

U.S. Department of Energy

Advanced Water Power



Alejandro Moreno

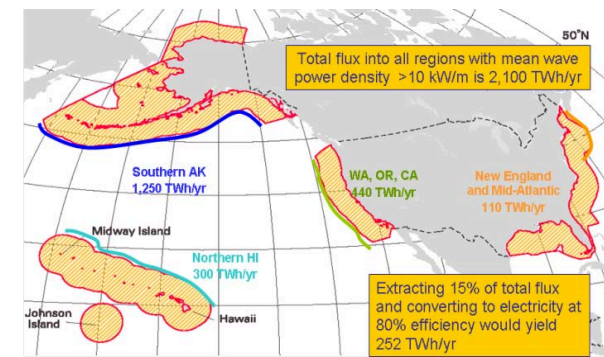
Technology Lead, Water Power

Office of Wind and Hydropower Technologies

Ocean Wave Energy



- Waves are caused by the wind blowing over the surface of the ocean.
- Ocean wave energy is captured directly from surface waves or from pressure fluctuations below the surface.
- Energy output is determined by wave height, wave speed, wavelength, and water density

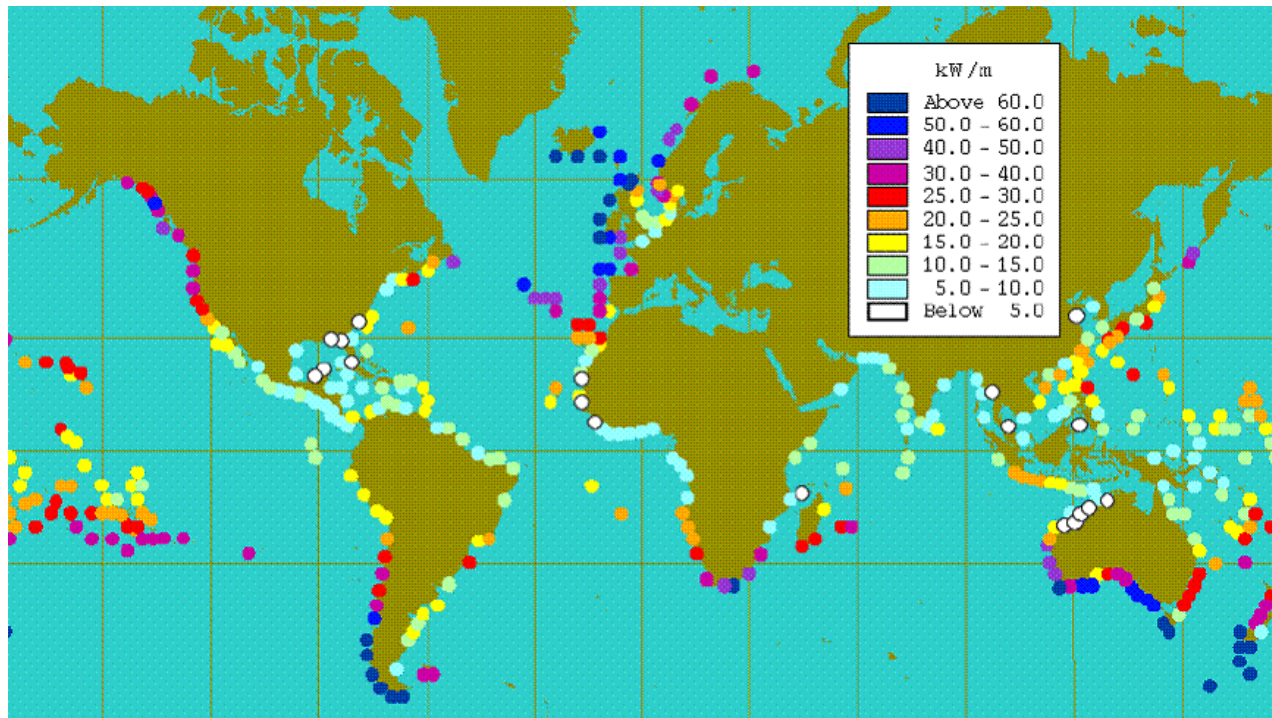


Ocean Wave Energy



Wave power vs other renewables

- Higher energy density
- Better predictability (reasonable forecasts 2-3 days out)
- Low visibility from on shore
- Proximity to coastal load centers – reduced transmission costs



The map shows annual average wave power in kW/m of crest width for various sites around the world.

Estimate includes:

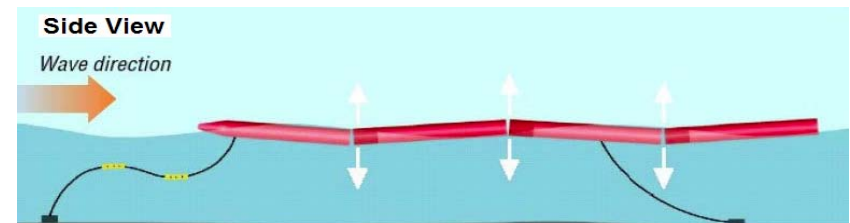
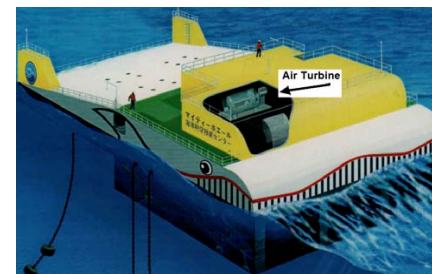
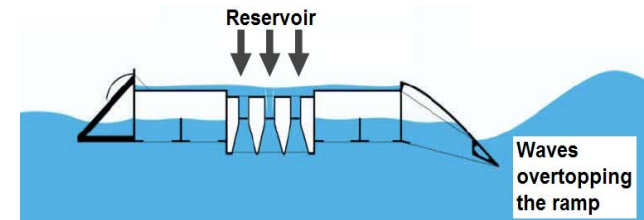
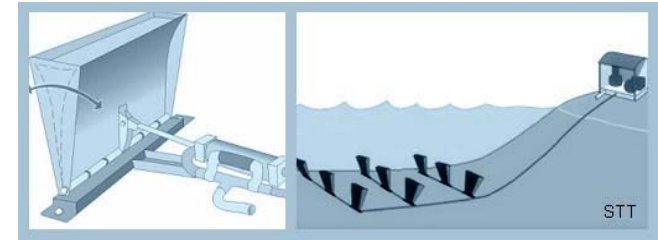
- H_s = Wave height
- T_e = Wave period

Wave Technology Types

Energy Efficiency &
Renewable Energy



- Attenuator
- Overtopping
- Oscillating Water Column (OWC)
- Oscillating Wave Surge Converter (OWSC)
- Point Absorber



International Wave Industry

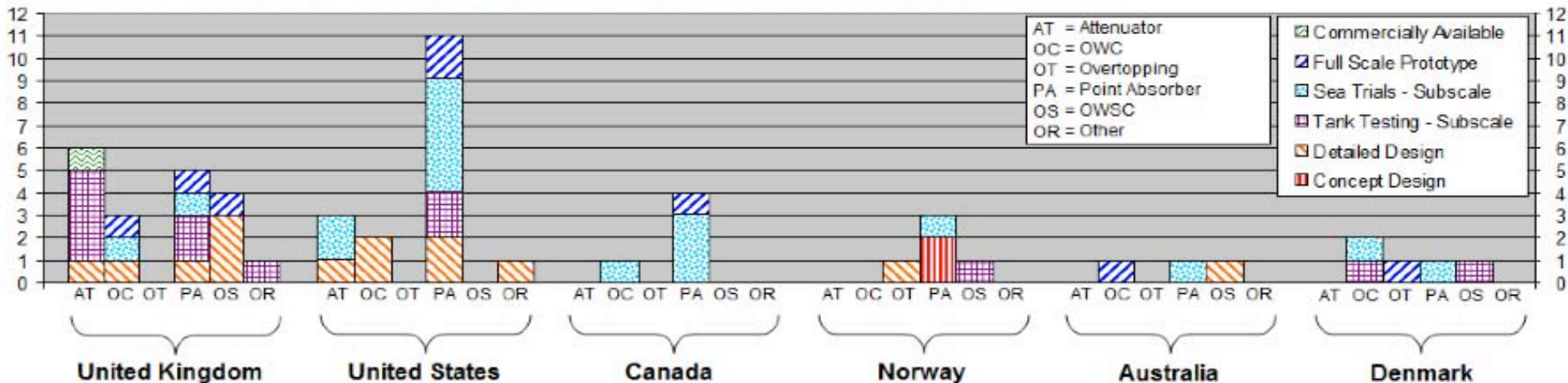
Energy Efficiency & Renewable Energy



What does the industry data say?

- Countries with better wave states lead the pack
- UK relatively has the most mature industry
- US leads globally in terms of number of technology types and developers
- Only commercially available technology is an attenuator
- Point absorber is moving the quickest toward commercialization – may indicate linear motor generator = less complex and expensive than other tech.

Global Wave Technologies by Country and Technology Development Stage (Top Six Countries)



International Wave Industry

Energy Efficiency &
Renewable Energy



Why has the industry developed in that manner?

- Only commercially available technology is an attenuator, but
 - High capital costs
 - Relatively more complex mechanical power take-off
- Point absorber is moving quickest toward commercialization
 - Linear motor generator is less complex and expensive than other tech



Bottom line: no clear technology winner

2008 DOE Wave Energy

Energy Efficiency &
Renewable Energy

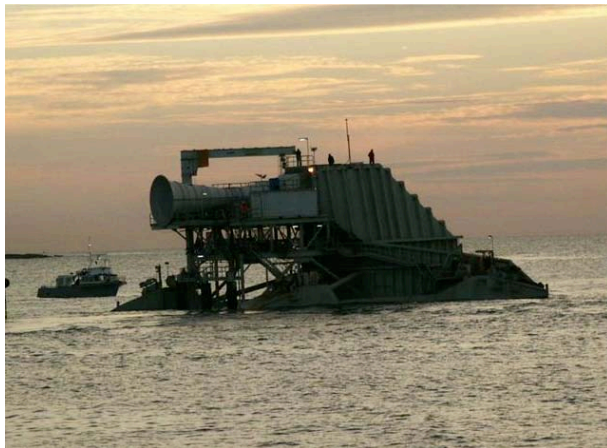


Awards

Demonstration and Testing of Wave Energy Technologies. Under the 2008 Funding Opportunity Awards (FOA), two awards were made to projects that would develop and test new technologies that generate electricity from the energy in ocean waves.

WaveConnect Wave Energy In-Water Testing and Development Project (Pacific Gas & Electric Company)

-- PG&E will complete engineering design, conduct baseline environmental studies, and submit all license construction and operation applications required for a tidal energy demonstration plant for the two WaveConnect sites in Northern California.



Development and Demonstration of an Oscillating Water Column (OWC) Power System (Concepts ETI, Inc). --

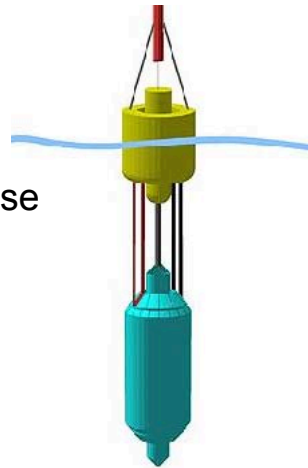
Concepts ETI will prepare detailed design, manufacturing and installation drawings of a bi-directional turbine for application in a floating Oceanlinx OWC wave energy converter. They will work with Oceanlinx to manufacture and install the system in Maui, Hawaii.

Next Steps for Wave Energy Industry

Energy Efficiency &
Renewable Energy



- Conduct wave states/regime resource assessments
- Partial and full-scale demonstrations necessary to
 - Obtain cost and performance data
 - Gather information on environmental, navigational, and competing use impacts
 - Familiarize regulatory bodies with the technology and appropriate permitting processes
- Reduce future capital costs as they relate to
 - Components and subcomponents
 - Operations and maintenance (O&M) through robust survivable designs and use of existing maritime infrastructure
- Develop performance measurement standards
- Characterize and evaluate different technology types



For more information

Energy Efficiency &
Renewable Energy



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Marine and Hydrokinetic Technologies/Project Database

<http://www1.eere.energy.gov/windandhydro/hydrokinetic/default.aspx>



Back Up Technology Slides

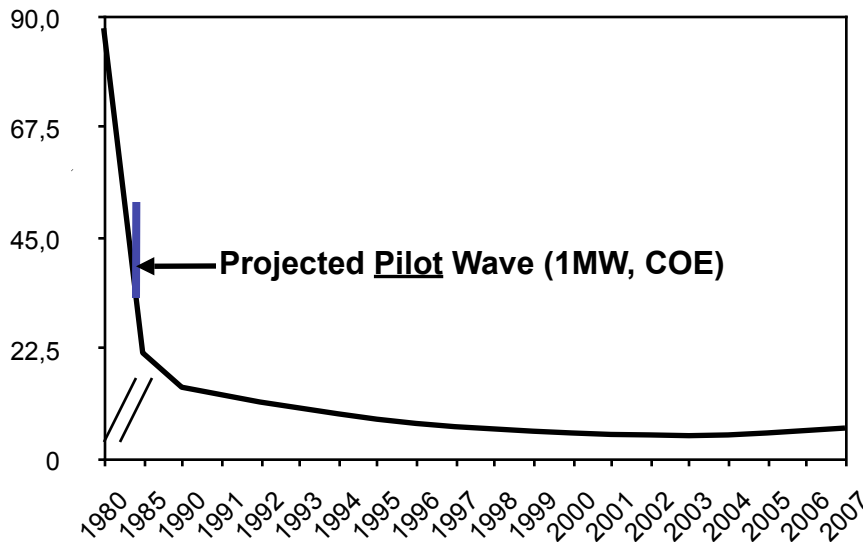
Wave Technology Cost Curves Similar to Wind and Better than Solar



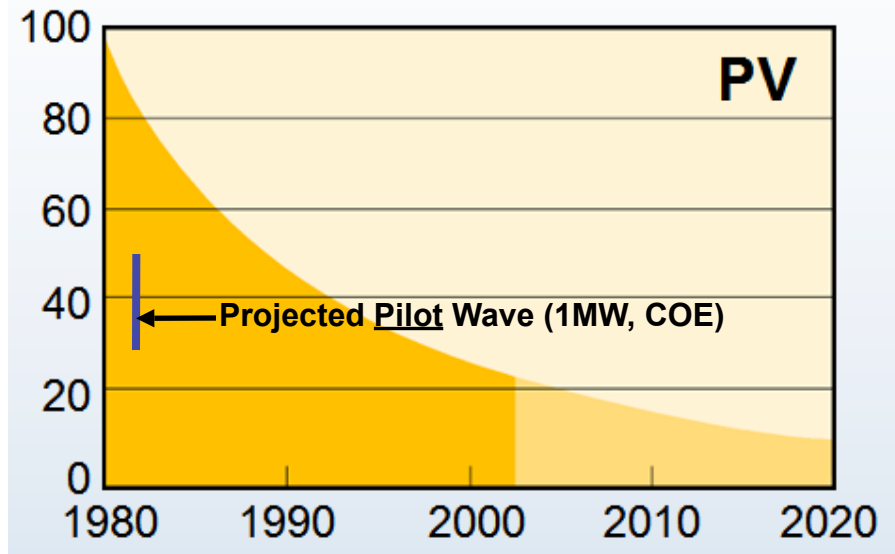
Projected Preliminary Data on Cost of Electricity (COE):

	Pilot 1 MW	Demonstration 10 MW	Commercial 100 MW
Installed Cost (\$/kW)			
Wave	\$5,300 - \$9,300 USD	\$4,100 - \$7,100 USD	\$2,100 - \$3,700 USD
Cost of Electricity (cents/kWh)			
Wave	30 - 52	20 - 36	14 - 28

2007 Wind COE (¢/kWh) Estimate



2002 PV COE (¢/kWh) Estimate



Cost Uncertainties Dominate the Picture

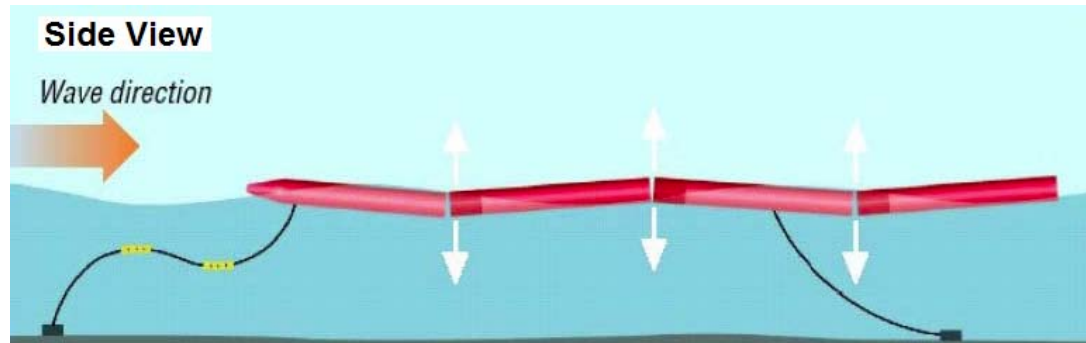
Wave Technology Types

Energy Efficiency &
Renewable Energy



- **Attenuator**
- Overtopping
- Oscillating Water Column (OWC)
- Oscillating Wave Surge Converter (OWSC)
- Point Absorber

Description: Wave energy capture device with principal axis oriented parallel to the direction of the incoming wave and converts the energy due to the relative motion of the parts of the device as the wave passes along it. 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.



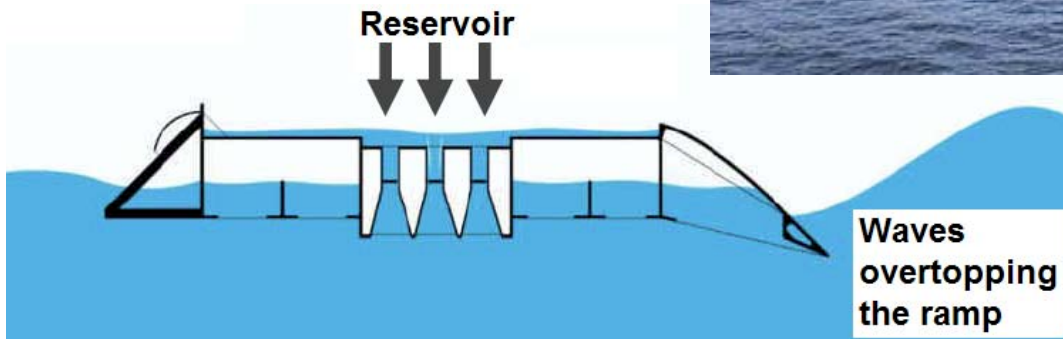
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Description: Partially submerged structure; a collector funnels waves over the top of the structure into a reservoir; water runs back out to the sea from this reservoir through a turbine.

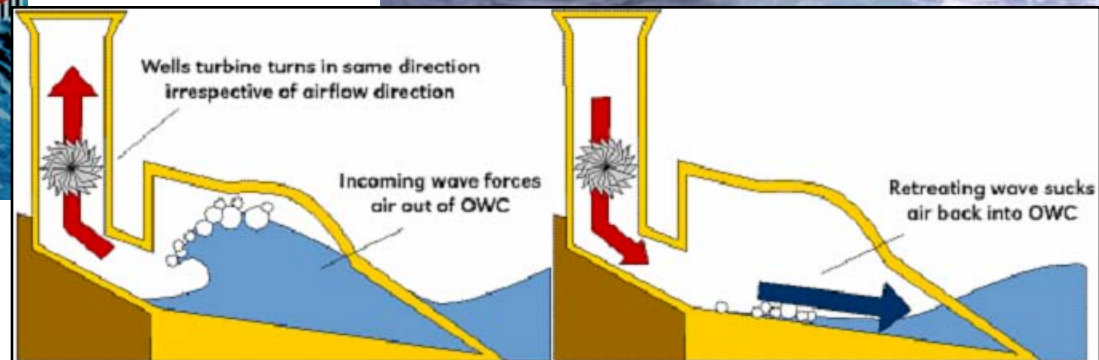
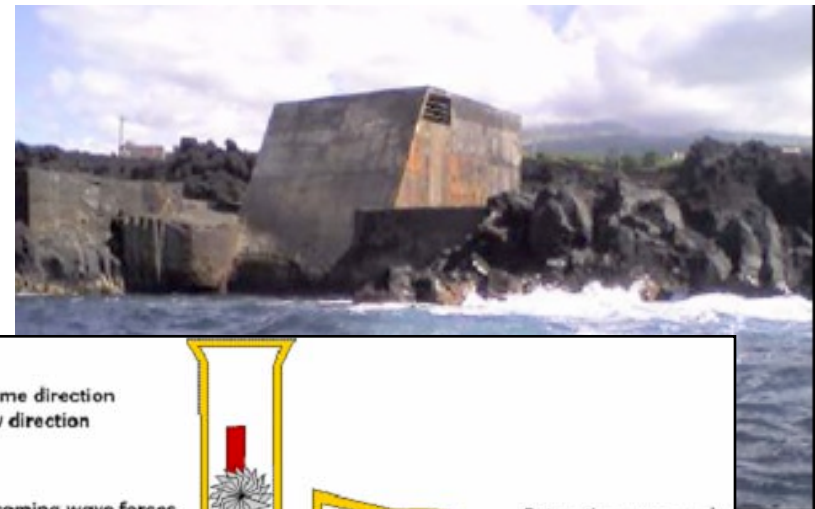
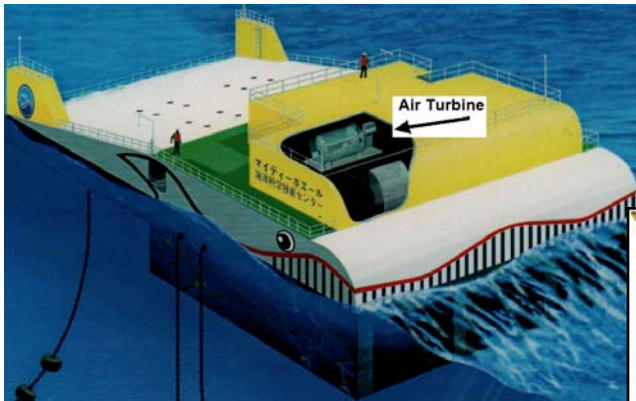


Wave Technology Types



- Attenuator
- Overtopping
- **Oscillating Water Column (OWC)**
- Oscillating Wave Surge Converter (OWSC)
- Point Absorber

Description: Partially submerged structure that encloses a column of air above a column of water; a collector funnels waves into the structure below the waterline, causing the water column to rise and fall; this alternately pressurizes and depressurizes the air column, pushing or pulling it through a turbine. There are two types of OWC: (1) shore/breakwater mounted and (2) floating.

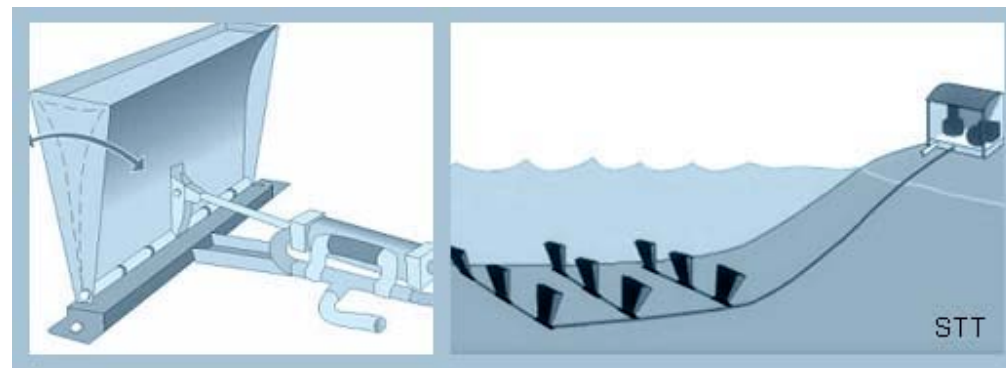


Wave Technology Types



- Attenuator
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- **Oscillating Wave Surge Converter (OWSC)**
- Point Absorber

Description: Any of several devices that capture wave energy directly without a collector by using relative motion between a float/flap/membrane and a fixed reaction point; the float/flap/membrane oscillates along a given axis dependent on the device; mechanical energy is extracted from the relative motion of the body part relative to its fixed reference.



Wave Technology Types



- Attenuator
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- **Point Absorber**

Description: Wave energy capture device with principal dimension relatively small compared to the wave length and able to capture energy from a wave front greater than the physical dimension of the device. There are two types of point absorbers: (1) floating and (2) submerged pressure differential.

