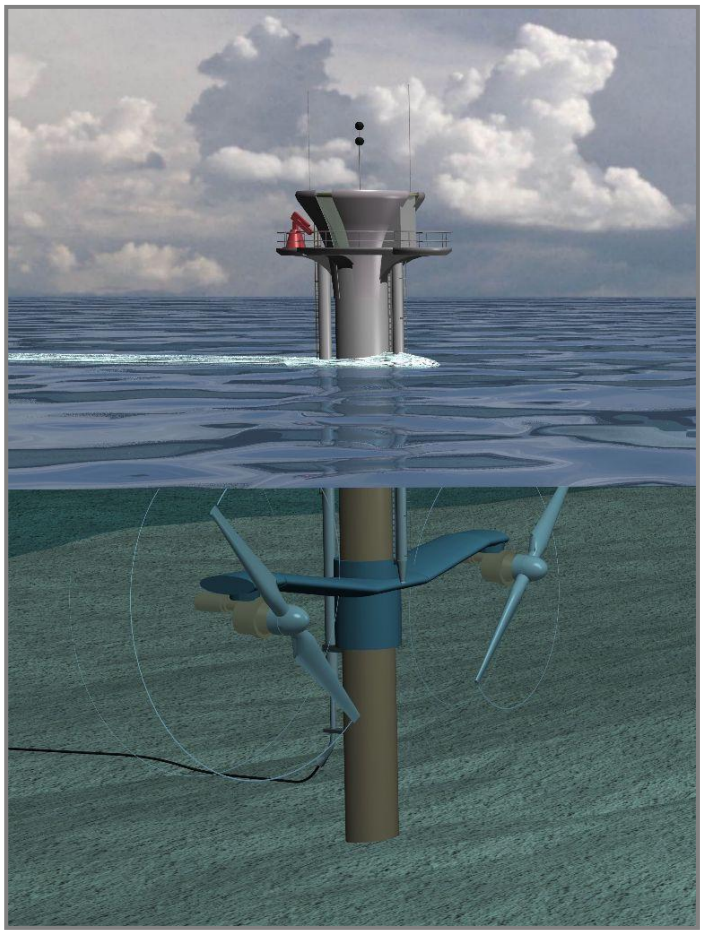
Ocean Renewable Systems

- Tidal-in-Stream (current)



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Oregon State University Wave Park

In collaboration with the Oregon Dept of Energy and EPRI, OSU has proposed an Ocean Energy Research Development and Demonstration Center off Gardiner (already tied to Virginia Tech)

Pilot project to determine wave energy feasibility

- Test the Permanent Magnet Linear Generator Buoy
- Determine operational costs / determine survivability
- Testbed for additional wave energy technologies

Co-locate with commercial wave energy farm

- Pelamis devices

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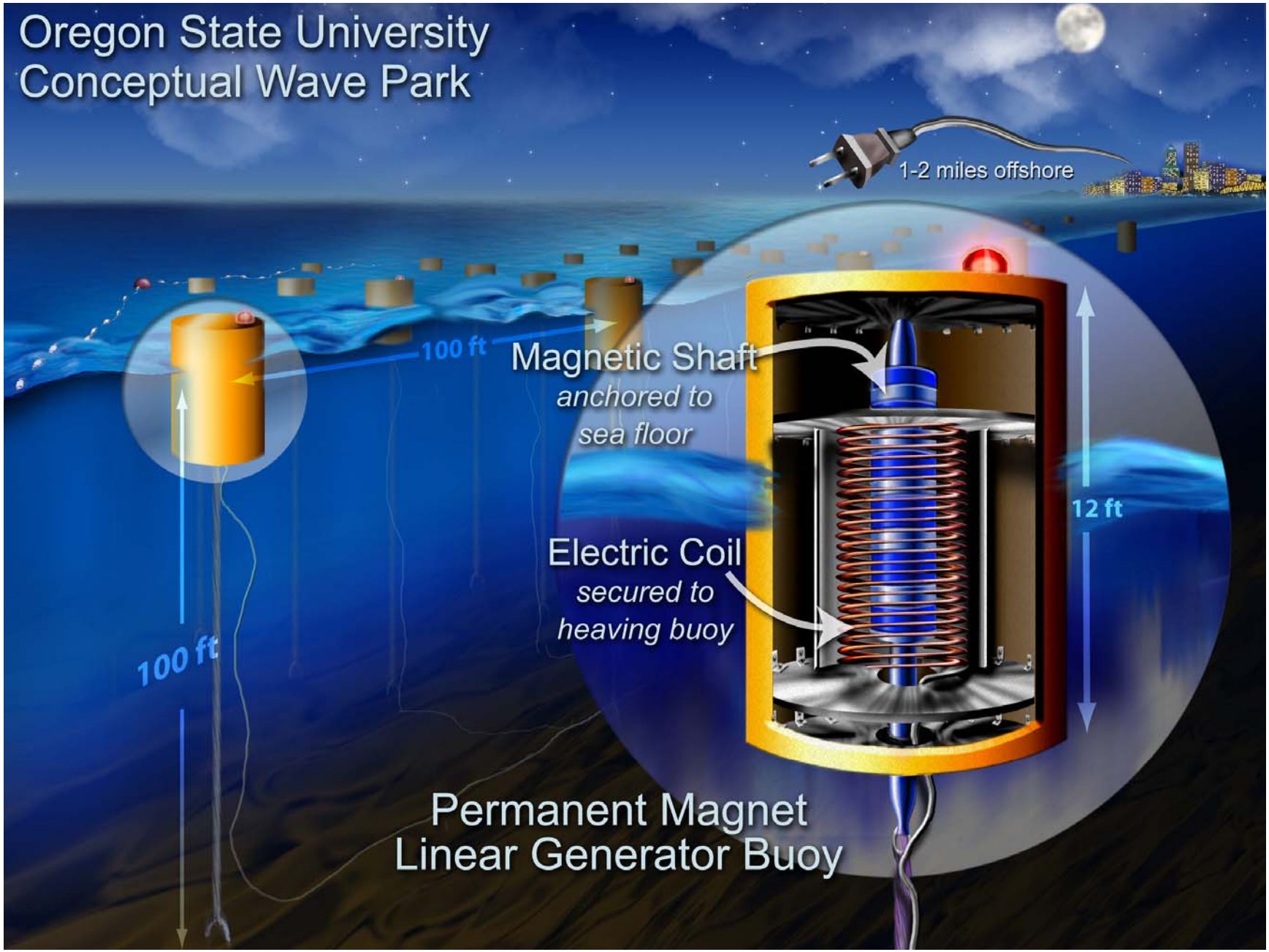
Oregon State University
Conceptual Wave Park
1-2 miles offshore
100 ft
Magnetic Shaft
anchored to
sea floor
12 ft
Electric Coil
secured to
heaving buoy
100 ft
Permanent Magnet
Linear Generator Buoy

Virginia Opportunities

As applied to Virginia:

Studies have shown that the coast of Virginia has the necessary conditions to develop a renewable offshore energy industry:

- Significant offshore wind
- Wave and current resources to produce effective energy levels
- Proximity to major load centers
- Major maritime industry
  - Heavy manufacturing in shipyards
  - Engineering and science skill sets
  - Potential for an R&D role in the future of this emerging industry with world market

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Recommendations / Next Steps

- Establish a coalition of state government, industry and academia to map a strategy
- Develop an Engagement Strategy
  - Local / State / Federal (congress, DOE, NSF)
  - Potential Partners / Small Business Technology
- Consider funding VA universities to begin studies on technology application, prototyping, placement and environmental assessments for maturing technologies

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BACK UP MATERIAL

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Renewable Electricity Technology Cost Trends

Chart Notes, Page 2

General Observations

- The renewable technology cost trends typically show a steep decline from 1980 to the present. Projections show this decline to continue, but at a slower absolute pace as the technologies mature.

- Historic cost of energy trends reflected in this chart are in broad agreement with the trends published in “Winner, Loser, or Innocent Victim? Has Renewable Energy Performed as Expected?“ Renewable Energy Policy Project, Report No. 7, April 1999.

Technology Specific Notes

- Wind technology cost projections represent wind power systems in locations with Class 6 resources. Low wind-speed turbine technology is under development, which will make available large amounts of usable wind resources that are closer to transmission. Lower costs will result from design and technology improvements across the spectrum from foundations and towers, to turbine blades, hubs, generators, and electronics.

- Biomass cost projections are based on gasification technology. Lower costs will result from technology improvements indicated by current pilot plant operations and evaluation, including improvements in feedstock handling, gas processing/cleanup, and overall plant design optimization.

- Geothermal cost projections are for Flash technology. Cost reductions will result from more efficient and productive resource exploration and characterization as well as from continued improvements in heat exchangers, fluid-handling technologies, turbines, and generators.

- Solar thermal cost projections are for Parabolic Trough and Power Tower Technologies and are based on a detailed due-diligence study completed in 2002 at the request of DOE. Cost reductions will result from improved reflectors and lower-cost heliostat designs, improved solar thermal receivers, heat exchangers and fluid handling technologies, and turbines and generators, as well as from volume manufacturing.

- Photovoltaic cost projections are based on increasing penetration of thin-film technology into the building sector. Likely technology improvements include higher efficiencies, increased reliability (which can reduce module prices), improved manufacturing processes, and lower balance of system costs through technology improvements and volume sales.

Ocean Renewable Systems

Operational and Prototype Systems in Europe:

- Horns Rev / Denmark (wind)
- UK (wind)
- Pelamis - Ocean Power Delivery - EMEC Orkney, Ireland
- Wave Dragon– WaveDragon - Denmark
- Wave Swing MK I – TeamWorks – Portugal

Prototype and Planned in the US:

- Winergy / Virginia (wind)
- New Jersey (wind)
- Cape Wind / Massachusetts (wind)
  - 130 turbine, 24 square mile farm off Nantucket
- PowerBuoy – Ocean Power Technology – Oahu HI
- GreenWave – Energetech – Point Judith RI
- Aqua Energy, Makah Bay / Washington (wave)
- Oregon Wave Park (wave)

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ALASKA

Who: EPRI Assessment Study

What: Tidal-in-Stream Energy Conversion

Output: unknown

Where: Cook Inlet, Anchorage

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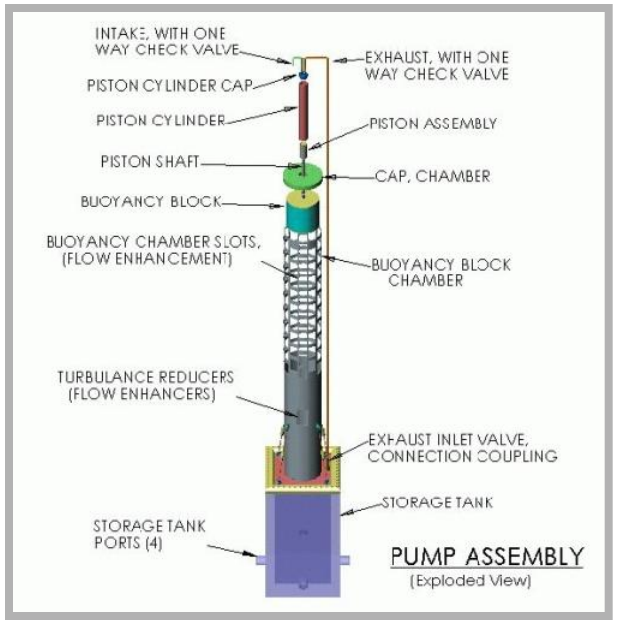
CALIFORNIA

Who: Independent Natural Resources, Inc.

What: Seadog Wave Pump

Output: unknown

Where: Table Bluff, Eureka



Seadog Wave Pump

Who: EPRI Assessment Study

What: Wave

Output: potential 10,000 – 20,000 MW

Where: Ocean Beach, San Francisco

Economic feasibility studies have been performed for a 30 MW wave converter to be located at Half Moon Bay. Additional smaller projects have been discussed at Fort Bragg, San Francisco and Avila Beach.

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CONNECTICUT

Who: EnergeTech, Connecticut Clean Energy Fund

What: shoreline is less than optimal, but the state wants to become a major manufacturer and distribution point for wave and other ocean energy technologies (tidal and OTEC)

Connecticut Clean Energy Fund

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HAWAI'I

Who: Ocean Power Delivery (OPD)

What: Pelamis Wave Energy Converter

EPRI Feasibility Study

Output: 750 kW

Where: Makapuu Pt, Oahu

Pelamis Wave Energy Converter

OPT Wave Power Buoy

Who: Ocean Power Technologies (OPT)
What: Wave Power Buoys
Output: 150 kW per buoy,
Where: Kaneohe Bay, Marine Corps Base, Oahu
Just received additional $2.8 M from the Navy for its ongoing contract to build a 1 MW wave power station

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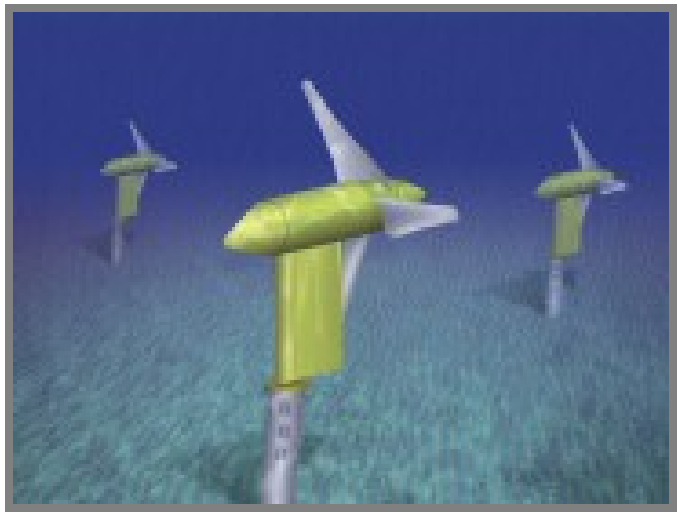
MARYLAND

Who: Verdant Power, CRADA with US Navy

What: want to become a major developer and tester of ocean energy technologies

Where: David Taylor Model Basin, in Carderock



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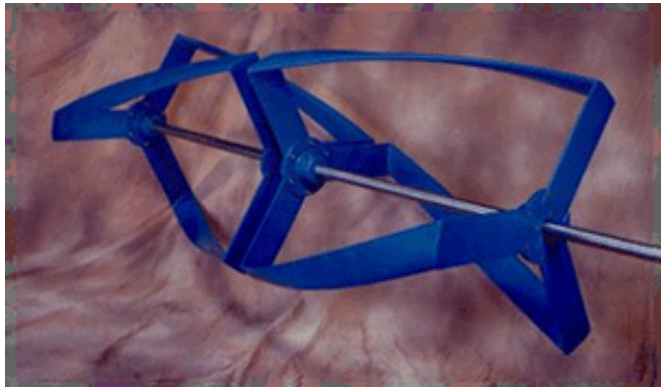
MASSACHUSETTS

Who: Verdant Power in partnership with GCK Technology
What: Gorlev Helical Turbine with operating platform with drive train, generators, and power conditioning systems.
First test of an integrated water to wire system
Output: up to 1 MW
Where: Merrimack River; intended to be replicated at other sites in MA



Gorlev Helical Turbine

Who: CapeWind, the Offshore Wind Energy Consortium (OWEC)
What: Cape Wind Offshore Wind Farm
Output: 420 MW, 130 turbines in depths to 50 ft
Where: off Nantucket

Who: GE Global, with Renewable Energy Trust support
What: deep water offshore wind farm
Output and location: TBD

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MAINE

Who: EPRI Assessment Study

What: Tidal-in-Stream Energy Conversion

Output: unknown

Where: Passamaquoddy Bay

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NEW JERSEY

Who: Ocean Power Technologies (OPT)

NJ Board of Public Utilities provided a $500,000 grant in 2003 for feasibility study

What: Electricity Generating Power Buoy

Output: unknown

Where: Tuckerton

Installed and in operation, the OPT PowerBuoy™ is invisible from the shoreline

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NEW YORK

Who: Verdant Power in cooperation with NYSERDA (New York State Energy Research & Development Authority), NY State Power Authority, Columbia University, EPRI, DOE's INEEL and ORNL, the Hudson Valley Technology Development Center, the USN David Taylor Model Basin, and the National Hydropower Association

What: Prototype surface mounted axial flow turbine system

rotors have a yaw system to rotate and capture energy from both ebb and flow tides

Output: 1st phase: 16 kW per 10 ft diameter rotor

2nd phase: 35 kW per 16 ft diameter rotor

Goal: 5 – 10 MK turbine field

Where: East River, initially tested in the Chesapeake (2002)

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NEW YORK, continued

Who: Long Island Offshore Wind Initiative

What: 40 turbines, in 60 ft depths

Output: approx. 3.6 MW generated by each 250 ft diameter rotors; 140 MW total for 40 turbines

Where: Offshore Long Island

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OREGON

Who: OSU in partnership with EPRI, and Oregon DOE

What: Wave Research and Demonstration Facility

Output: goal: 250 kW per Magnetic Wave Energy Buoy

Where: Gardiner

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RHODE ISLAND

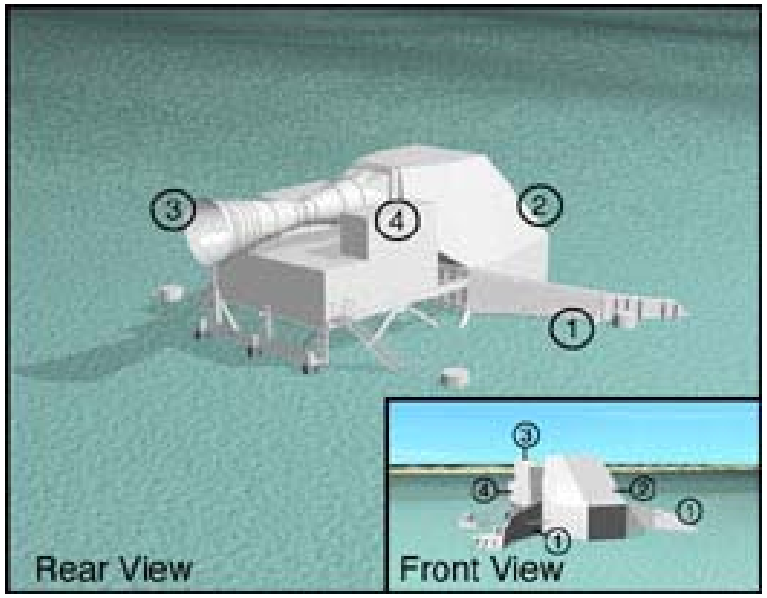
Who: EnergeTech, funded by Rhode Island, Massachusetts and Connecticut renewable energy funds

What: GreenWave 3 year Demonstration Project

Output: 50 kW

Where: Harbor of Refuge,

near Pt Judith



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WASHINGTON

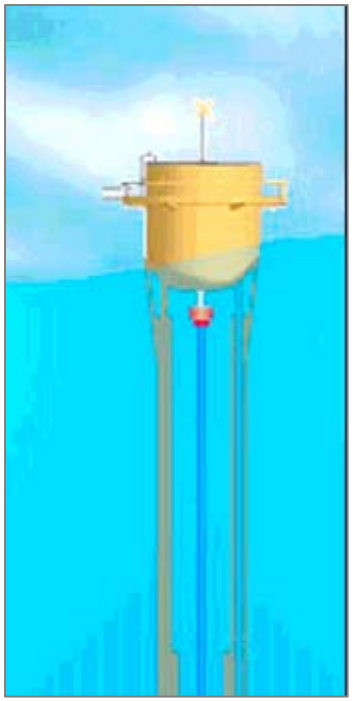
Who: AquaEnergy in cooperation with Clallum County PUC and the NW Energy Innovation Center

Strategic Partners: Dunlop Oil and Marine Systems, Ramboll, AXYS Environmental Systems

What: AquaBuoy demonstration power plant

Output: 4 buoys at 250 kW per buoy, for a total of 1 MW

Where: Makah Bay, at 150 – 200 ft depth



Who: EPRI Assessment Study

What: Tidal-in-Stream Energy Conversion

Output: unknown

Where: Tacoma Narrows, Tacoma

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