



Wave Energy Converters

Power from the Ocean

ECE 4833

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Overview

- Introduction
- Why use wave energy
- How is the energy stored in the waves measured
- How is the energy converted to electricity
- Examples of devices
- Current Projects
- Challenges/cost

Introduction

- Wave Energy- is the energy stored at the oscillating motion of the waves. The wave is produced from the wind and therefore makes this an indirect form of solar energy. It will gather the energy, store it, and transmit it across the ocean surface.
- Tidal Energy – form of hydropower that converts the energy of the tides into useful forms of power.
- Devices like buoys and turbines can capture the power of the waves and tides and convert it into clean, pollution free electricity.
- The technology needed to generate the electricity is still at an early stage
- Although not widely utilized, it has a lot of potential for generating power.

http://en.wikipedia.org/wiki/Wind_wave#Science_of_waves

http://en.wikipedia.org/wiki/Tidal_power#Tidal_fences_and_turbines

<http://www.oceanrenewable.com/wp-content/uploads/2008/03/power-and-energy-from-the-ocean-waves-and-tides.pdf>

Why use the Wave Energy?

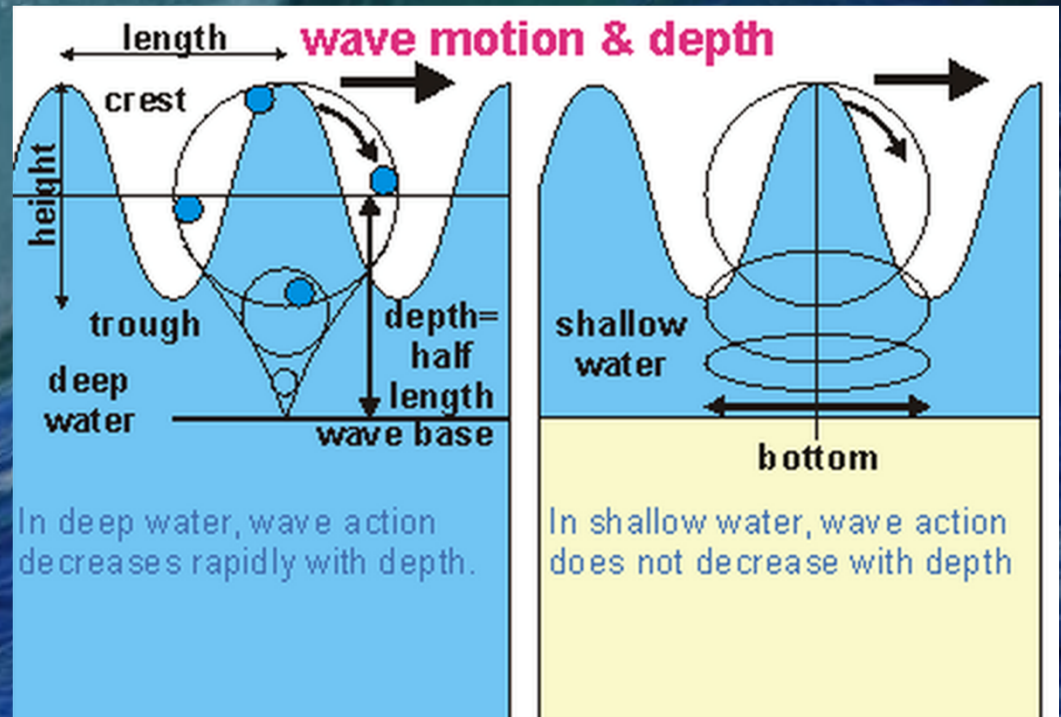
- Water is one of the most abundant resources on the earth.
- The waves can travel long distances without losing significant energy loss and the power produced is steady and predictable.
- Wave energy contains 1000 times the kinetic energy of wind.
 - Smaller devices can be used to produce the same amount of power

How is the energy stored measured?

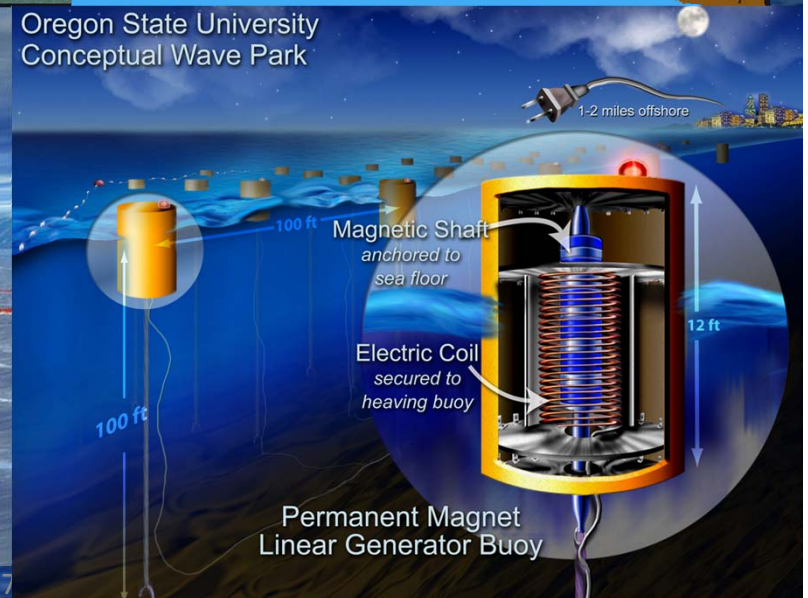
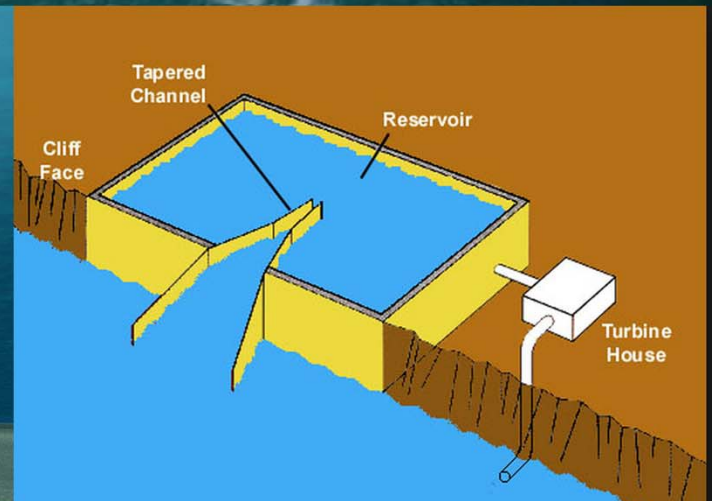
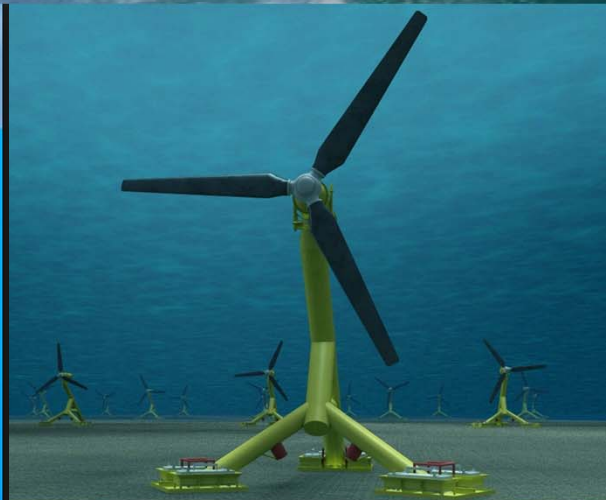
- The energy of the wave is measured by the wave speed, height, length, and density

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T_e \approx \left(0.5 \frac{\text{kW}}{\text{m}^3 \cdot \text{s}} \right) H_{m0}^2 T_e,$$

- ρ = Density of the water
- g = acceleration due to gravity
- H = wave height
- T = period of the wave



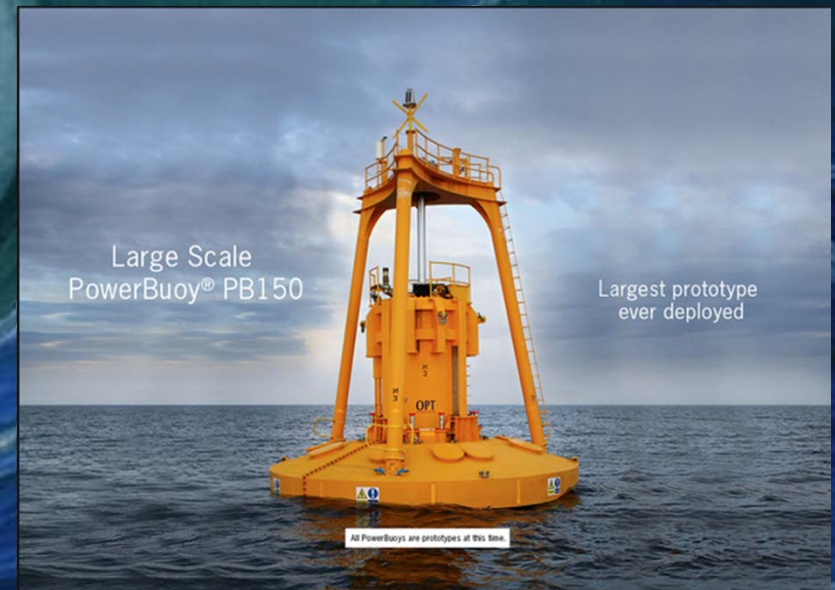
Power wave Generators



https://www.google.com/search?q=wave+energy+devices&espv=2&biw=1107omVeKGI4qqsAWWooToBw&ved=0CAcQ_AUoAg#imgrc=_

Wave Energy Devices

- Point Absorber-A devices that captures the energy from the vertical motion of the waves.
- Best known is the PB150 PowerBuoy
 - Developed by Ocean Power Technologies
- 200 ton, 80 foot tall floating structure
 - Coast North of Reedsport
- OPT is developing PowerTower, a system with 500 kW capacity that will drive the OPT system into a greater level of scale product capability

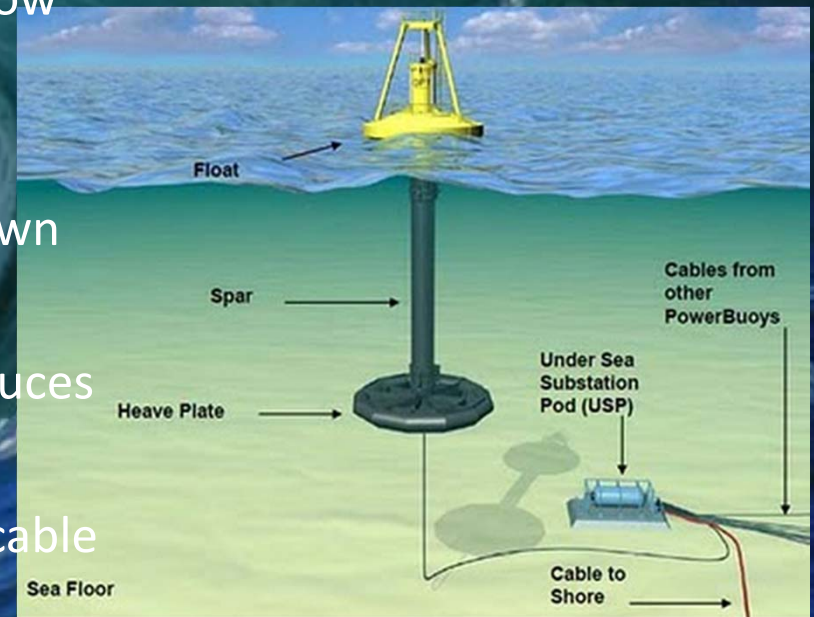


<http://seagrant.oregonstate.edu/sgpubs/onlinepubs/r100003.pdf>

https://www.google.com/search?q=PB150+PowerBuoy%C2%A9&es_sm=91&source=Inms&tbm=isch&sa=X&ei=L9EmVYS6O8SWsAWV9IHICw&ved=0CAgQ_AUoAg&biw=863&bih=864#imgrc=_

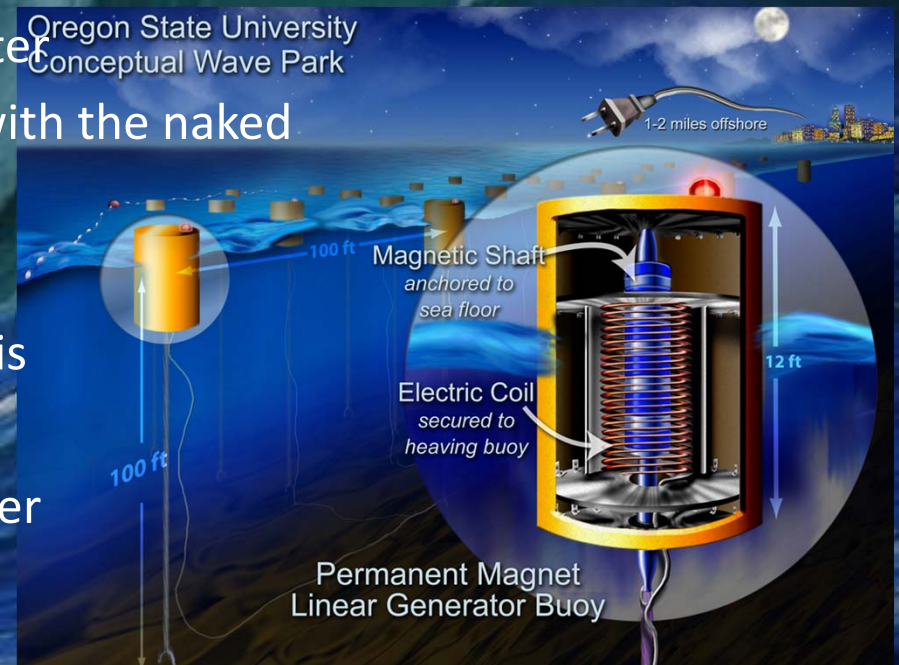
Point Absorber

- The PB150 is a floating structure with a low surface profile
- The inside is a piston like structure that oscillates as the devices bobs up and down with the wave's movement
- This motion drives a generator that produces electricity
- The power is captured by a underwater cable and get sent to the shore



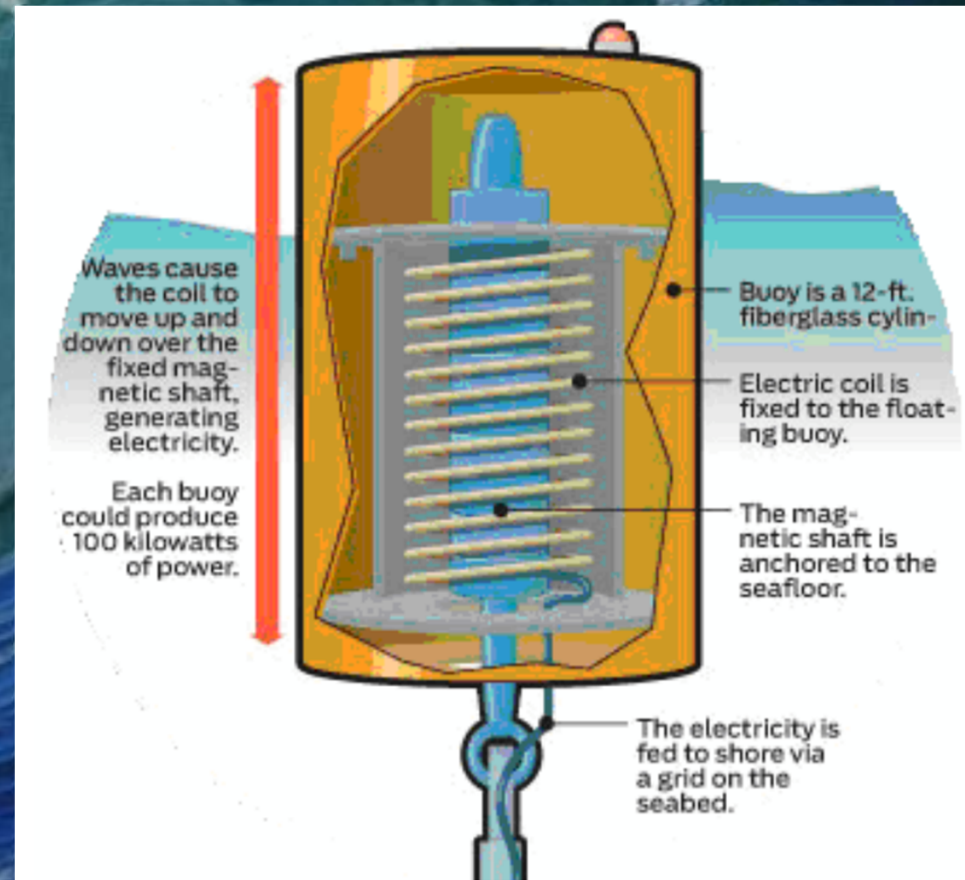
Permanent Magnet Linear Generator Buoy

- Developed by OSU, designed to be anchored 1-2 miles offshore in water depths greater than 100 feet
- 15 feet across and 12 feet tall
- Buoy sits neutrally buoyant in the water
 - Impossible to see from the land with the naked eye
- An Array of buoys will be placed in a sectioned off area, however the size is yet to be determined
- Estimated that 10 sq miles could power the entire state of Oregon



Permanent Magnet Linear Generator Buoy

- Permanent linear magnets attached to the shaft
- Magnets induce a current in the coil inside of the buoy
- The AC voltage is fed via a cable to a junction box on the seabed
- Produces 12000 V DC
- DC is converted into AC on the shore before fed into the grid

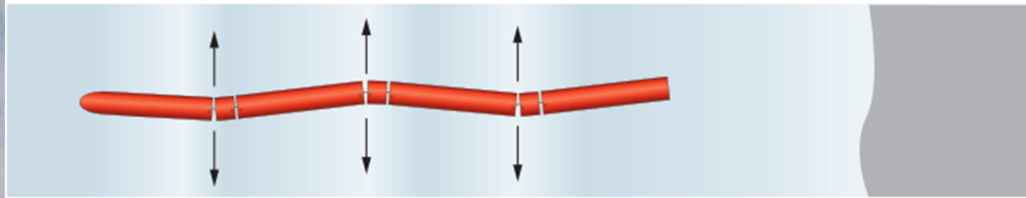


Pelamis Wave Energy Converter

- A wave energy convertor, built by Pelamis Wave, Pelamis is a floating device comprised of multiple cylindrical hollow steel segments connected by a two degree of freedom hinged joints.
- The shape and mooring of Pelamis lets it orient itself to the wave direction and its length so that it can survive storms
- World's first offshore wave machine to generate electricity into the grid
- Is capable of producing 750kW
- On average, the device can produce 30-40% of the rate value of 750kW to power 500 homes.



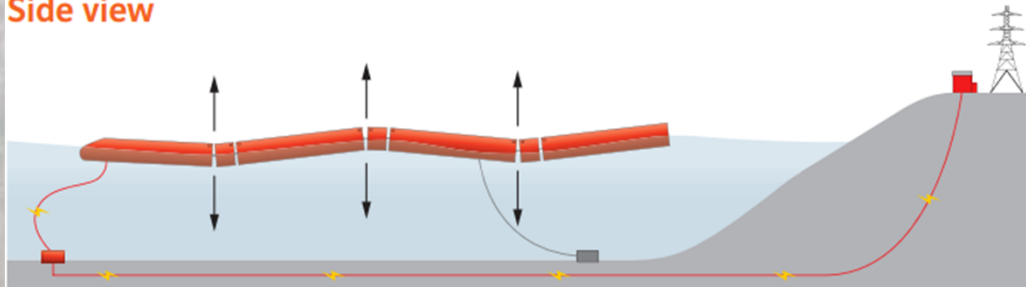
Top view



Wave direction →

The wave-induced motion of these joints is resisted by hydraulic rams, which pump high pressure fluid through hydraulic motors via smoothing accumulators.

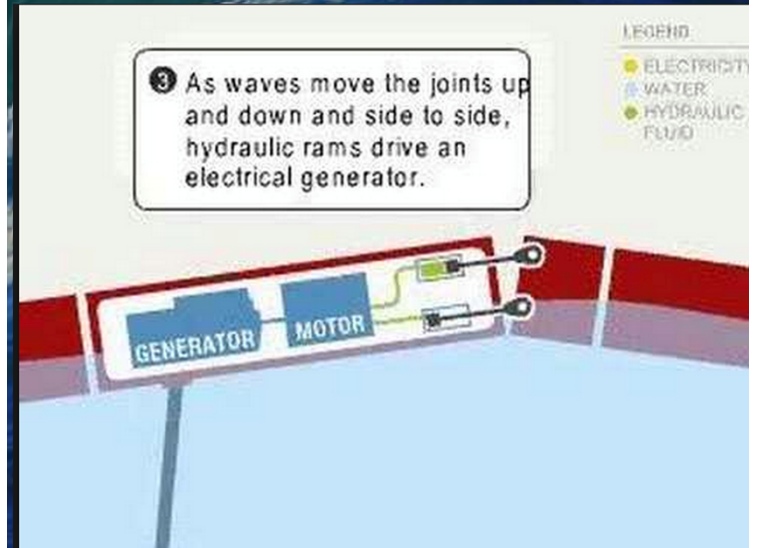
Side view



Wave direction →

The hydraulic motors drive electrical generators to produce electricity. Power is fed to the seabed via a single dynamic umbilical, connected to a transformer in the machine's nose. The complete machine is flexibly moored so it can swing head-on to the incoming waves.

Note: Pelamis P1 machine shown

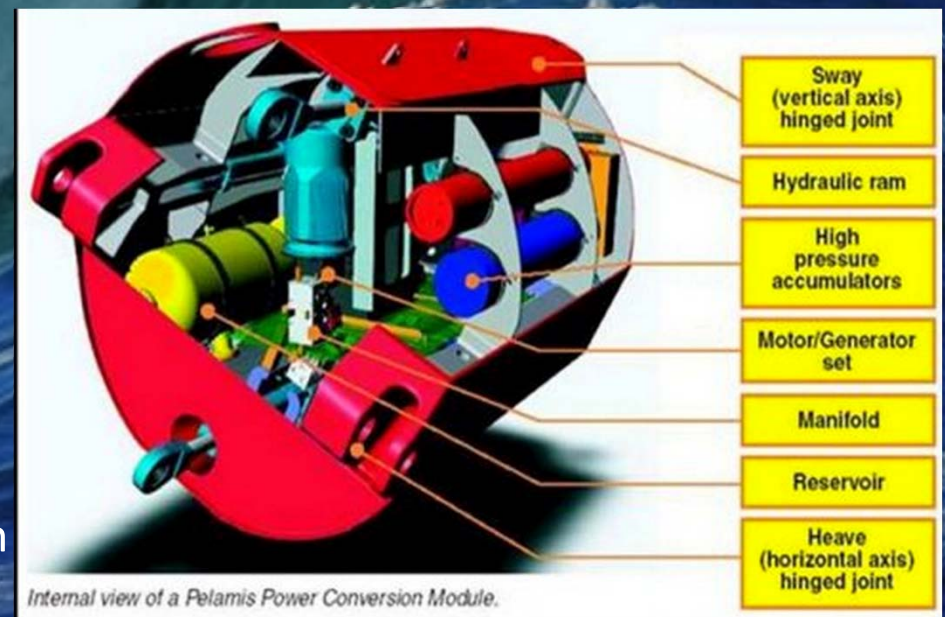


<https://www.google.com/search?q=Pelamis&espv=2&biw=1341&bih=864&site=webhp&source=lnms&tbm=isch&sa=X&ei=WuomVYjOJcqZsAWMDoH4Dg&ved=0CAyQAUoAQwrbm=isch&q=pelamis+diagram&revid=1542129843>

http://www.eon-uk.com/Pelamis_demonstration_project_information_sheet.pdf

Pelamis Wave Energy Converter

- Each Pelamis is 120m long, with 3 power modules, each rated at 250kW.
- Designed to operate in water depths of 50m.
- Four hydraulic cylinders accommodate for vertical and horizontal motion
- Cylinders act as pumps that drive fluid through a hydraulic motor which drives an electrical generator
- Accumulators are used in the circuit to decouple the pumps with the motor and helps aid in regulating the flow of fluid to produce a constant generation
- Cylinder resistance can be altered to increase/decrease energy generation as waves increase/decrease in size



<http://www.forcedgreen.com/wp-content/uploads/2010/06/diagram051.jpg>
http://abs-5.me.washington.edu/pub/tidal_wave/a_review_of_WEC_tech.pdf

Pelamis Wave Energy Converter Advantages

- One of the most environmentally benign forms of electricity generation in the world.
- Since the machine remains stationary, the efficiency increases because the marine growth on it that causes drag on a moving vessel is negligible.
- The use of anti-foulants, which is a chemical to slow down marine growth, is limited thanks to the semi-submerged design.
- Requires minimal onsite construction and impact on the shoreline.



<http://buildipedia.com/aec-pros/public-infrastructure/pelamis-wave-energy-converter-renewable-energy-from-ocean-waves>

<http://www.earthtimes.org/enviro-image/images/SPR-tube-transport450px.jpg>

Pelamis Projects

- World's first commercial wave energy project
- Located 5 km off the Agucadoura coast in Portugal
- Farm delivers 2.25MW
 - Produced by 3 Pelamis generators
 - September 2008
- Another 28 machines were planned as phase 2 to generate 22.5MW
- Plans were canceled due to leaks affecting their buoyancy



<http://www.power-technology.com/projects/pelamis/>

<https://s-media-cache-ak0.pinimg.com/236x/fa/e2/ed/fae2edcea877c14abeaf657e105d00af.jpg>

Challenges

- Lack of long term ocean wave measurements inside the 100 meter depth contour
- With the lack of data, it is difficult to know where the best location would be to place wave energy converters.
- The Wave energy converter output is reduced if the WEC runs at wave conditions below or above what it is designed for
 - The overload could potentially damage the structure
- The current technology for wave power is not as advanced as it is for solar or wind