Wave Energy Opportunities and Developments

Wave Energy Lead Professors:

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School of Electrical Engineering and Computer Science (EECS)

Oregon State University (OSU)

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Solomon Yim, Alex Yokochi, and an

Excellent Multidisciplinary Group of *Undergraduate and Graduate Students*

Oregon Coastal Community Contributors:

Port Liaison Project Team (fishermen and crabbers)

Newport Wave Energy Team (local government, utilities, other stakeholders)

OSU's multidisciplinary wave energy team is pursuing Wave Energy innovation in four thrust areas:

1) Researching novel direct-drive wave energy generators

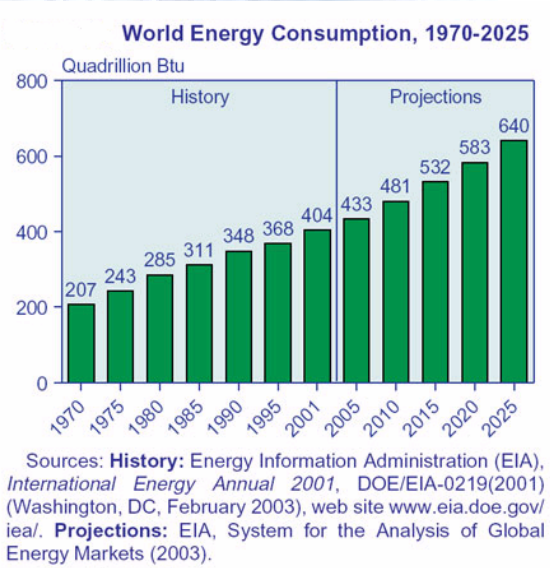
2) Developing an action plan for a National Ocean Wave Energy Research and Demonstration Center ***(Goal)***

-Essential for the U.S. to be a leader in wave energy
-Currently very little investment by Federal Government/DOE compared to the rest of the world (OSU has received NSF, DOE STTR, BPA funding)

3) Working closely with the Oregon Department of Energy (ODOE) and a variety of stakeholders to promote Oregon as the optimal location for the *nation's first* commercial wave parks.

4) Examining the biological and ecosystem effects of wave energy systems

Introduction



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2001*, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2003).

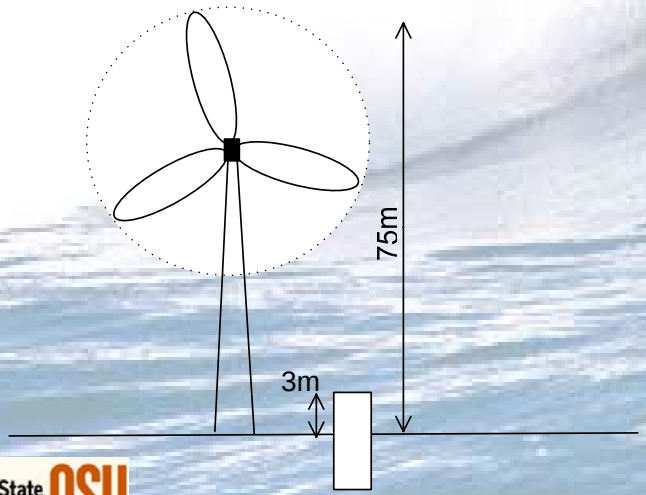
New forms of Energy are required !

- ***It is estimated that if 0.2% of the ocean's untapped energy could be harnessed, it could provide power sufficient for the entire world.***

Compared to Other Renewables, Wave Energy Advantages:

Higher energy density, availability (80 – 90%) and predictability

- ***OSU is an Excellent Location to conduct ocean wave energy extraction research:***
- ***Highest Power University-Based Energy Systems Lab***
- ***O.H. Hinsdale Wave Research Lab***
- ***Hatfield Marine Science Center***
- ***Wave energy potentials of the Oregon coast.***



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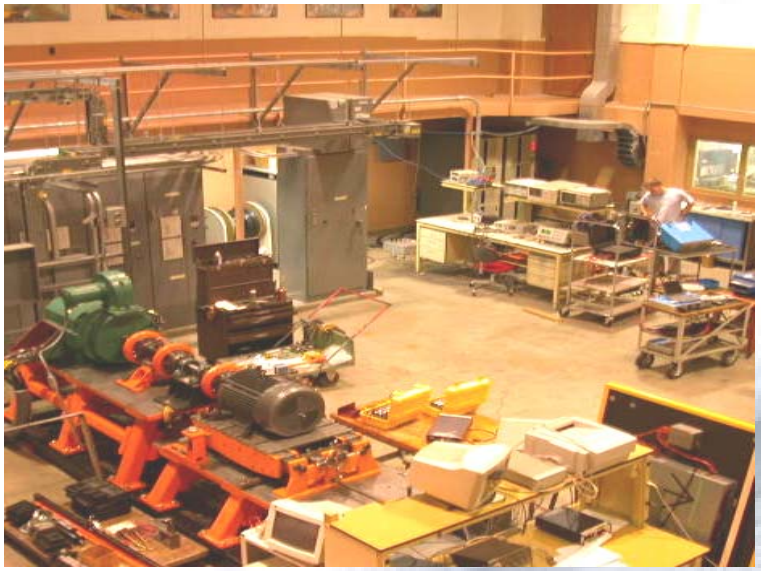
OSU Strategic Facilities to Advance Wave Energy



Motor Systems Resource Facility (MSRF)

O.H. Hinsdale Wave Research Lab (HWRL)

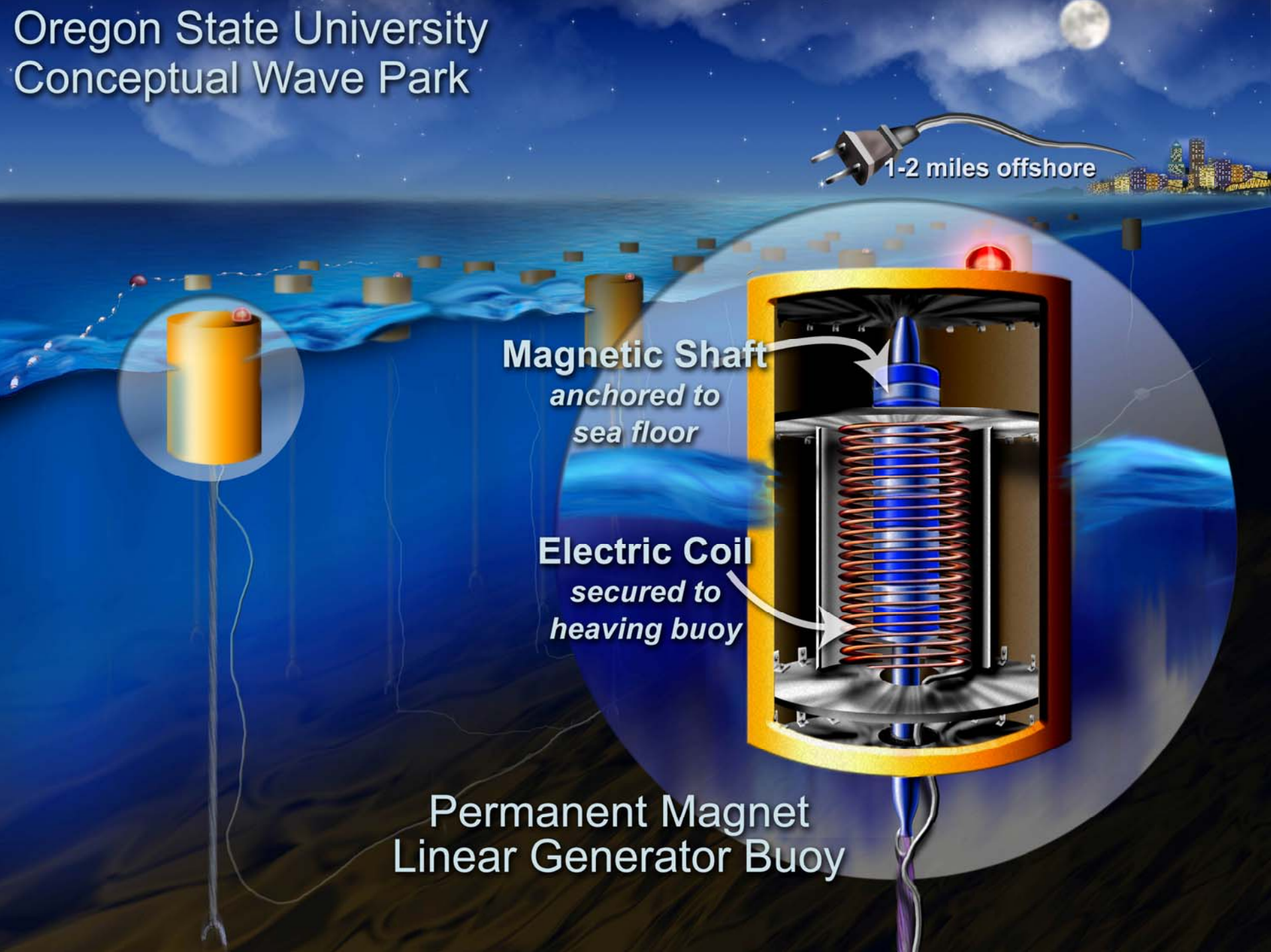
Wave Energy Extraction Technologies

Point Absorber (OPT, Finavera)

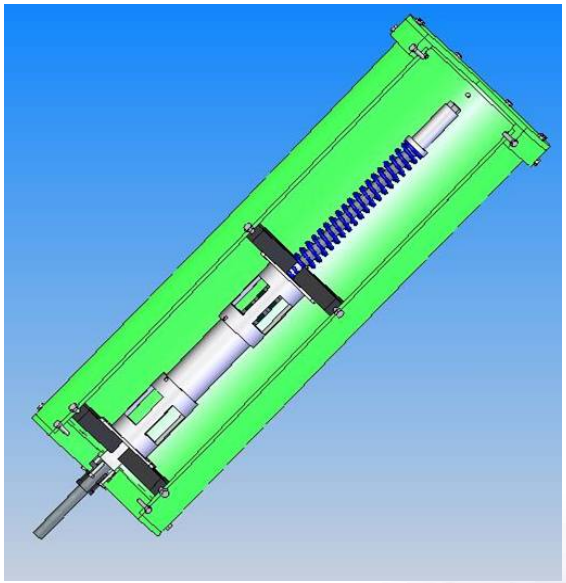
Oscillating Water Column (Energetech/Oceanlinx)

Attenuator, OPD

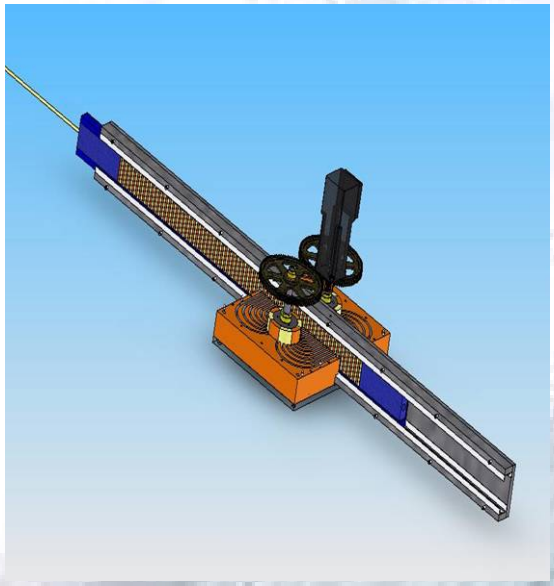
Overtopping, Wave Dragon


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

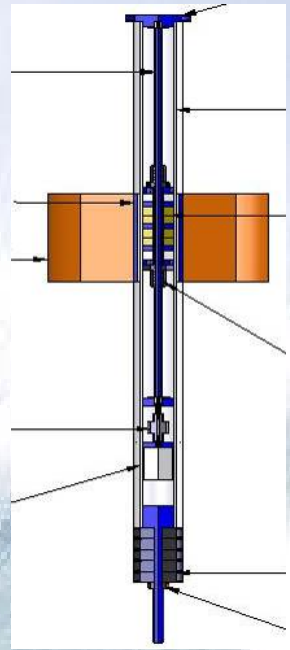
OSU's Direct Drive Buoy Approaches (Now working on 5th and 6th prototypes)



Permanent Magnet Linear Generator



Permanent Magnet Rack and Pinion Drive



Contact-less Force Transmission

Licensing through Columbia Power Technologies
(Further Wave Lab and Ocean Testing Planned this summer)

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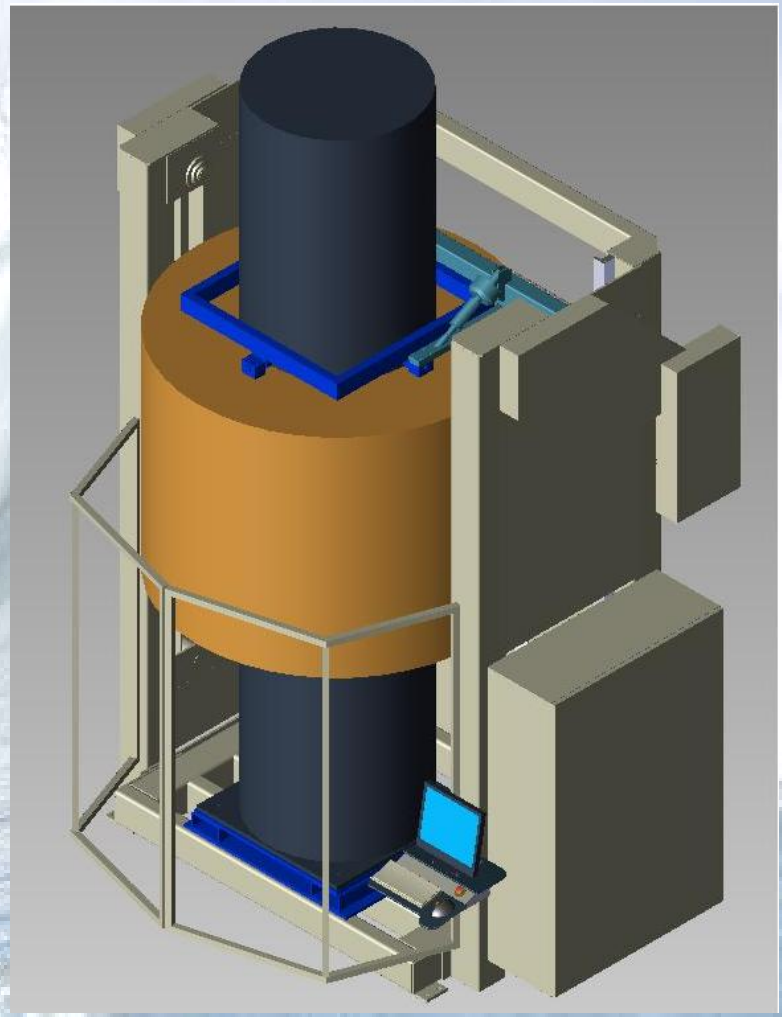
OSU Wave Energy Linear Test Bed

Creates the relative linear motion between a center “spar” and a surrounding “float” (active components)

Enables dynamic testing, using captured wave profiles, while simulating the actual response of ocean waves

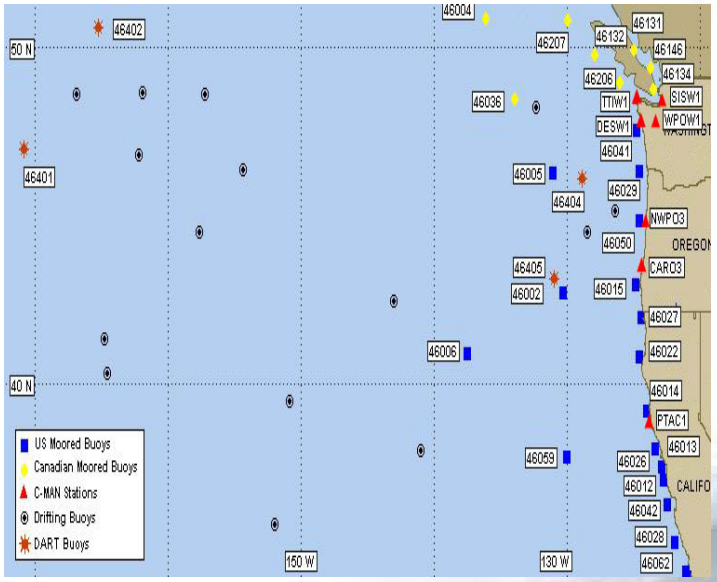
Specifications:

- 10kW with a 50% efficient device, and up to 19kW @ 95% efficiency, will also test generator sections
- 1m/sec @ 20,000 N Thrust (4500 lbf)
- 2m/sec @ 10,000 N Thrust (2250 lbf)
- Modes: Velocity, Point-Point, & Force Control (through feedback from load cells/force meters)
- 2m relative motion/stroke (6.5 feet)
- Upper & Lower Gimbal mounting (for alignment variation)
- 14ft tall x 10.5ft wide x 8.5ft deep

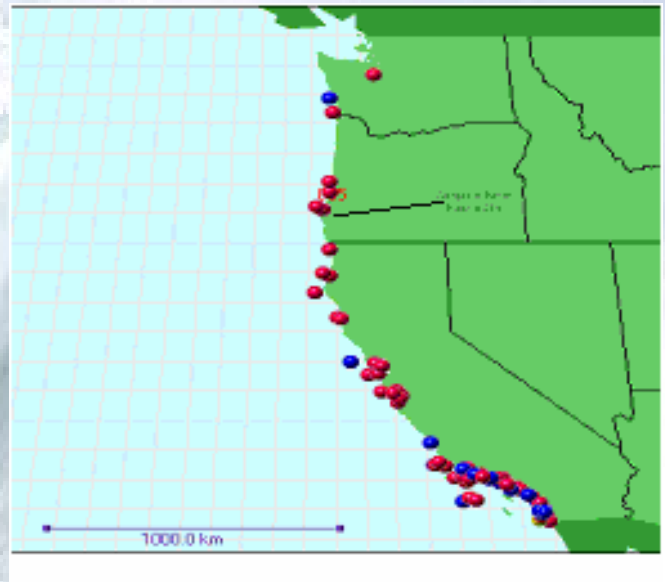


Design: Mundt and Associates Inc.

Power from Ocean Waves
Available Resource off Oregon Coast



NDBC Data Buoys

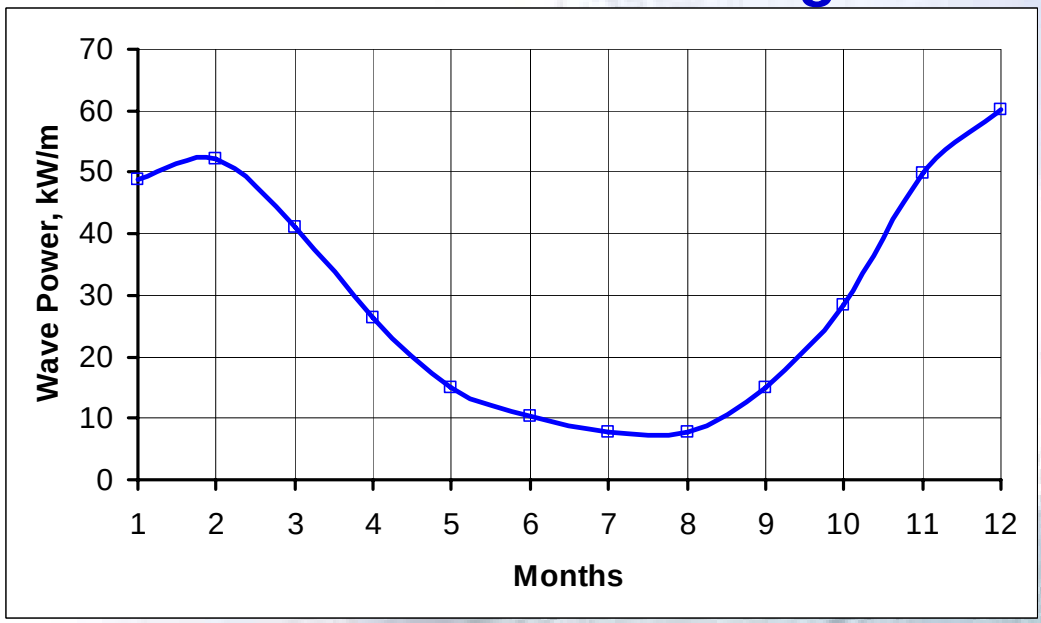


CDIP (SCRIPPS) Data Buoys

- **50% of the US population lives within 50 miles of the coast**
- **Wave Energy Resource Assessment Study carried out for Oregon Coast**
  (Note that there are already a number of ocean monitoring buoys in the ocean)
- **Report confirmed that Oregon has some of the richest ocean wave energy extraction sites in the world**

Power from Ocean Waves
Available Resource off Oregon Coast

Seasonal variation – Good match for the NW load demand



Data buoys are 2-200mi off shore, with waves traveling 15-20mph, gives 10+ hours forecast time for buoy generators located 2 mi out

(wave data From National Data Buoy Center, Power estimated from 5 buoys off the Oregon coast over past 10 years)

Power from a wave is $P = \frac{\rho g^2 T H^2}{32\pi}$ W/m of crest length (distance along an individual crest)

ρ = the density of sea water = 1025 kg/m^3

g = acceleration due to gravity = 9.8 m/s^2

T = period of wave (s) (averages 8s in the winter to 6s in the summer)

H = wave height (m) (averages 3.5m in the winter to 1.5m in the summer)

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Wave Energy preliminary permits filed with FERC

Finavera Renewables

Makah Bay WA (1MW)

Oceanlinx Ltd

Florence OR (15MW)

Douglas County

Douglas County OR (20-180MW)

Coos Bay OR (100MW)

Humboldt CA (100MW)

Lincoln County OR (20-180MW)

Lincoln County

Oregon Wave Energy Partners II Newport OR (100MW)

Reedsport OPT Wave Park OR (50MW)

Oregon Wave Energy Partners Coos Bay OR (100MW)

Fairhaven Ocean Power Humboldt CA (20MW)

Pacific Gas & Electric

PGE Humboldt WaveConnect (5-40MW)

PGE Mendocino WaveConnect (5-40MW)

Ocean Power Technologies

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Wave Energy Park Environmental Monitoring Protocol Development

Effects of Electromagnetic Fields:

- Sea bird attraction?
- Marine Mammal attraction, repulsion. Changes in whale migration pathways.
- Change in larval dispersion.
- Change in fish use of area, change in fish migration, change in fish reproductive success.
- Shark attraction.

Effects from construction/deployment/service of cables

- The most destructive aspect of laying natural gas lines is during the deployment of lines; the seafloor with its inhabitants are altered as the line is laid with large machinery. Similar effects could be expected with lying of electric cables if similar methods are used.
- Impact on invertebrates or seafloor structure from placement of anchors and power lines.
- Creation of a sediment plume and resulting impacts on fish/invertebrates.

Effects of the physical structure of the buoy field.

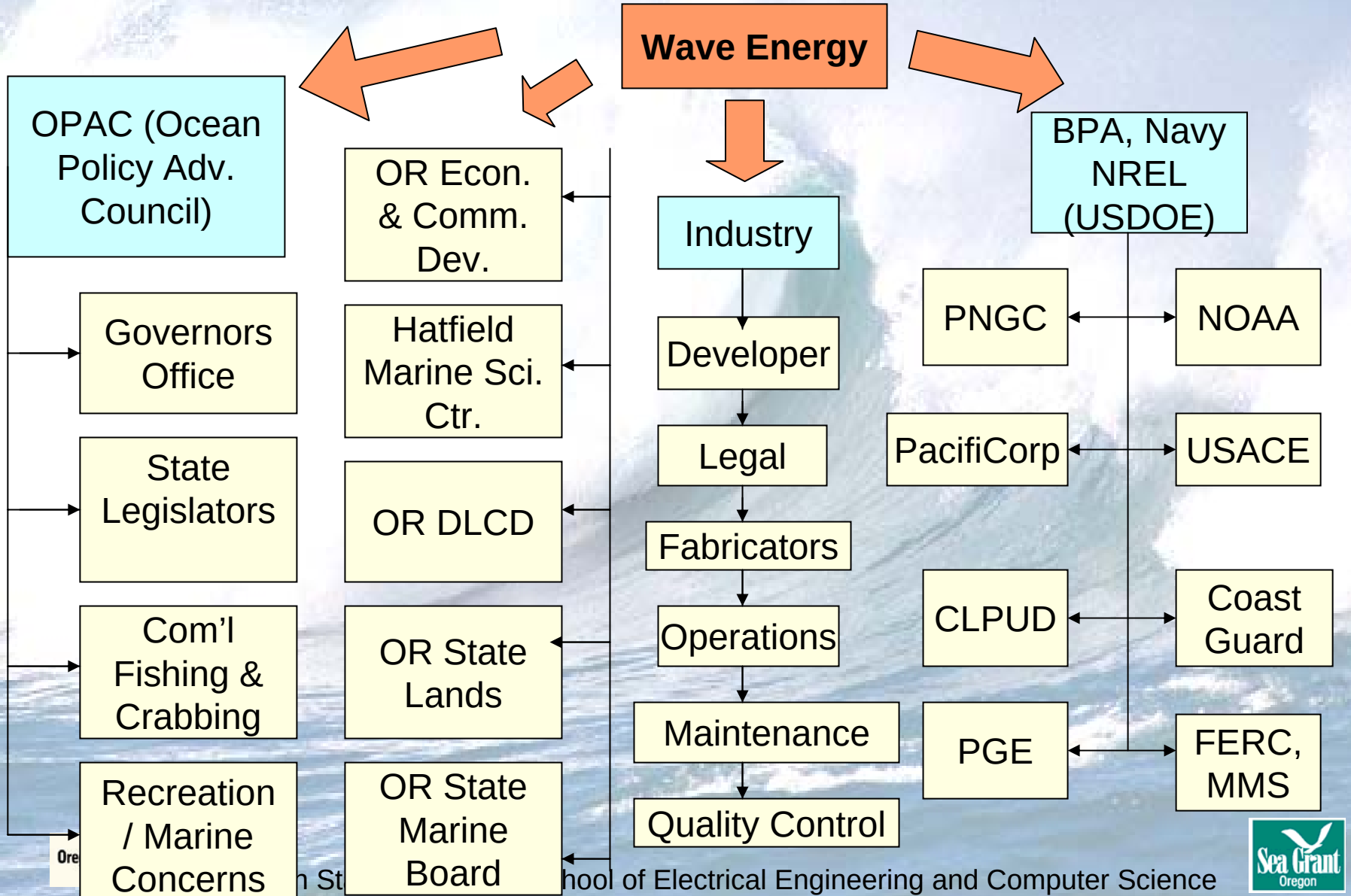
- Entanglement of marine mammals: whales, dolphins.
- Effects of using antifouling agents: introduction of toxics.
- Creation of a new community:
  - Does the new structure act as a filter for larval dispersal so that recruitment in surrounding areas is decreased?
  - Will the structure create a new habitat that will facilitate recruit and production of marine organisms?

Monitoring needs to be scale appropriate.

- Impacts from small scale may not be scaleable to large energy generation farms.
- Monitoring program needs to be adaptive in design to respond to evolving impacts

Monitoring needs to compare manipulated and un-manipulated areas.

Oregon Wave Energy Industry Collaboration



Wave Energy Summary

- The Federal Government needs to significantly increase the investment in ocean wave energy R&D.
- A National Wave Energy Research and Development Center is necessary for the U.S. to lead the world in Wave Energy Research, Development and Production.
- Oregon is a “sweet spot” for ocean wave energy (facilities, successful research, wave climate, collaboration).
- The State of Oregon is currently reviewing a proposal to invest state dollars in ocean wave energy research, evaluation, and streamlining the permitting process.