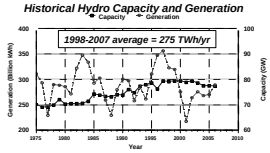
U.S. Department of Energy
Water Power

Stefan M. Moreno
Technology Lead, Water Power
Office of Wind and Hydropower Technologies
July 29, 2008

Significant increases in water power generation are possible

Energy Efficiency & Renewable Energy

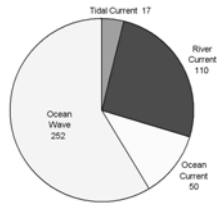
Historical Hydro Capacity and Generation



Potential increases in conventional hydropower by 2025

- Operational optimization (+ 3-5% new generation)
- Capacity gains at existing plants (2.3 GW)
- New plants at existing nonpower dams (5 GW)
- New small, low-power dams/diversions (2.7 GW)
- Total of ~48 TWh/yr on average

Hydrokinetic Production Potential (TWh/yr)

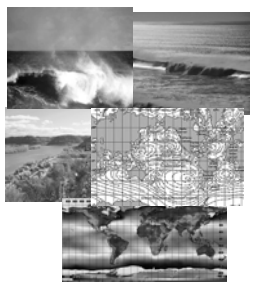


Total of 429 TWh/yr … by when?

Marine and Hydrokinetic Resources

Energy Efficiency & Renewable Energy

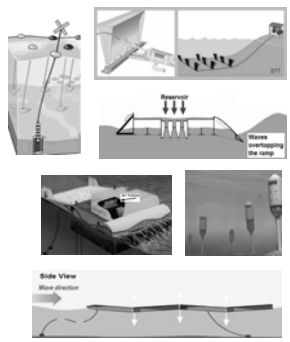
- Ocean Wave
- Currents (3 Variants)
  - Ocean (unidirectional)
  - River (unidirectional)
  - Tidal (bidirectional)
- Ocean Thermal (OTEC)



Technology Types – Wave

Energy Efficiency & Renewable Energy

- Attenuator
- Overtopping
- Oscillating Water Column (OWC)
- Oscillating Wave Surge Converter (OWSC)
- Point Absorber
  - Floating
  - Submerged Pressure Differential
- Other



Technology Developers – Wave

Energy Efficiency & Renewable Energy

- Finavera (AquaEnergy) – AquaBuOY (point absorber)
- AWS Energy - Archimedes Wave Swing (submerged pressure differential)
- Aquamarine Power – Oyster (oscillating wave surge converter)
- Pelamis Wave Power – Pelamis (attenuator)
- Ocean Power Technologies - PowerBuoy® (point absorber)
- Oregon State University – Direct Drive Point Absorbers
- Renewable Energy Holdings - Cylindrical Energy Transfer Oscillator (CETO) (submerged pressure differential)
- Wavebob Ltd - Wavebob WEC (point absorber)
- Wave Dragon Ltd - Wave Dragon (overtopping)
- Wave Energy - Sea Wave Slot-Cone Generator (overtopping)

Industry activity is concentrated overseas, but increasing in the US

Energy Efficiency & Renewable Energy

Technology Development

- 62 wave energy tech developers (12 → full scale prototype); **6 in US**
- 42 current energy developers (9 → full scale prototype); **12 in US**
- 50 replies to DOE solicitation (across all technologies)

Test/deployment facilities

- European Marine Energy Center (Scotland), Galway Bay (Ireland), WaveHub (England),

R&D efforts

- SuperGen (Scotland), NaREC (England), Wave Energy Centre (Portugal), Oregon State, U of Washington, Florida Atlantic, Texas A&M, University of Delaware, U of Hawaii; UMass, Georgia Tech…

Projects

- Agoucadoura, Portugal (Pelamis); Oahu, HI (OPT); Newport, OR (Finavera)

Most devices in design and testing phases; attenuators and point absorbers most common

Energy Efficiency & Renewable Energy

Technology Stage

- 3 in Concept design
- 13 in Detailed design
- 13 in Scale model testing – tank testing
- 13 in Scale model testing – sea trials
- 12 in Full scale prototype – single device at sea

Tech Category

- 20 attenuators
- 21 point absorber technologies
- 10 co/univ developing OWC
- 6 oscillating wave surge
- 5 overtopping device technologies

But there are a number of barriers to marine and hydrokinetic deployment

Energy Efficiency & Renewable Energy

- Early development stage
- Lack of reliable resource assessments
- Potential environmental impacts
- Competing uses for resource
- Regulatory uncertainty
- Unique survivability/reliability challenges
- Accessibility to the grid

DOE water power activities (re)initiated in FY 2008

Energy Efficiency & Renewable Energy

- DOE authorized to establish marine and hydrokinetic technology program by EISA 2007
- $10 million appropriated in FY08 to address advanced water power technologies (including conventional hydro)
- '09 House mark → $40m; Senate → $30m

FY 08 DOE Activities

Energy Efficiency & Renewable Energy

- Competitive solicitation
  - Tech development
  - Market acceleration
  - National marine Renewable Energy Centers
- Identification and comparison of existing marine and hydrokinetic technologies
- Report on environmental impacts (as directed by EISA 2007 -- Sec 633 b)
- International collaboration and standards development (IEA, IEC)
- Inter agency collaboration
- Cooperative Research and Development Agreements
- Industry/stakeholder collaboration

Water power questions?

Energy Efficiency & Renewable Energy

Alejandro Moreno
Technology Lead, Water Power
Wind and Hydropower Technologies
U.S. Department of Energy
202-586-8171
alejandro.moreno@ee.doe.gov

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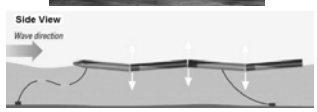
- Other

Description: An attenuator is a long, semi-submerged floating structure aligned in parallel with wave direction and anchored to the seafloor. Existing forms of this technology are composed of multiple sections that rotate relative to one another in a pitch-and-heave motion. The differing heights of the waves create an up and down motion of the sections, creating a flexing at the hinges, which is turned into electricity via hydraulic pumps or other forms of power take-offs.



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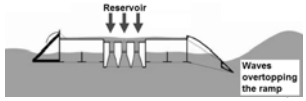
Description: An overtopping device is a floating reservoir structure consisting of (1) a ***collector*** (a.k.a. reflecting arms), (2) a ramp, and (3) a ***terminator***/terminating reservoir. Waves are concentrated by the collector and delivered via the ramp(s) to the reservoir (above sea level), which creates a head of water that is then released through hydro turbines as the water flows back out into the sea.



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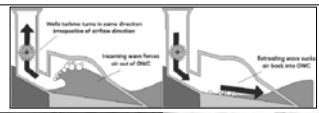
Description: The OWC is a form of ***terminator*** that can utilize ***collectors*** to increase electricity output. There are two types of OWC: (1) shore/breakwater mounted and (2) floating. Both OWCs operate by the same principle in which water enters a chamber through a subsurface opening. The wave action causes this column of water to move up and down much like a piston - compressing and decompressing the air. The changes in air pressure are channeled through an air turbine (usually a bi-directional Wells turbine) making use of airflow in both directions.



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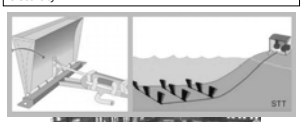
Description: An OWSC is a shoreline or near-shore device situated perpendicular to the direction of the waves that extracts the horizontal energy that exists in waves caused by the movement of water particles within them. The device consists of a paddle arm pivoting back-and-forth on a horizontal axis. The oscillation of the paddle arm is absorbed by a hydraulic pump to create electricity.



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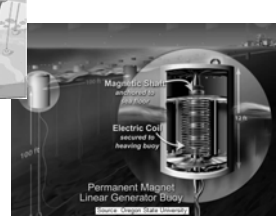
Description: There are two types of point absorbers: (1) floating and (2) submerged pressure differential. Wave action causes the components of both types to move relative to each other. A floating point absorber absorbs energy in all directions through its movements at/near the water surface. The wave action drives an electromechanical or hydraulic energy converter.



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Description: The submerged pressure differential point absorber consists of an air-filled chamber resting on an anchored shaft on the seafloor. The motion of passing waves causes the sea level to rise and fall above the, causing a pressure differential in the device. This up and down motion of the air-filled chamber can either serve as a water pump or can be directly converted to electricity through use of a hydraulic system.