Industry Status: Ocean Wave and Tidal and Open-Ocean Marine Hydrokinetic Technologies - US and International

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Types of Marine or Ocean Renewable Energy

"*Marine or Ocean Renewable Energy*" is a term used to describe all forms of renewable energy derived from or at sea including:

Scope of this briefing

- Wave
- Tidal In-Stream or Current
- Open-Ocean In-Stream or Current
- River In-Stream or Current
- Tidal Hydropotential (Barrage-type)
- Ocean Thermal
- Ocean Salinity Differences
- Offshore Wind Energy

3 Variants of Current Energy
Basically the same type of energy conversion machine

sometimes called hydrokinetics

Some exclude offshore wind energy

What is the Industry Status in terms of Capacity in the US?

- Installed Wave and Tidal and Open-Ocean Hydrokinetic Capacity (as of June 30, 2009)
  - Wave = < 2 MW
  - Tidal Current = < 3 MW
  - Open-Ocean Current = 0

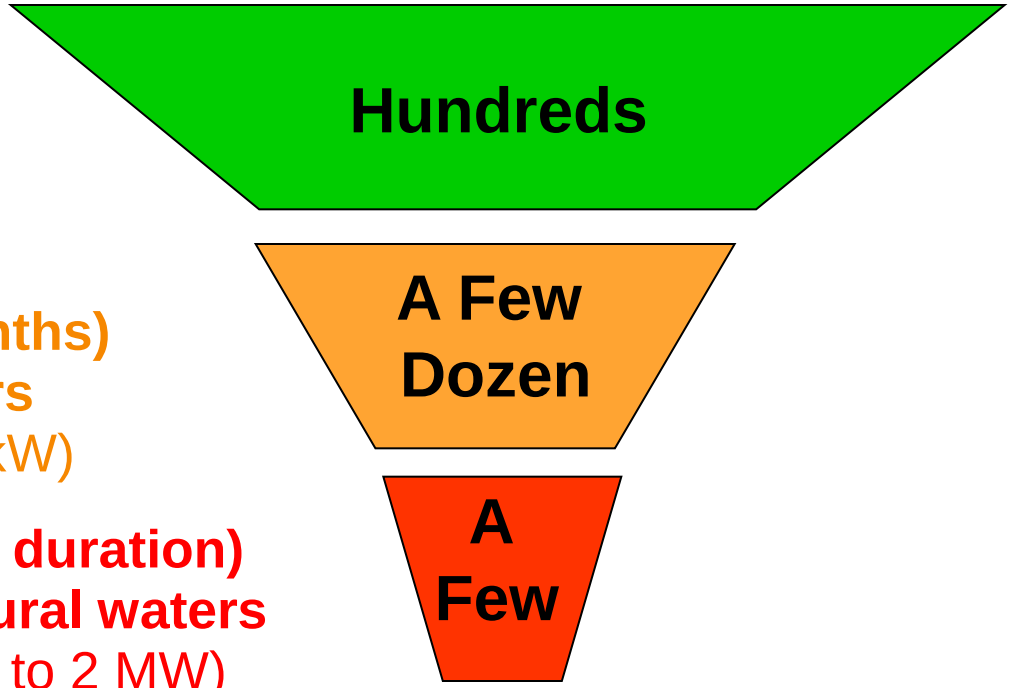
- I estimate the US could have 12,500 MW in 2025
  - Ocean Wave = 10,000 MW
  - Tidal = 500 M
  - Open-Ocean = 2,000 MW

If we solve our regulatory conundrum, the Government supports pilot scale demonstration projects and ocean energy plays on a level field with other forms of energy

What is the Industry Status in terms of Technology Development Status?

Emerging Technology with some ready for testing in natural waters

Thousand of concepts and patents on ocean energy conversion technology



Rigorous laboratory physical model tests
(1/50- to 1/5-scale)

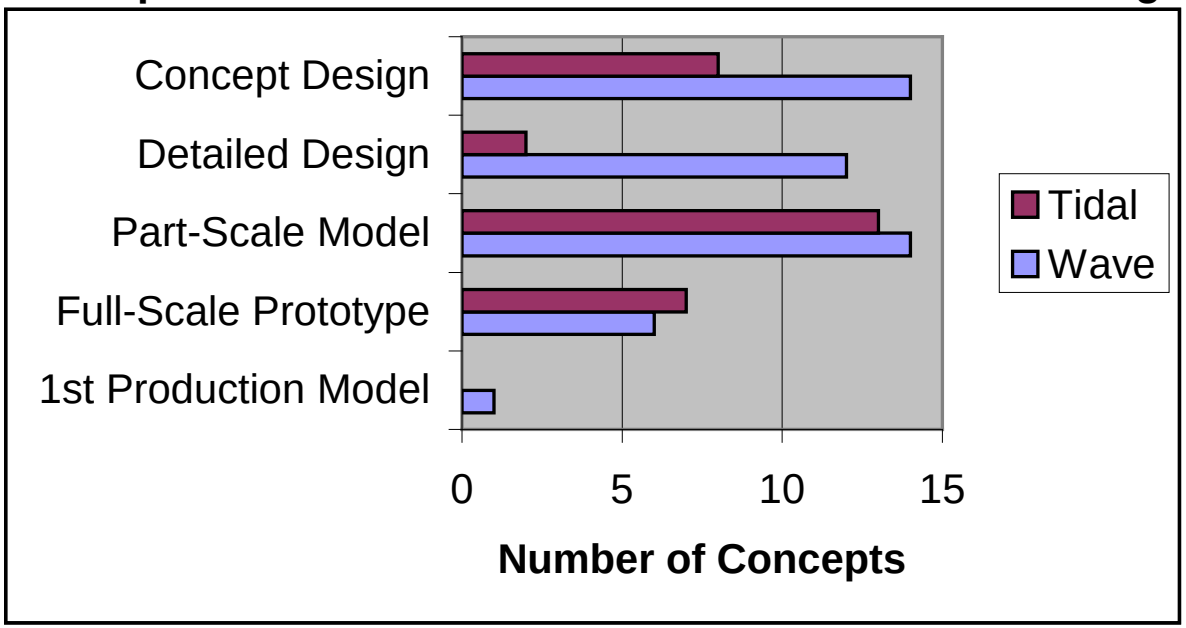
Short-term (days to months) tests in natural waters
(typically 10 kW to 100 kW)

Long-term (>1 yr duration) prototypes in natural waters
(typically 100 kW to 2 MW)

It typically takes 5 to 10 years for a technology to progress from concept-only to deployment of a long-term prototype

What do you mean by the "Emerging" Technology Development?

- Emerging Technology – Various Devices in Various Stages of Development with none of them yet commercialized



Data from the Carbon Trust Report titled "Future Marine Energy: Results of the Marine Energy Challenge: Cost Competitiveness and growth of wave and tidal stream energy" January 2007

RDD&D Needs Workshop – Oct 2008

18 Topics

- Resource Modeling
- Device modeling
- Experimental Testing
- Moorings & Sea bed attachments
- Electrical Infrastructure
- Power Take Off and Control
- Engineering Design
- Lifecycle & Manufacturing
- Installation, O&M
- Environmental
- Standards
- System Simulation
- Materials – low cost, corrosion and biofouling
- Storage
- System configuration evaluations
- Vision, Goals, Objectives and Roadmap
- Master Generation/Transmission Planning
- Education

The two highest prioritized topical areas were

1). Testing (development including experimental through pilot demonstration)

2). Environmental (which will require device testing and deployed projects)

Results in Dec 2008 EPRI Report

What is the Industry Status by Country?

- European Union countries are leading the development and commercialization of emerging ocean wave and marine hydrokinetic energy technologies. Their activities include:
  - Supporting the technology developers with funding
  - Establishing subscale and full scale test facilities
  - Establishing goals for commercialization
  - Developing roadmaps that point out the pathways to meet these goals
  - Providing financial incentives necessary to meet those goal
  - The Europeans are 10 years in front of the U.S.

- Other nations are also starting to engage. In Canada for example, the Bay of Fundy project is funded at $70 million and the first of three large scale (1 MW class) machines has been deployed. A 65kW tidal project has also been deployed at Race Rocks in BC

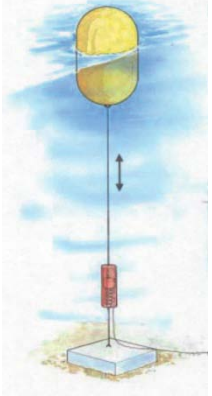
- The U.S. is starting to show signs of having similar activities as the Europeans

What affects the Performance and Cost of Ocean Wave and Marine Hydrokinetics

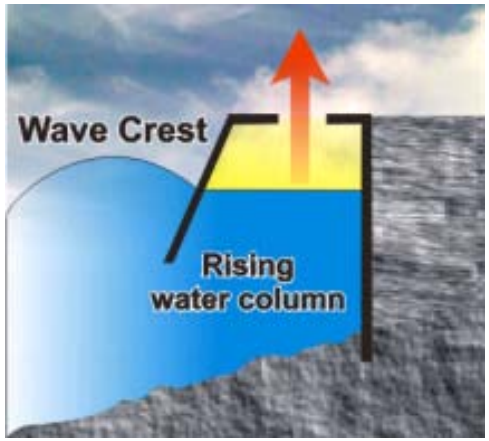
- First, I will briefly describe the energy conversion systems being developed
- Then I will address what affects the performance
- And then I will address what affects the cost

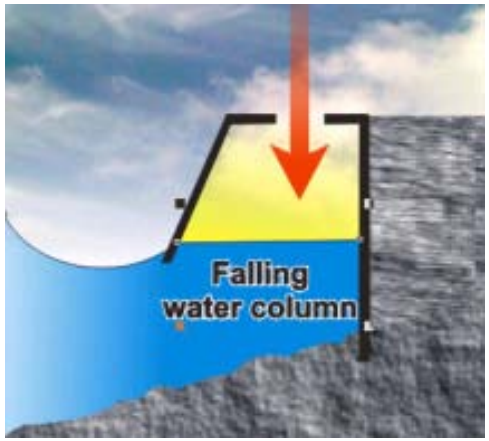
4 Primary Types of Wave Energy Conversion

Point Absorber

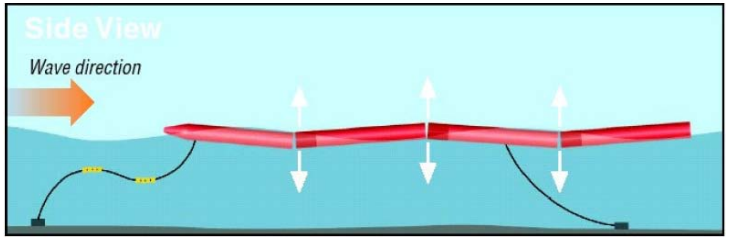


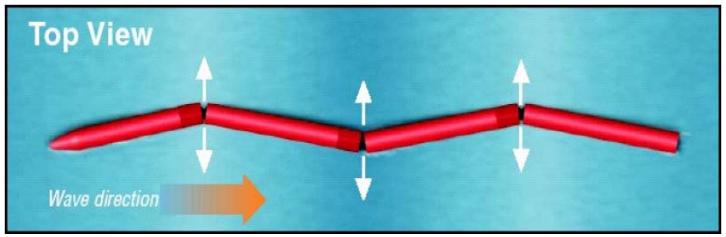
Terminator- Oscillating Water Column



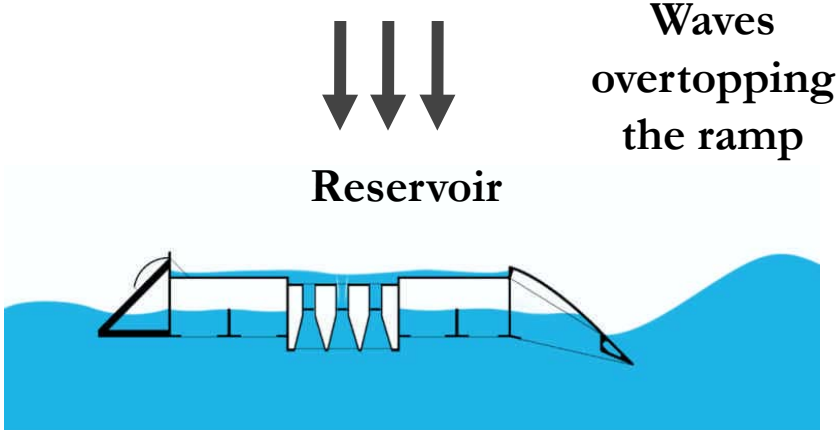


Attenuator





Overtopping



Wave Energy Conversion Technology

Ocean Power Technologies
Point Absorber

OceanLinx Oscillating Water
Column

Pelamis Linear Attenuator

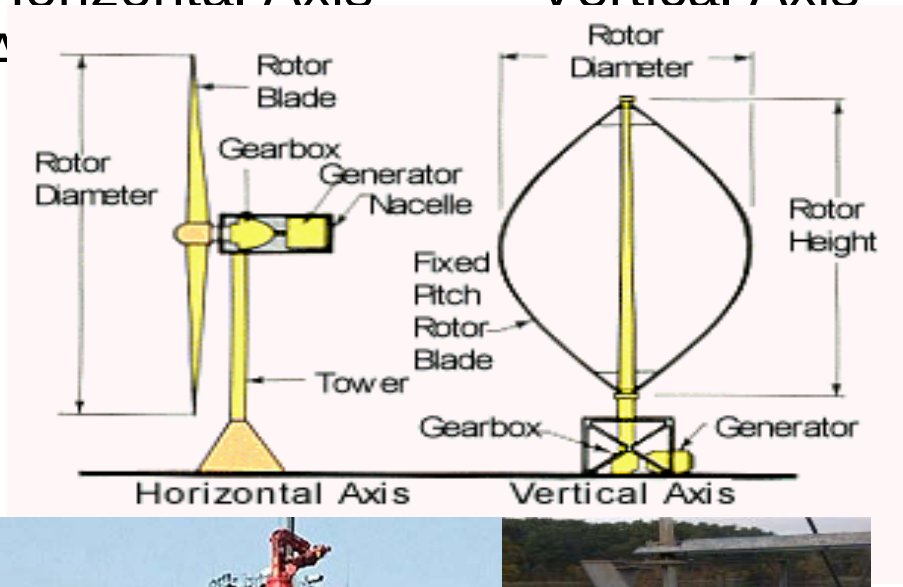
Wave Dragon Overtopping

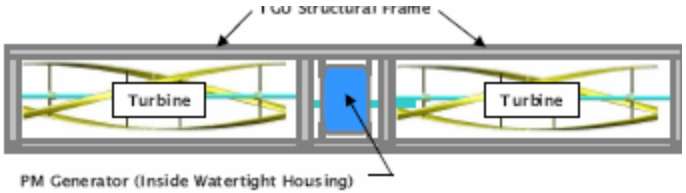
Santa Cruz Wave Pump - 1898

Operated 1898 – 1910
Solved a need – how to water local wagon roads to keep dust down
A ‘new 1910” technology put the Armstrong Brothers out of business

Three Types of Water Turbines

- Axial Cross Flow
  Horizontal Axis Vertical Axis and Horizontal
  A

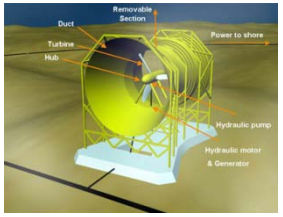


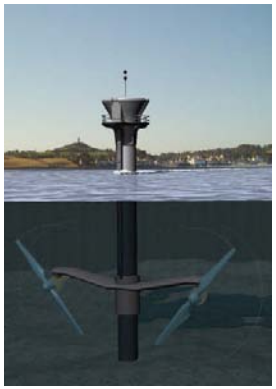


Courtesy: Marine Current Turbines, GCK and Ocean Renewable Power Corporation

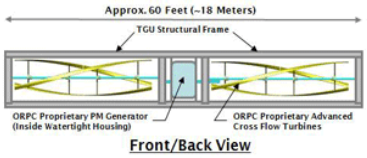
Tidal Current Turbine Technology

Courtesy: All below



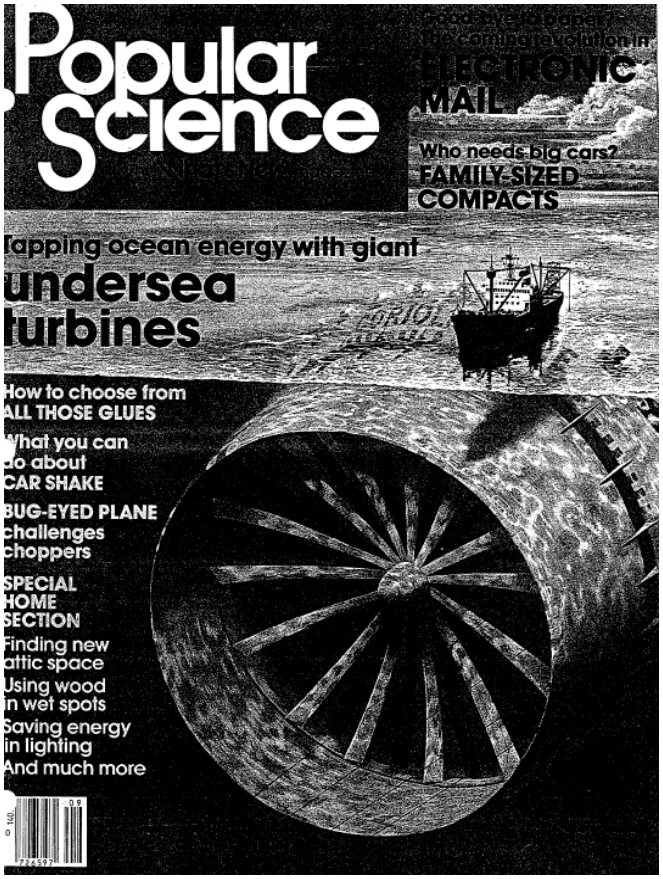


- Clean Current (h-axis, shrouded rotor)
- GCK (vertical-axis, Gorlov helical rotor)
- Lunar Energy (h-axis, shrouded rotor)
- Marine Current Turbines (h-axis, open rotor)
- Open Hydro (h-axis, shrouded open rotor)
- Ocean Renewable Power Corp (Xflow- axis)
- Ponte de Archimeda (v-axis)
- SeaPower (vertical axis, Savonius rotor)
- SMD Hydrovision (h-axis, open rotor)
- UEK (h-axis, shrouded rotor)
- Verdant Power (h-axis, open rotor)



Open-Ocean Current Turbine Technology

A Bit of History – the 1970s Coriolos Project Popular Science, Sep 1980



Today's Technology

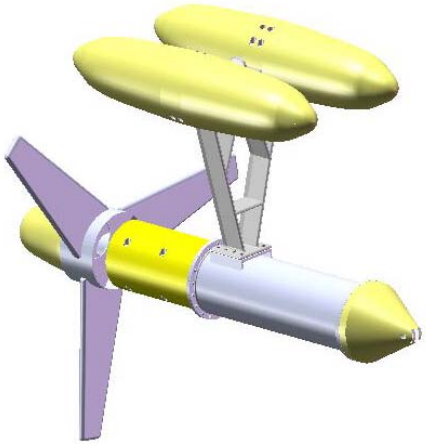
Courtesy: Florida Atlantic University

Demonstrate feasibility of extracting ocean current energy

Investigate technology gaps and hurdles

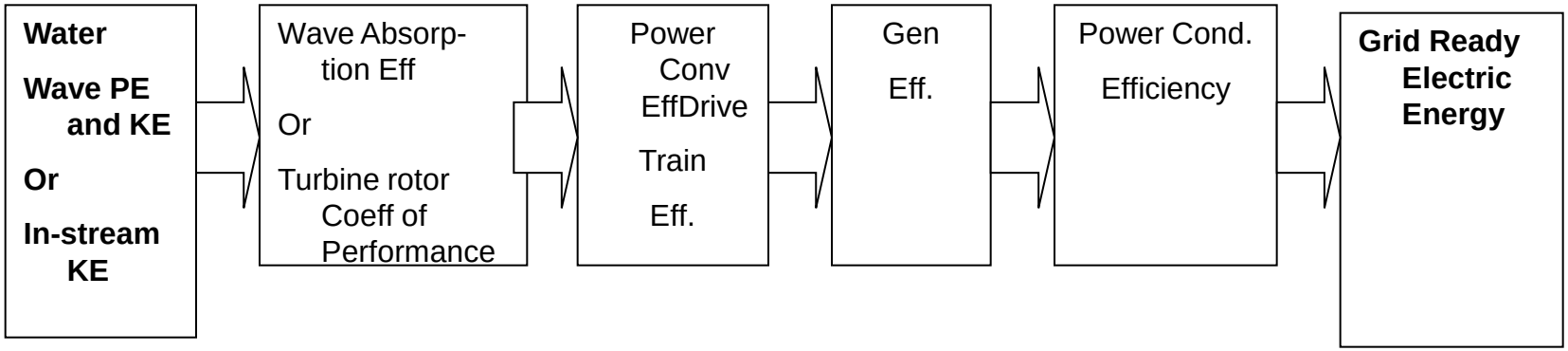
Study environmental and ecological interactions

Develop a 20 kW platform to support ocean energy technology development



What affects the performance?

- The energy recovery efficiency and performance of a wave or tidal/open-ocean in-stream conversion devices is a function of the various component efficiencies

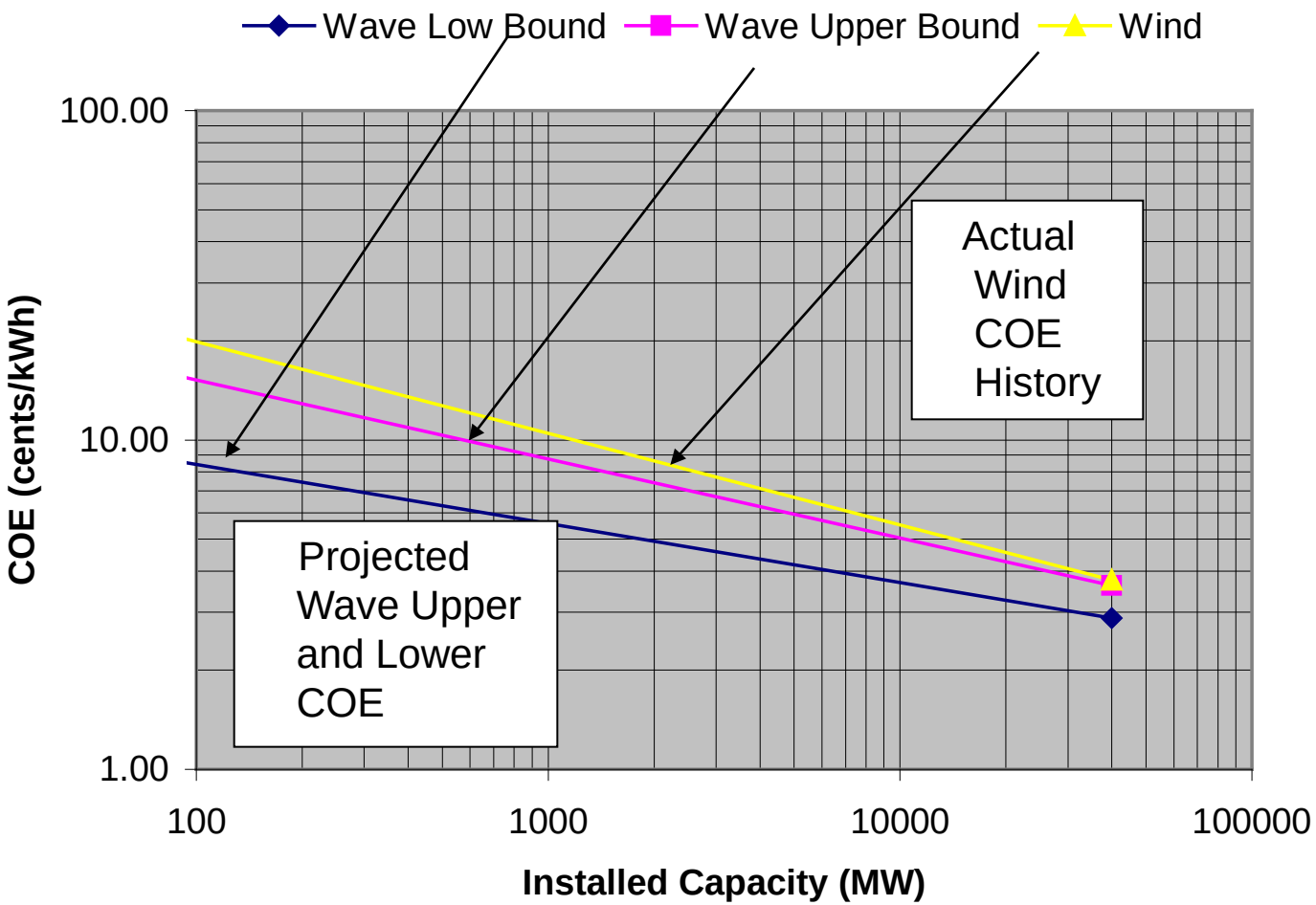


- For wave energy, a key factor is power take off controls to match the incoming frequency of the waves
- For oscillating water column wave devices and tidal and open-ocean turbines, a key factor is maximizing the the coefficient of performance of the rotor blades over the entire operating spectrum

What affects the cost?

- Power density of the resource - Ocean Wave and MHK energy has an inherent cost advantage compared to wind and solar
  - Lower initial capital cost due to the higher power density of the resource
  - However the deployment, operation and maintenance cost is higher due to the remoteness and sometimes hostility of the environment
  - The challenge to the industry is to develop highly reliable machines with low deployment and O&M costs
- Costs are also affected by many other factors including:
  - Cumulative learning
  - Size of the power plant
  - Ownership type
  - Financing costs
  - Government tax laws (rates, depreciation, etc) and incentives

Economics – Reedsport Oregon 100 MW Plant (constant 2004$ - Regulated utility – Existing Gov't Wind Incentives)



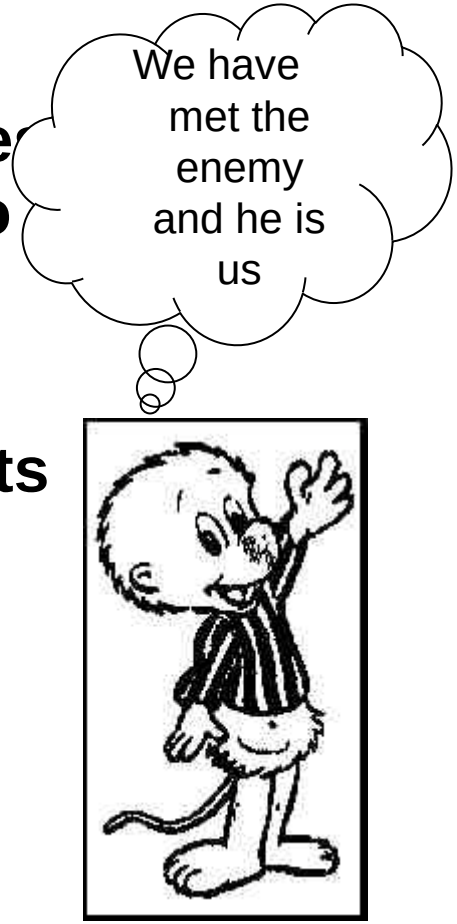
Is ocean wave and marine hydrokinetic energy cost competitive with wind energy?

- Today, Ocean Wave and MHK energy is more expensive than wind energy due to the fact that these two technologies are at very different levels of commercialization. There is well over 100,000 MW of worldwide wind power deployed to date. Worldwide deployment of MHK power to date is only a few MWs.

What are the obstacles to getting wave and tidal/open-ocean current projects in the water?

These are two big barriers to investigating whether ocean wave and MHK technologies ought to be added to our national portfolio of energy supply alternatives

- **Regulatory (permitting and licensing)**
- **Legislative - U.S. and State Governments (with a few exceptions) Do Not Allow Ocean Energy to Compete on a Level Playing Field with:**
  - **Fossil fuel generation with their externalities**
  - **Other Renewables such as Wind and Solar with their government incentives**



PogoPossum.jpg

What is role of states in advancing technology?

- First – I know of no energy technology that has made it to the commercial marketplace without Government funding support
  - $$$$$ - Clean coal technology in the US recently
  - Count Rumford in the 18th century
- Given that Government support is required, the role of the states, in my view, is the result of a negotiation between the Federal Government and the States
  - Some technologies are applicable to only a few states
  - Some states have energy funds
  - States have a responsibility and cannot leave it to the Feds, and this includes knocking down the regulatory and legislative barriers

In Summary (1 of 2)

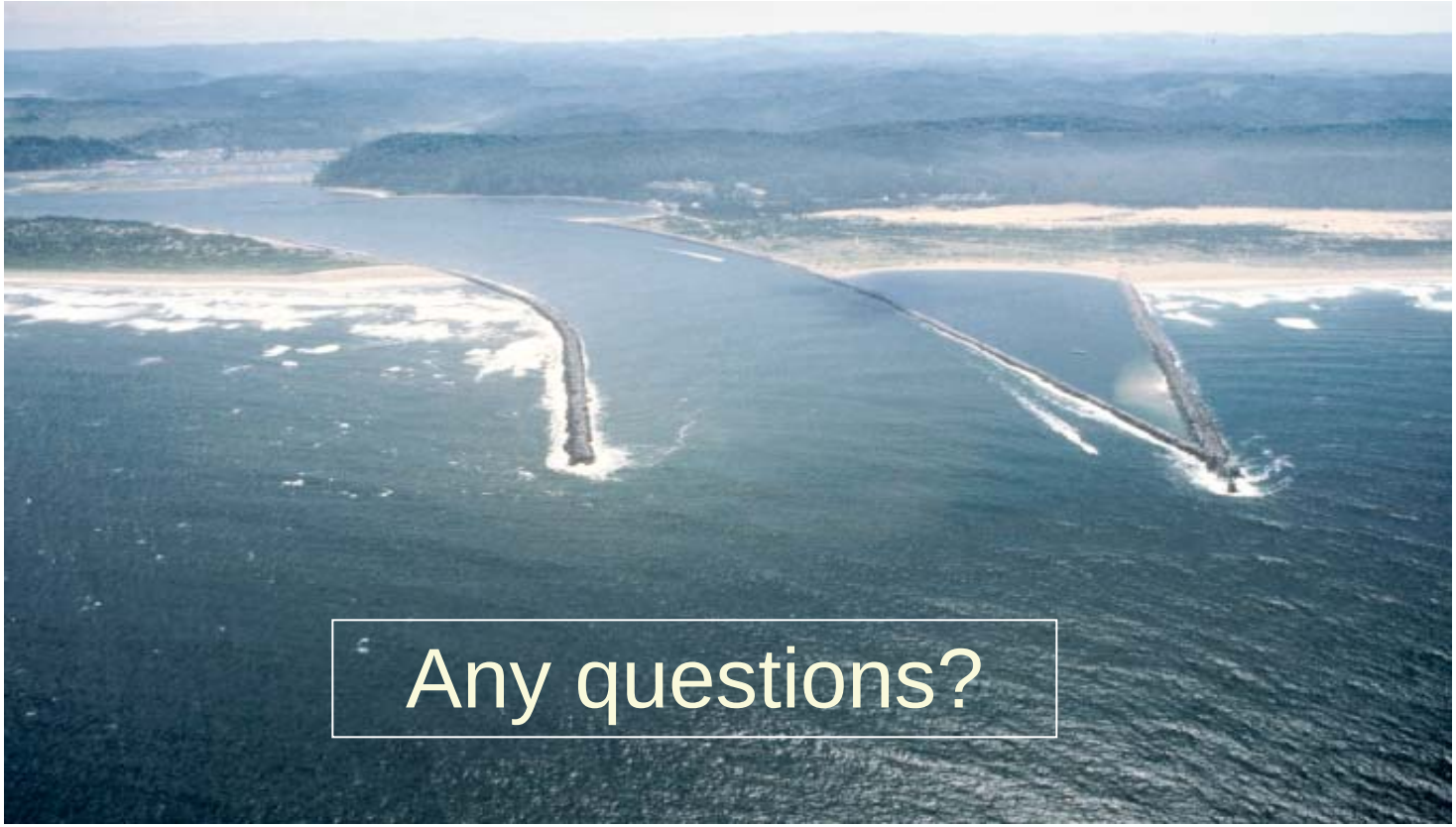
- Electricity generation potential is about 10% of current U.S. need
- The technology is ready
- Initial studies suggest that these technologies can be commercially competitive with other forms of renewable power generation.
- Significant technical, economic, operational, environmental and regulatory barriers remain to be addressed in order to progress this emerging industry to commercial development.
- An urgent and current need is the deployment and testing of prototype and pilot demonstration systems in the ocean.
- Successful deployment of prototype and pilot demonstration systems are needed

Summary (2 of 3)

- Market push pull mechanisms are needed
- It is very unlikely that any of this early stage development will be funded by the private sector because the risk of failure is too high.
- Given the long technology development and deployment lead times inherent in capital intensive industries like energy, investment and policy decisions cannot be delayed without risk of losing opportunities for technology options that we expect will prove tremendously valuable to our nation in a carbon-constrained future.
- Getting economical power from ocean waves and tidal and open-ocean currents will be difficult and will require the very best engineering and communication skills.
- The trend is for demonstration projects and early commercialization projects deployed over the next decade in Europe, Canada and Australia (and the U.S. if regulatory and legislative obstacles are overcome).

Stay Tuned!

Let's All Work Together to Move the Investigation of the Potential of Ocean Energy Technology Forward



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