Overview of Wave and Current Energy:

Resource, Technology, Environmental and Business Issues

For: LSU

April 25, 2007

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Ocean Energy Leader

Two of the Basic Forms of Ocean Energy

CURRENTS

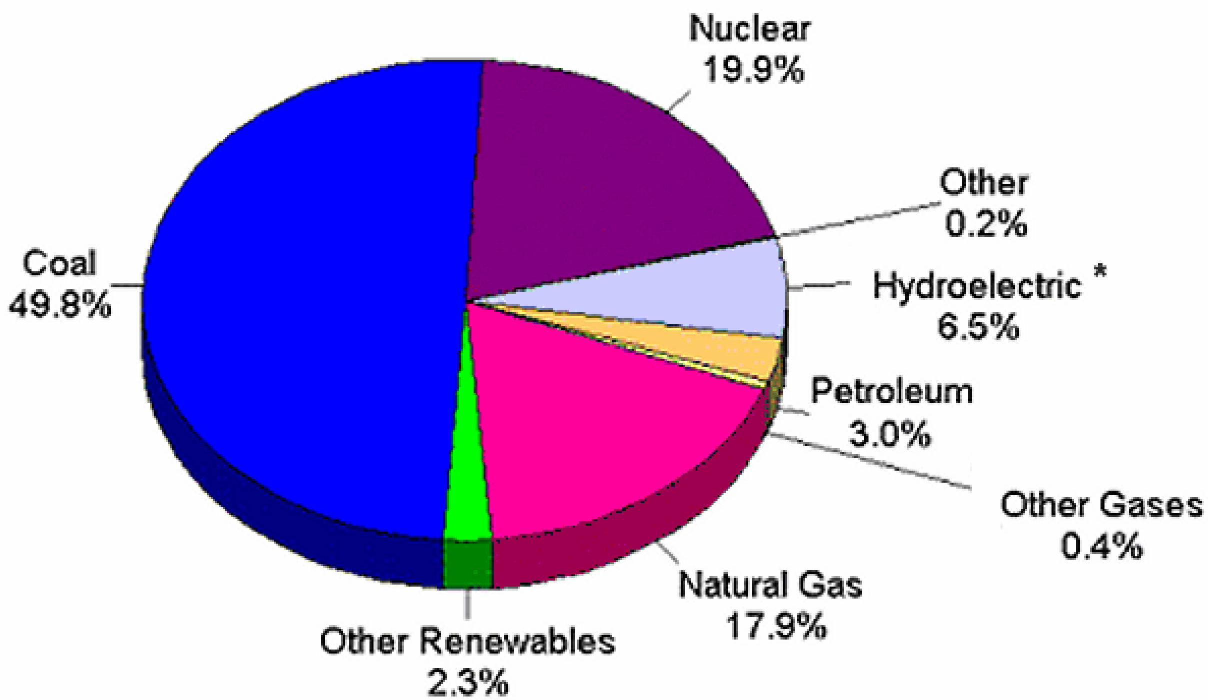
- Tidal, river, and ocean variants
- Conversion technology is some sort of submerged turbine

WAVES

- Conversion technology can be floating or submerged, with a wide variety of devices still being invented and developed

U.S. Wave and Current Energy Potential

U.S. Annual Electric Power Generation by fuel type in 2004 was 3,971 Terawatt-Hours (TWh)



* Note: Hydroelectric includes generation from pumped-storage facilities after subtracting energy used for pumping

U.S. conventional hydro-electric generation in 2004 was ~260 TWh/yr

Wave and current generation potential

- Offshore wave 250-260 TWh/yr if 15% utilized
- Tidal, river, and ocean currents TBD but maybe half of wave

Credible potential to meet nearly 10% of national demand

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Advantages of Wave and Current Energy

High power density as compared to most renewable resources – translates to lower installed cost

With proper siting, installation, O&M and decommissioning, could be one of the more environmentally benign of electricity generation technologies

Minimizes NIMBY – submerged or barely visible

No emissions – including CO_2

Job creation and economic development for maritime communities

Decrease national dependence on foreign fuel suppliers and risk of future fuel price volatility

Assimilates well into grid load balancing because of predictability

Increases diversity and robustness of electricity energy supply portfolio

EPRI Pilot Demonstration Projects

2004 | 2005 | 2006 | 2007 | 2008

Wave Energy Conversion (WEC)

Phase 1 Project Definition Study

OR Phase 1.5 Pre-Implementation Planning

Phase 2 Design, Permitting and Financing
Many in Oregon

WEC

CA Phase 1.5 Pre-Implementation Planning

Phase 2 Design, Permitting and Financing
Three in Ca, many more to come

Phase 1 – Study It
Phase 2 – Permit It
Phase 3 – Build It
Phase 4 – Test It

Tidal In-Stream Energy Conversion (TISEC)

Phase 1 Project Definition Study

Phase 2 Design, Permitting and Financing
SF, Tacoma Power, SnoPUD, AK, ME and NS

River In-Stream Energy Conversion (RISEC)

Phase 1 Project Definition Study - AK

Phase 2 Design, Permitting, & Financing

Completed
In-progress
Future

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EPRI Feasibility Studies are Having an Impact

- Investors filed >40 FERC applications for ocean energy preliminary permits
- May, 2006, NSPI announced a multi million dollar pilot tidal plant project
- June 2006, OPT filed for the 1st US commercial wave plant; a 50 MW plant at Reedsport OR, the site we selected in 2004; Coos Bay and Newport filings
- July 2006, Lincoln and Douglas County OR applied for FERC preliminary permit for multiple wave plants
- December 2006, Finevera AquaEnergy filed preliminary permit applications for plants in southern Oregon and northern California
- February, 2007, PG&E filed two preliminary permit applications for Northern California Wave Plants
- Forecasting a very wet 2007

May 16, 2006 Halifax Chronicle

The Chronicle

Volume 58 Number 116

EAGLE TO LAND

Ex-president Bill Clinton to speak in Halifax on July 26. / B3

Ralph Tedesco, president of Nova Scotia Power, responds to the release of an international study on potential tidal power project sites at the Bedford Institute of Oceanography in Dartmouth on Monday afternoon. Nova Scotia was identified as the best location in North America to develop tid power, with possible commercial implications. (ERIC WYNNE / Sta

Turning the tides of power

NSP boss 'bullish' on alternative energy source, N.S. vows go-slow approach on tidal potential

By JUDY MYRDEN
Business Reporter

Nova Scotia is going to take a go-slow approach to developing its tidal power potential, Energy Minister Bill Dooks says, after an international study found it to be the most promising loca-

needs to be protected."

The $400,000 study, conducted by the Electric Power Research Institute of California over the past 15 months, identified eight potential sites for tidal power projects on the Nova Scotia side of the Bay of Fundy, which has among the most powerful tides

288-megawatt project would be roughly $485 million.

Ralph Tedesco, Nova Scotia Power's president and chief executive officer, said he is "bullish" on tidal power and is keen to undertake a demonstration project in the Bay of Fundy with other partners to pay for the

Currents

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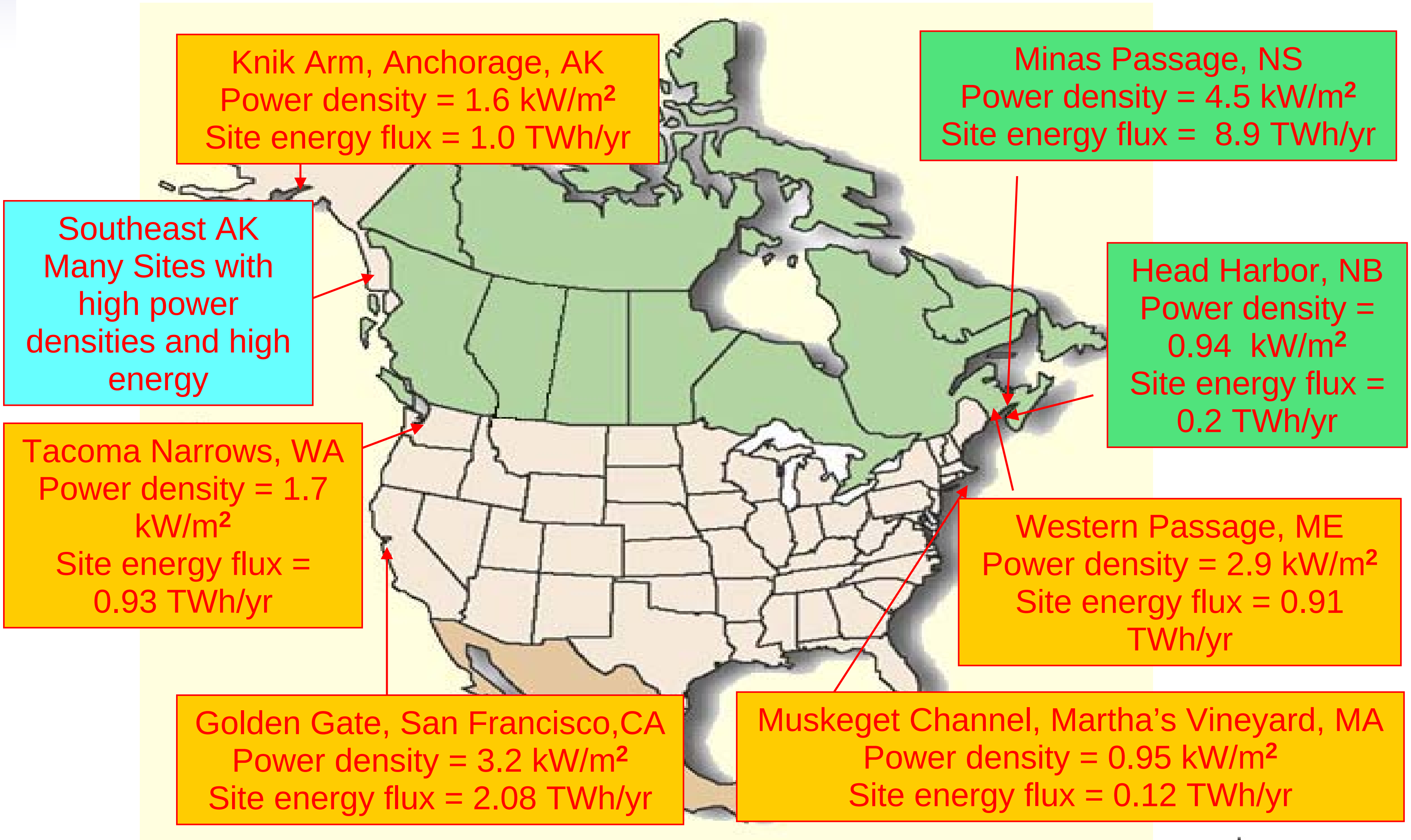
Tidal Resources at EPRI Study Sites



Tidal Current Turbines

EPRI state and provincial Advisory Groups selected turbines in **bold** font for more detailed study

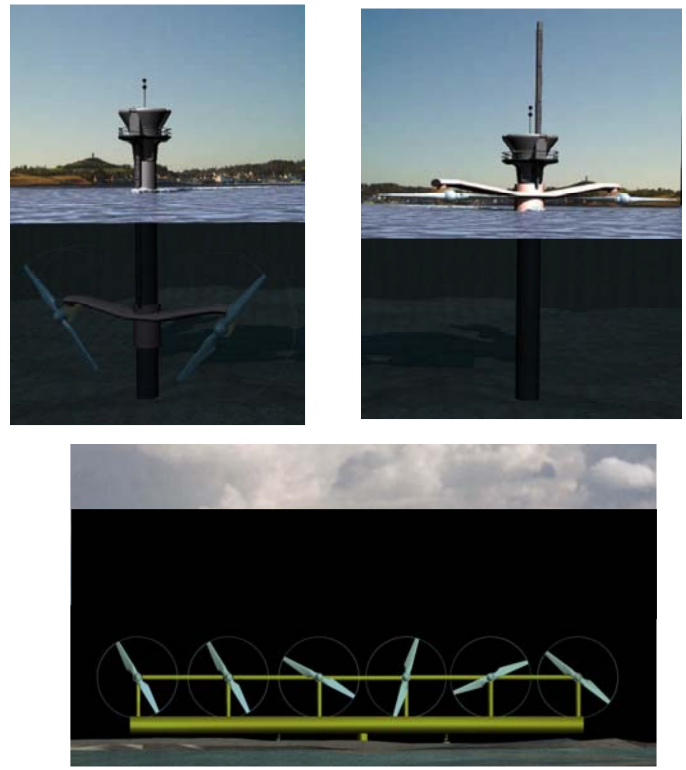
- GCK (vertical-axis, Gorlov helical rotor)
- **Lunar Energy (h-axis, shrouded rotor)**
- **Marine Current Turbines (h-axis, open rotor)**

- Open Hydro (h-axis, open rotor, rim-drive)
- SeaPower (vertical axis, Savonius rotor)
- SMD Hydrovision (h-axis, open rotor)

- UEK (h-axis, shrouded rotor)
- **Verdant Power (h-axis, open rotor)**

UK-Based Marine Current Turbines

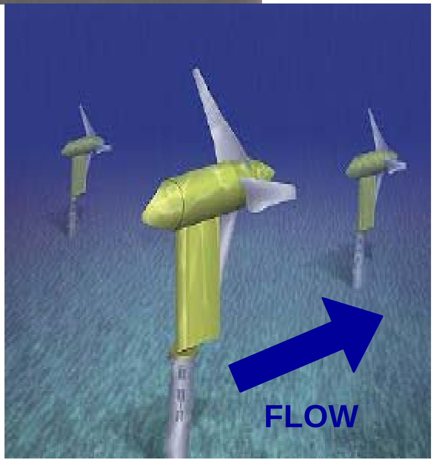
SeaFlow experimental 300 kW prototype (11-m rotor diameter) operating in Bristol Channel since May 2003; not connected to grid)



SeaGen commercial 1.2 MW prototype consists of dual 16-m rotor diameter unit being installed at Strangford Lough, No Ireland

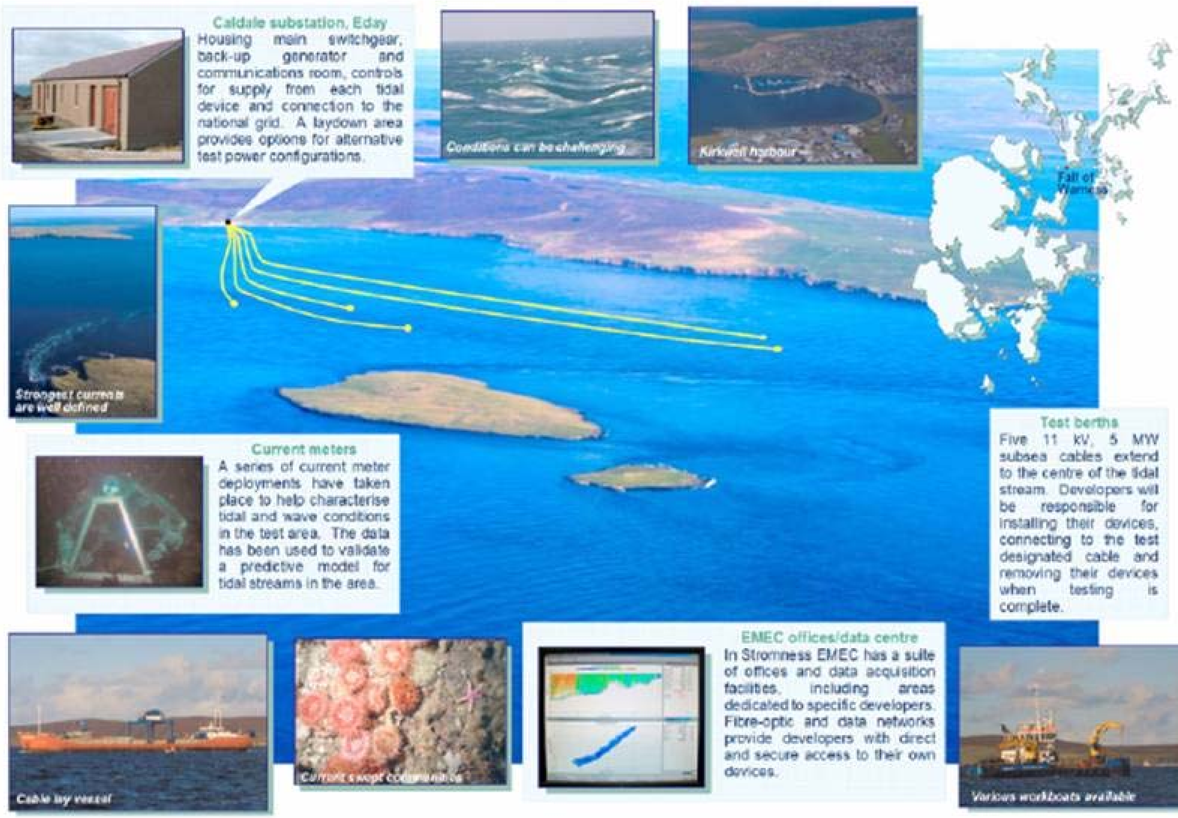
US-Based Verdant Power

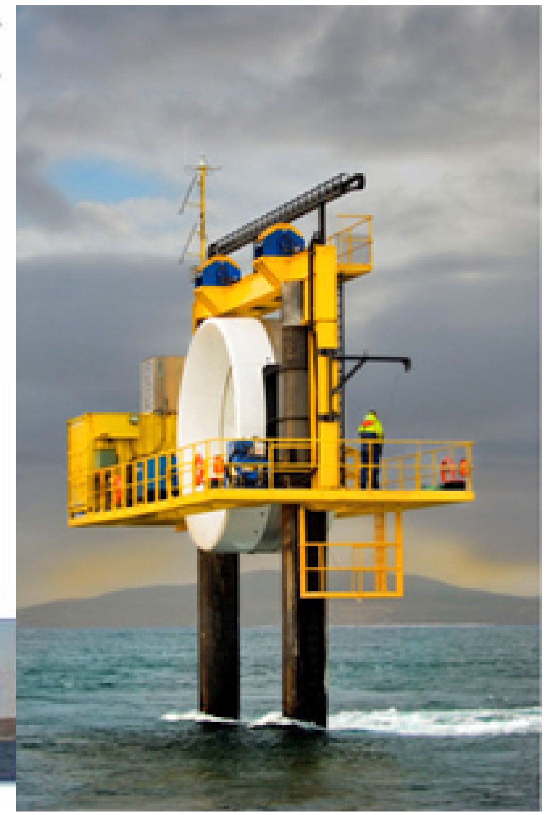
Six-turbine, 200 kW array – first 2 deployed Dec 2006 – next 4 in April 2007 in East River, New York City for 18 month environmental monitoring pursuant to FERC project licensing



Downstream, 3-blade rotor 5-m in diameter, yaws to accommodate reversing flow

Open Hydro – 1st in EMEC – Dec 2006





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River Current Energy

- **Resource characteristics**
  - Stochastic – governed by precipitation
- **U.S. production potential**
  - ~110 TWh per year (NY University, 1986
  - EPRI feasibility study for Alaska rivers in 2007
- **General types of conversion technology**
  - Underwater turbines in various configurations

Ocean Current (Florida Gulf Stream) Energy

- **Resource characteristics**
  – Gulf Stream relatively steady
- **U.S. production potential**
  – EPRI not engaged in ocean current
- **General types of conversion technology**
  – Underwater turbines in various configurations
- **Conversion technology status**
  – Challenges: potential climate impacts, large water depths (350-450 m), long submarine cable distances (20-35 km), single state resource

Waves

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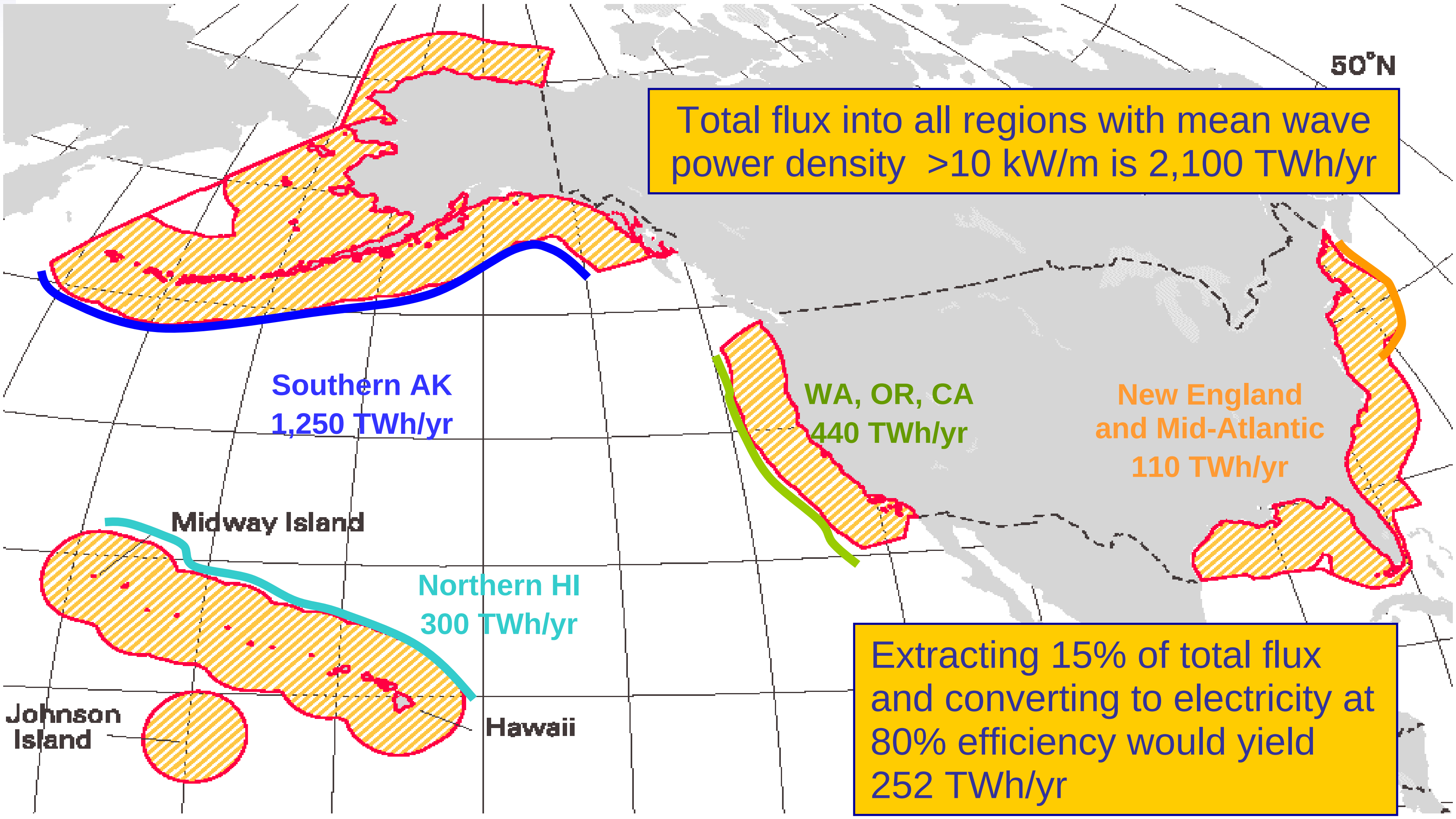
U.S. Offshore Wave Energy Resources



Total flux into all regions with mean wave power density >10 kW/m is 2,100 TWh/yr

Extracting 15% of total flux and converting to electricity at 80% efficiency would yield 252 TWh/yr

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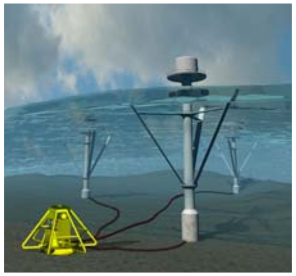
Wave Energy Conversion Devices

EPRI December 2006 WEC Device Survey – 14 Respondents

The two in bold were used in 2004 Feasibility Studies

- Able Technologies - Electricity Generation Wave Pump
- AquaEnergy Group, Finevera - AquaBuOY
- AWS Energy - Archimedes Wave Swing
- Ecofys - Wave Rotor
- **Energetech - Uiscebeathe**
- Fred Olsen - FO Research Rig "Buldra"
- Independent Natural Resources Inc - SeaDog™
- **Ocean Power Delivery - Pelamis**
- Ocean Power Technologies - PowerBuoy®
- Renewable Energy Holdings - Cylindrical Energy Transfer Oscillator (CETO)
- Wavebob Ltd - Wavebob WEC
- Wave Dragon Ltd - Wave Dragon
- Wave Energy AS - Sea Wave Slot-Cone Generator (SSG)
- Wave Star Energy - Wave Star



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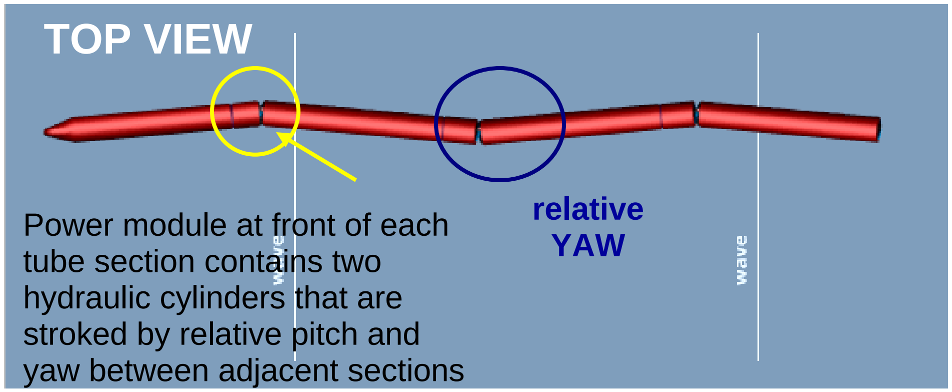
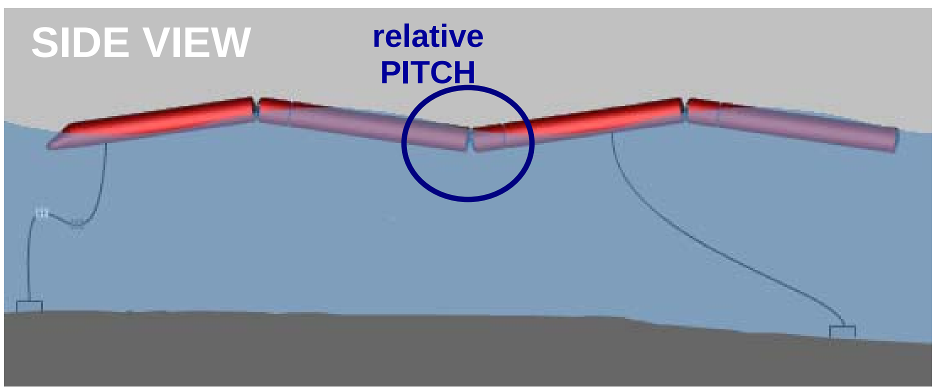
UK Based Ocean Power Delivery Pelamis





Pelamis 750 kW prototype installed in August of 2004 in 50 m water depth, 2 km offshore the European Marine Energy Centre, Orkney, UK

Pelamis 1st commercial sale occurred 2005 – OPD Pelamis in Portugal – contains an early 3 unit qualification

Energetech

Port Kembla Prototype

Size:	25 x 35 m
Average power:	500 kW @ avg wave resource of 35 kW/m
Max rated power:	1.5 MW
Structural Steel Wt:	150 ton
Deployed Water Depth:	9 m

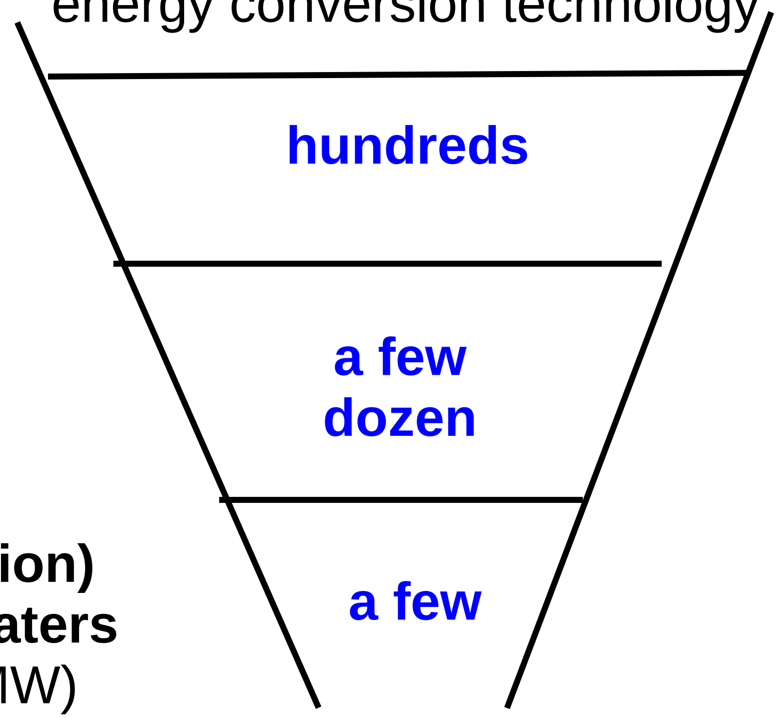
Milestones

2005 - Completed installation of a 500 kW prototype at Port Kembla Australia

2006 - Energetech begins development of a slack moored floating version of the PK prototype with an expected completion of the first project using the floating technology in Q1 2008.

Technology Development Status

Thousand of concepts and patents on ocean energy conversion technology



Rigorous laboratory tow- or wave-tank 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

Will these devices affect the environment?

Ocean power may be one of the more environmentally benign of the known electricity generation technologies.

The Environmental Issues

- Withdrawal of wave and tidal flow energy on the ecology
- Interactions with marine life (fish and mammals)
- Atmospheric and oceanic emissions
- Visual appearances
- Conflicts with other uses of sea space (fishing, boating, shipping, clamming, crabbing, etc)
- Installation and decommissioning

Wave Energy Environmental Impact Statements (EIS)

- Belt Collins EIS for Navy Hawaii WEC Project - FONSI[#]
- Devine Tarbell EIS for AquaEnergy Makah Bay WA Project – FONSI[#]
- Many European EIS - FONSI[#]

- Finding of No Significant Impact

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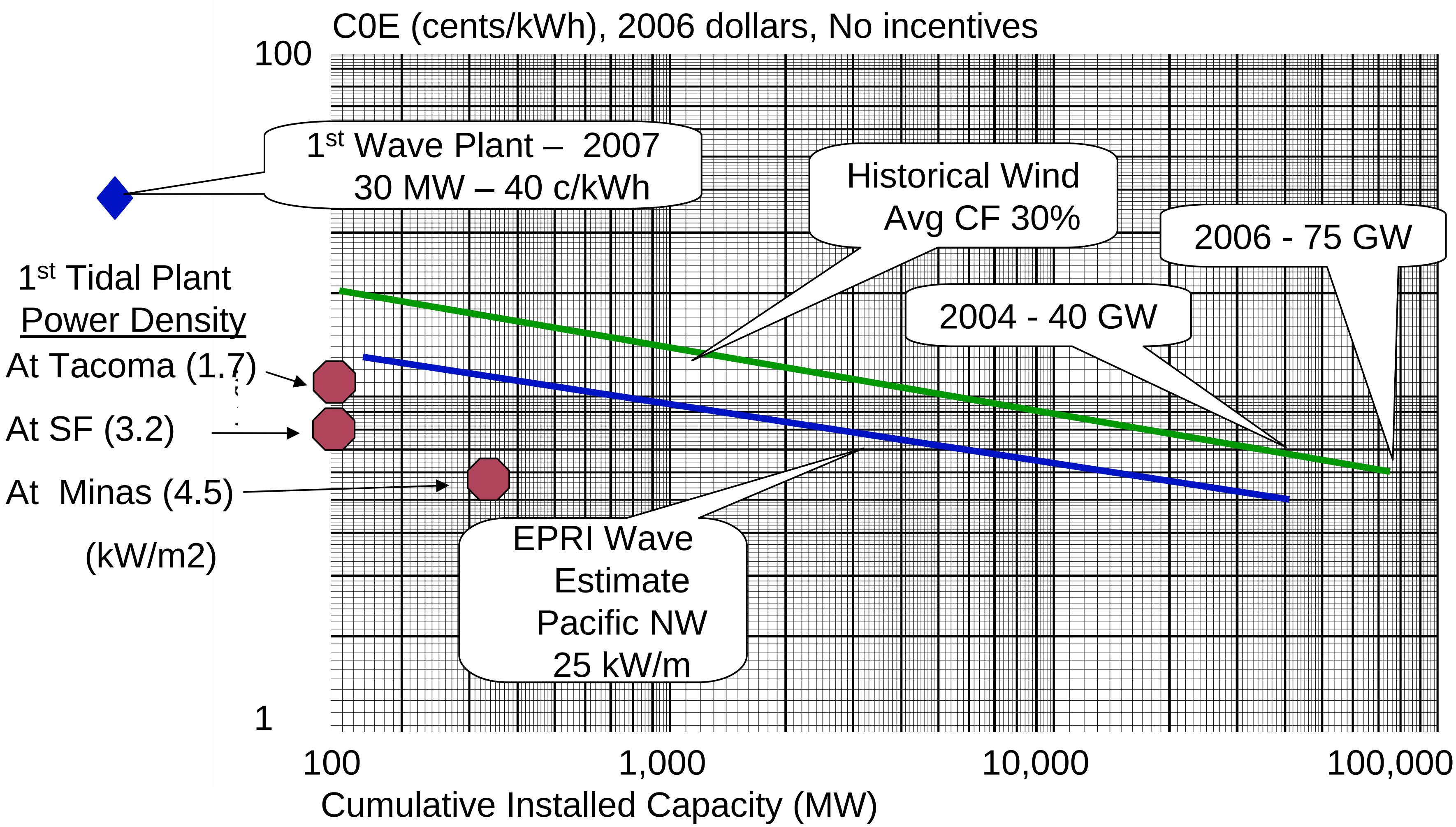
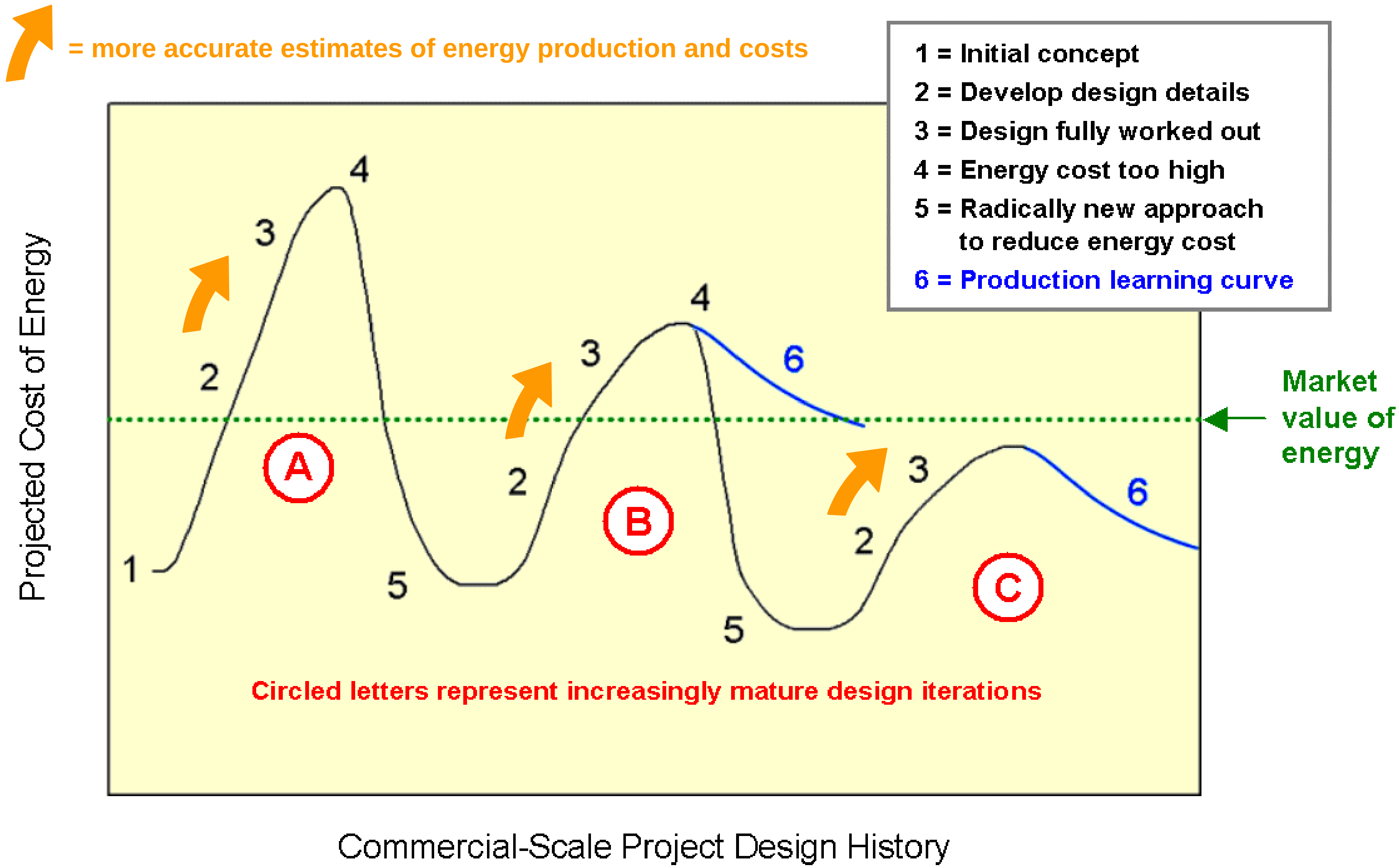
Notional Cost of Electricity as a Function of Cumulative Installed Capacity



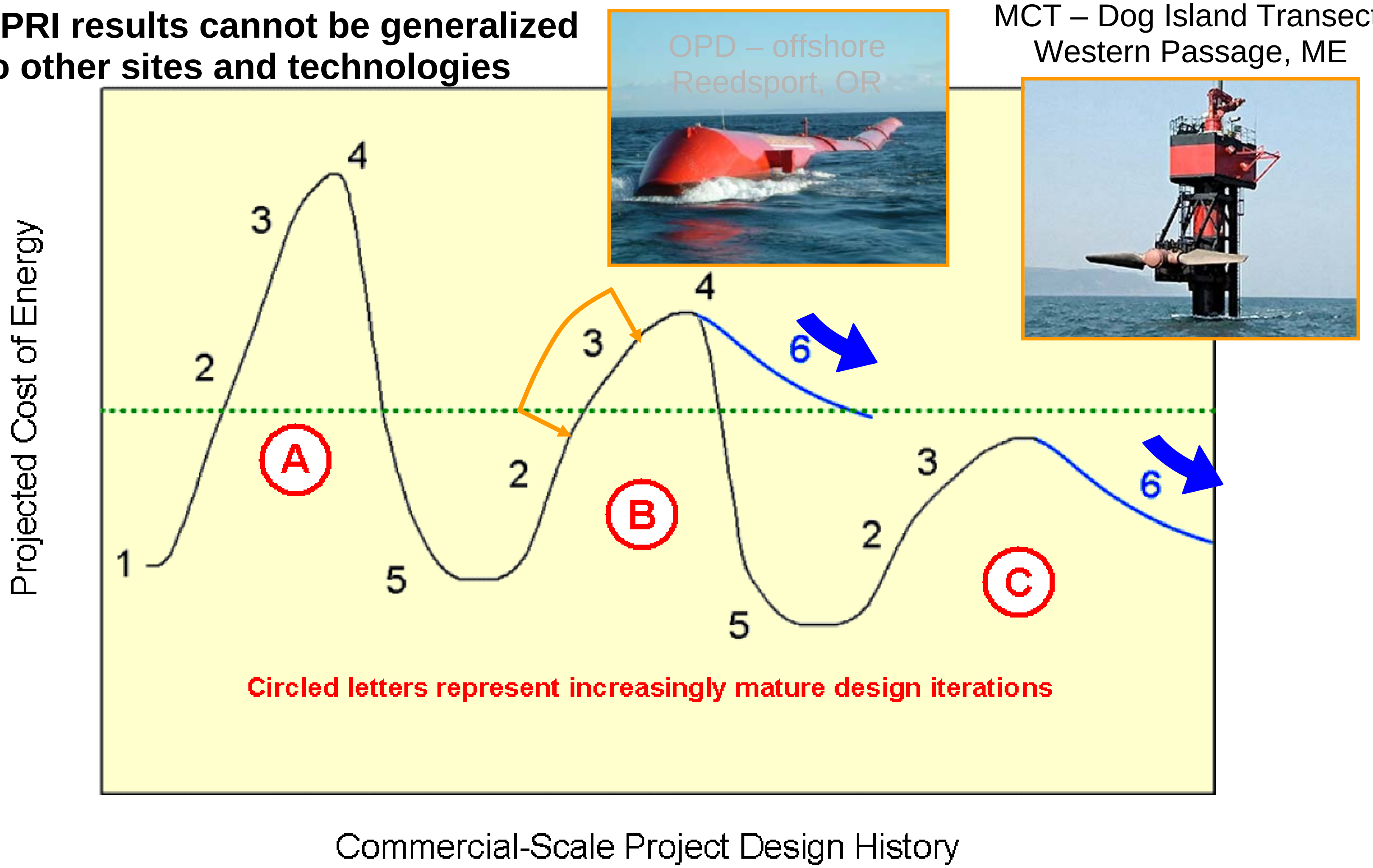
Where is the Project Business Case?



Where are the EPRI Case Studies?

EPRI results cannot be generalized to other sites and technologies

MCT – Dog Island Transect, Western Passage, ME



Cost to Society – Fossil Fuel-based Emissions

- Nearly 70% of US electricity is fossil fuel-based
- Current costs some are paying is a pragmatic approach to monetizing the emissions cost

CO_2	SOx	NOx	Mercury
$/ton	$/ton	$/ton	$/lb
10-20	500-1,000	3,000-4,000	10,000-25,000

- For a standard 500 MW Coal Plant, the effect of COE is
  - Monetizing SOx, NOx and Mercury
    from 4.8 to 5.0 cents/kWhr
  - Monetizing Carbon at $15/ton
    from 5.0 to 6.2 cents/kWhr

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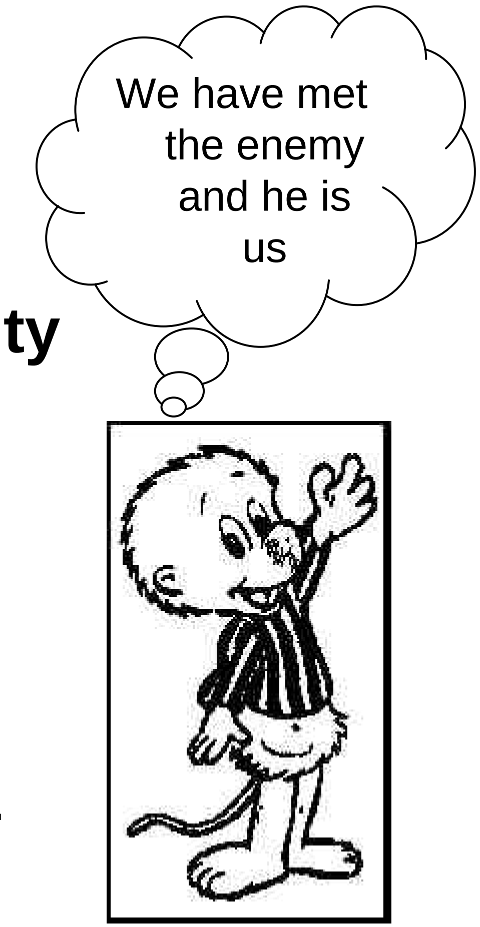
Key Points and Concerns

- Basic oceanography and hydrology are well understood, but “extractable” resource (percent utilization) is not
- Energy conversion technology is well understood and continues to evolve
- Environmental effects of commercial projects uncertain – commercial-scale units must be deployed in “pilot” arrays before full build-out and adaptively managed

The Barriers

The primary barriers to wave and current energy applications are :

- **U.S. Government regulatory uncertainty**
- **No U.S. Government Incentives to Allow Ocean Energy to Compete on a Level Playing Field with:**
  - **Fossil fuel generation with its externalities**
  - **Other Renewables such as Wind and Solar Tax Credits**



PogoPossum.jpg

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And Now, Let's All Work Together to Move Ocean Energy Technology Forward

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