

# Wave Energy Generation

The Power of waves...

ECE 4833

By: Aftab Chithiwala

# Introduction

- **Tidal Energy** is a form of Hydropower that harnesses energy from the tides, that occur on daily cycles, and converts that to useful form of energy like electrical energy.
- **Wave Energy** is the energy stored in the oscillatory motion of the ocean waves. Waves get their energy from the wind which in turn comes from solar energy. Waves gather, store, and transmit this energy across thousands of miles with little loss.
- Since as early as 1890, attempts have been made to create Wave Power Generators but not much progress has been made in terms of commercial power generation using Wave or Tidal Energy.
- Even though Wave and Tidal power has not been widely utilized, it has great potential to contribute handsomely in the future.

[http://en.wikipedia.org/wiki/Tidal\\_power#Tidal\\_fences\\_and\\_turbines](http://en.wikipedia.org/wiki/Tidal_power#Tidal_fences_and_turbines)

[http://en.wikipedia.org/wiki/Wave\\_power](http://en.wikipedia.org/wiki/Wave_power)

<http://www.outsidelands.org/wave-tidal3.php>

# Why use Wave Energy?

- Water is one of the most abundant renewable on the Earth with about 70% of earth's surface being covered by water.
- Waves in large water bodies can have significant amount of energy density depending on its geography.
- Wind and incoming solar radiation transfer energy to waves which can have power levels that can exceed 1,000 kW/m along the wave crest length, in major storms.
- Even in normal conditions, the power levels of ocean waves can hit up to a few tens of kW per meter.
- Just to keep in perspective, this is quite a bit more than the Solar irradiation that the earth receive from the sun (about 1kW per m<sup>2</sup>).

# Energy Stored in an Ocean Wave

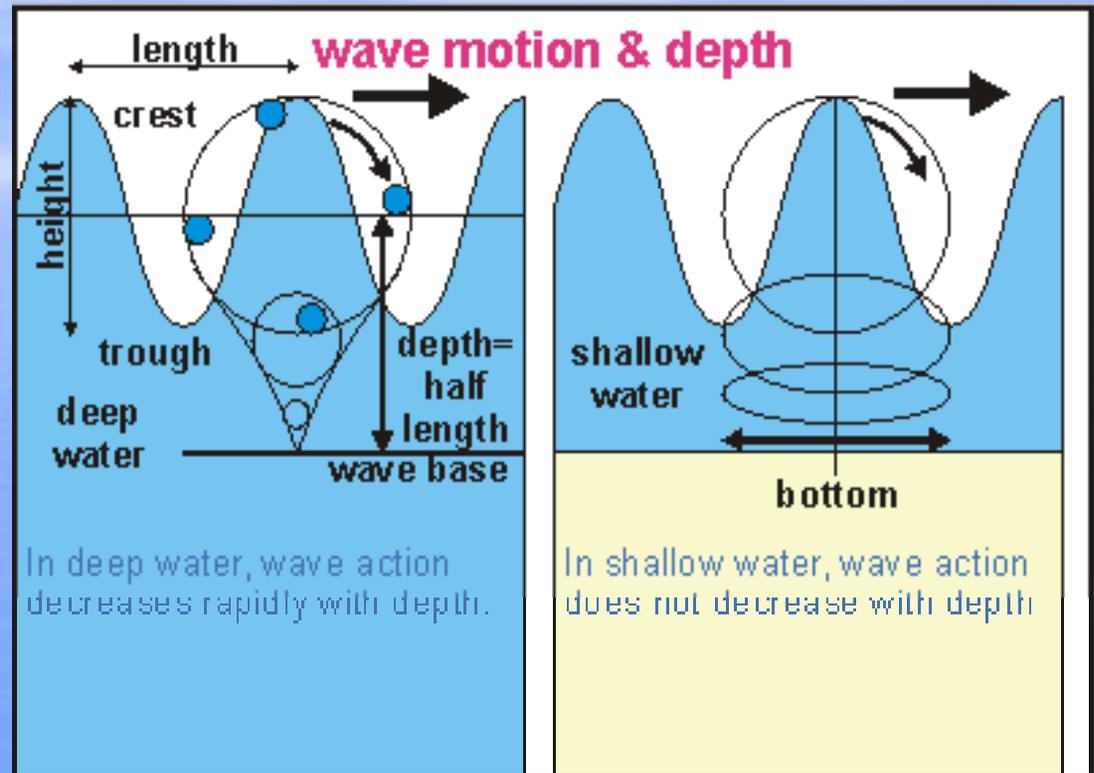
$$P = \frac{\rho g^2 T H^3}{32\pi}$$

$\rho$  = the density of seawater = 1,025 kg/m<sup>3</sup>,

$g$  = acceleration due to gravity = 9.8 m/s/s,

$T$  = period of wave (s), and

$H$  = wave height (m).

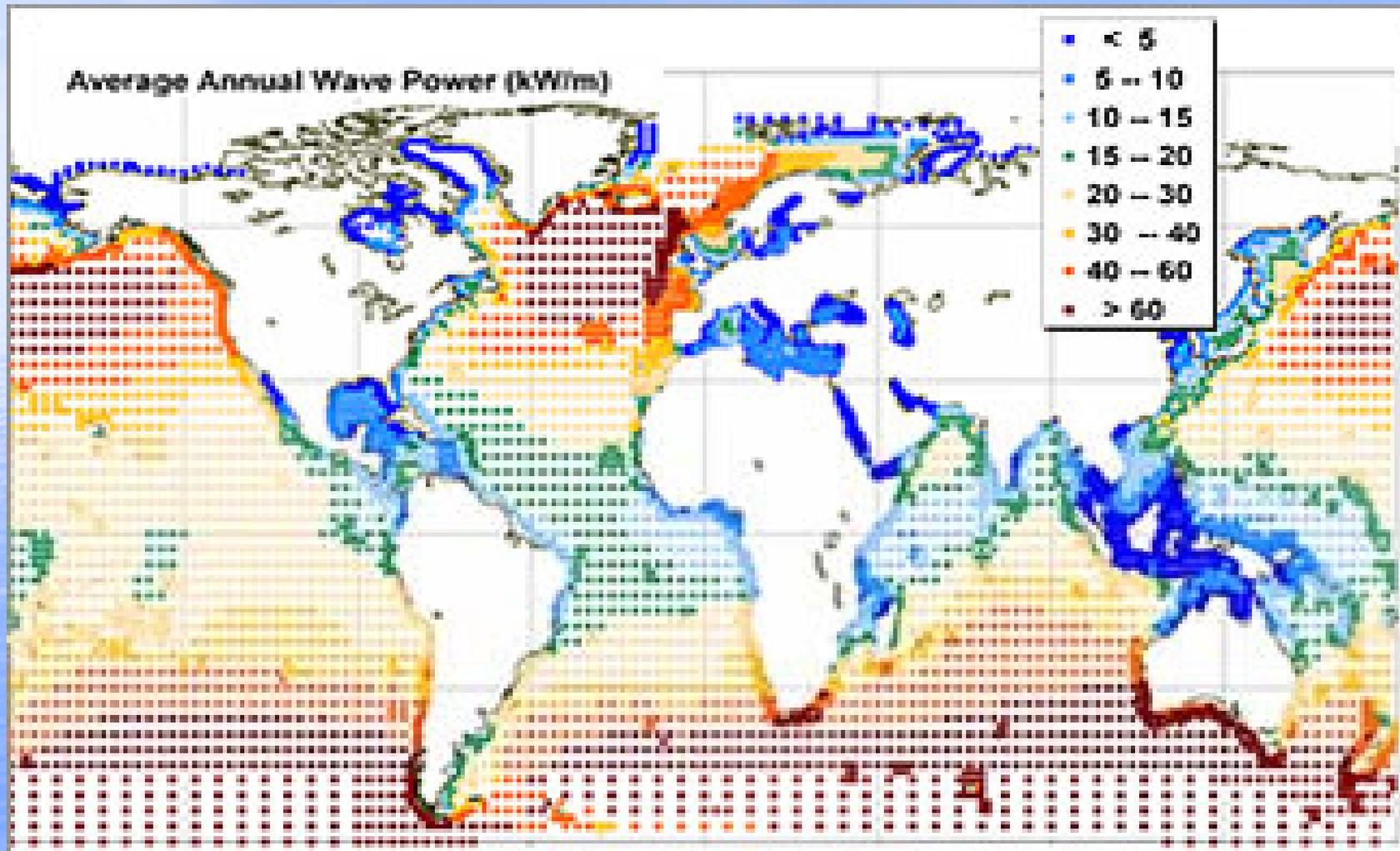


- Thus it seems that there is lot of energy trapped in the waters of our planet that can be harnessed using smart technology and help meet our ever demands.

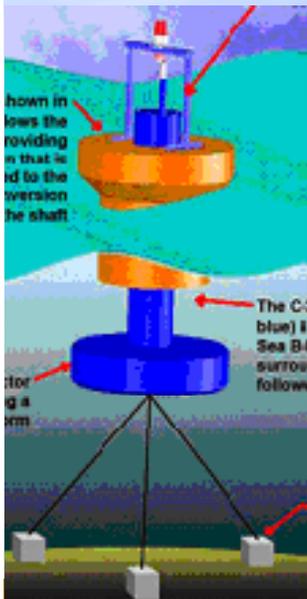
<http://www.seafriends.org.nz/oceano/ocean04.gif>

[http://www.ocsenergy.anl.gov/documents/docs/OCS\\_EIS\\_WhitePaper\\_Wave.pdf](http://www.ocsenergy.anl.gov/documents/docs/OCS_EIS_WhitePaper_Wave.pdf)

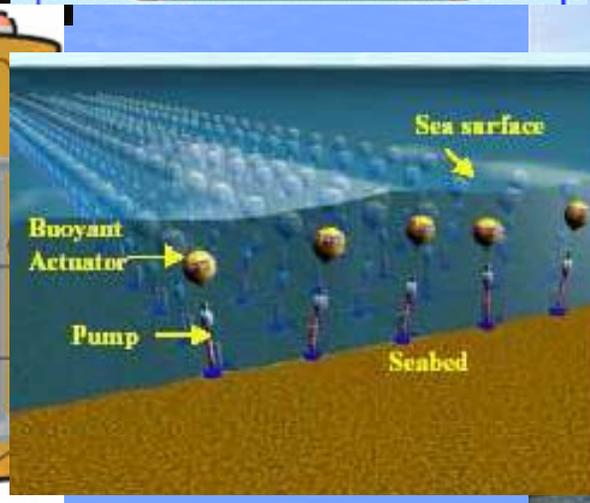
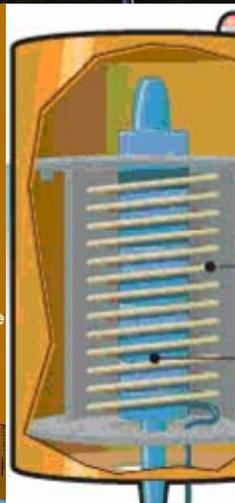
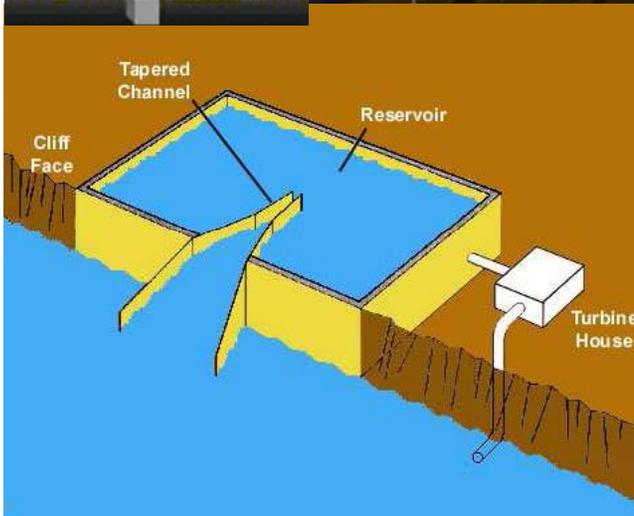
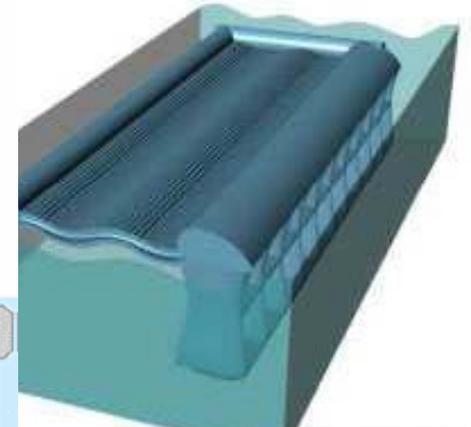
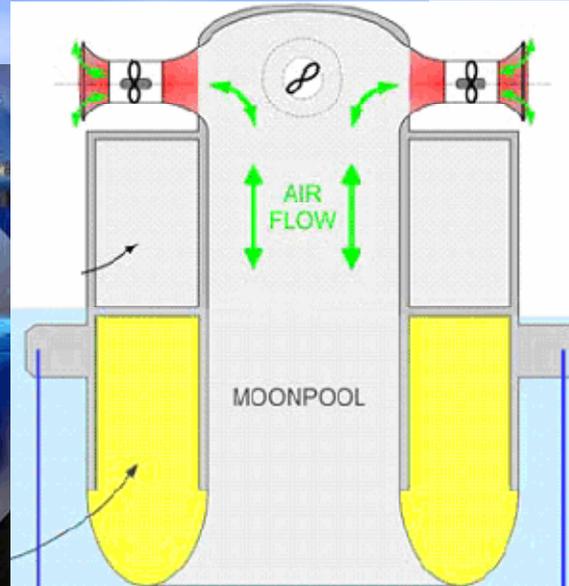
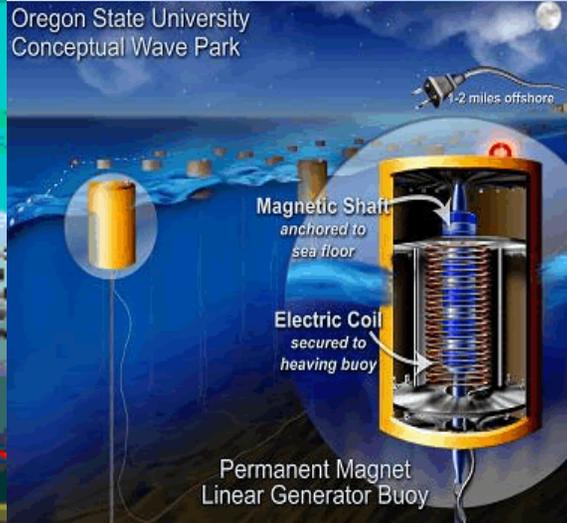
# Wave Power Density across the World



# Some Interesting designs of Wave Power Generator



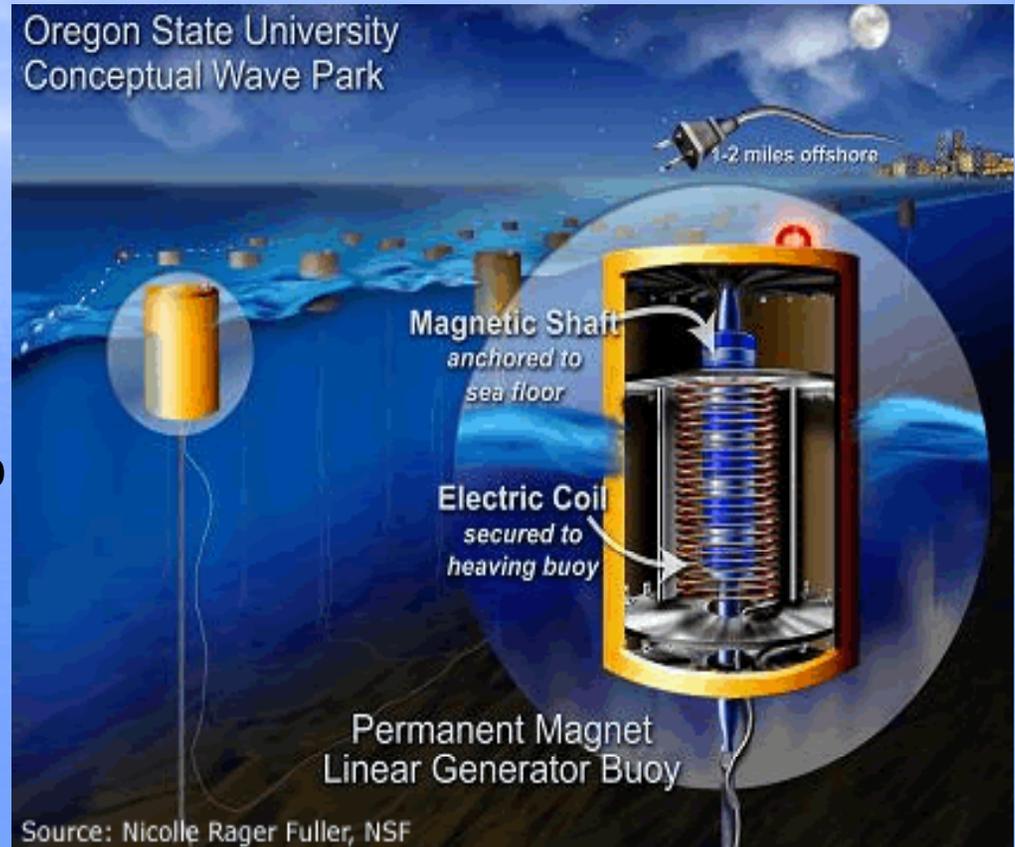
Oregon State University  
Conceptual Wave Park



# Permanent Magnet Linear Generator Buoy

## Oregon State University Project:

- OSU-developed buoys are designed to be anchored 1-2 miles offshore in water depths greater than 100 feet.
- At about 15 feet across by 12 feet tall, the buoys will sit neutrally buoyant in the water, and will be almost impossible to see from land with the naked eye.
- The research team pictures an array of buoys, or wave park, placed within a sectioned off area of a yet to be determined size.
- It is estimated that a wave park of 10 square miles could power the entire state of Oregon.



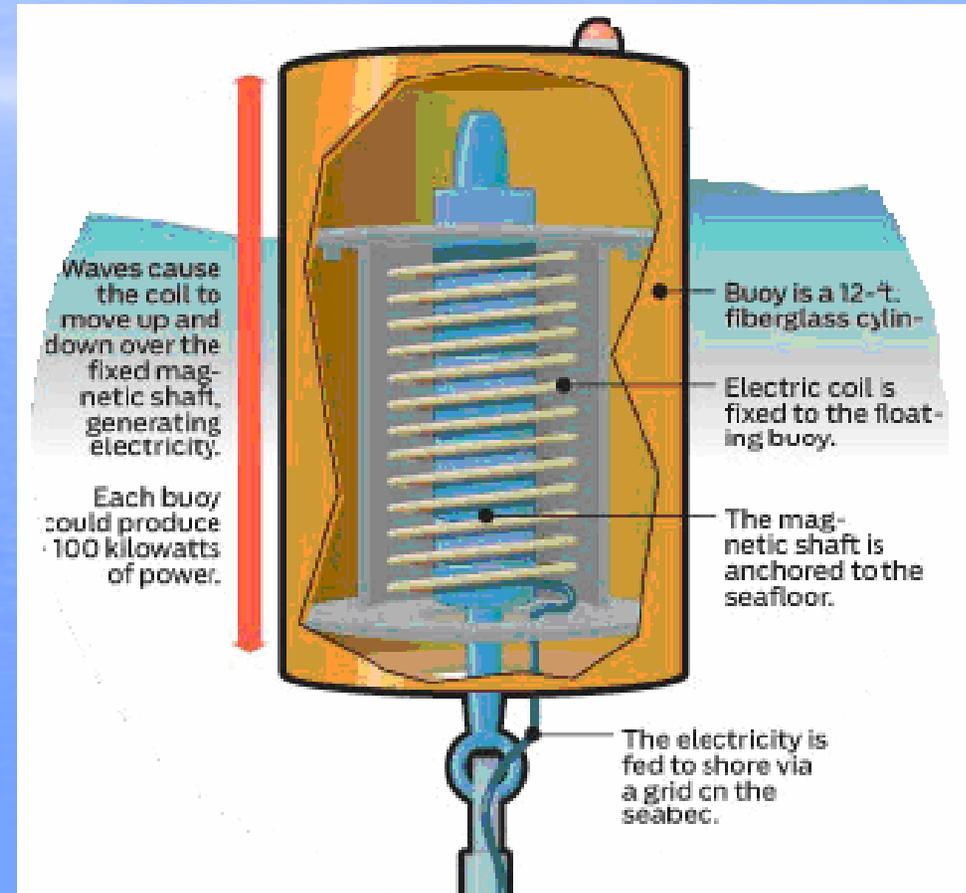
<http://enr.oregonstate.edu/news/ar/2005/waveenergy.html>

<http://www.crses.sun.ac.za/oen/images/pdf/WaveEnergyConvertors.pdf>

# Permanent Magnet Linear Generator Buoy

## MECHANISM:

- The buoy has permanent linear magnets that are attached to the shaft.
- Due to the wave, the buoy undergoes up – down motion and so does the coil, placed inside the buoy.
- The magnet induces a current in the coil that's housed inside the buoy.
- This unregulated AC voltage (from the buoys) is fed via a cable to a junction box on the seabed where it is converted to 12000V DC.
- The DC voltage will be changed back into AC on the shore before it feeds into the grid.



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# Pelamis Wave Energy Converter

- Pelamis is Wave power generator using Surface-Following technology.
- Pelamis Wave Energy Converter is a semi-submerged, structure composed of cylindrical sections linked by hinged joints.
- At present, Pelamis is one of the most developed wave power generating devices in the world.
- It is the world's first commercial scale wave energy converter to generate electricity to a national grid.
- Pelamis is capable of producing 750kW.
- Depending on the site, on average, the device will produce 25 to 40% of the rated value of 750kW which would be enough to meet demands of 500 homes.



## Comparison to Fossil fuel powered Generators:

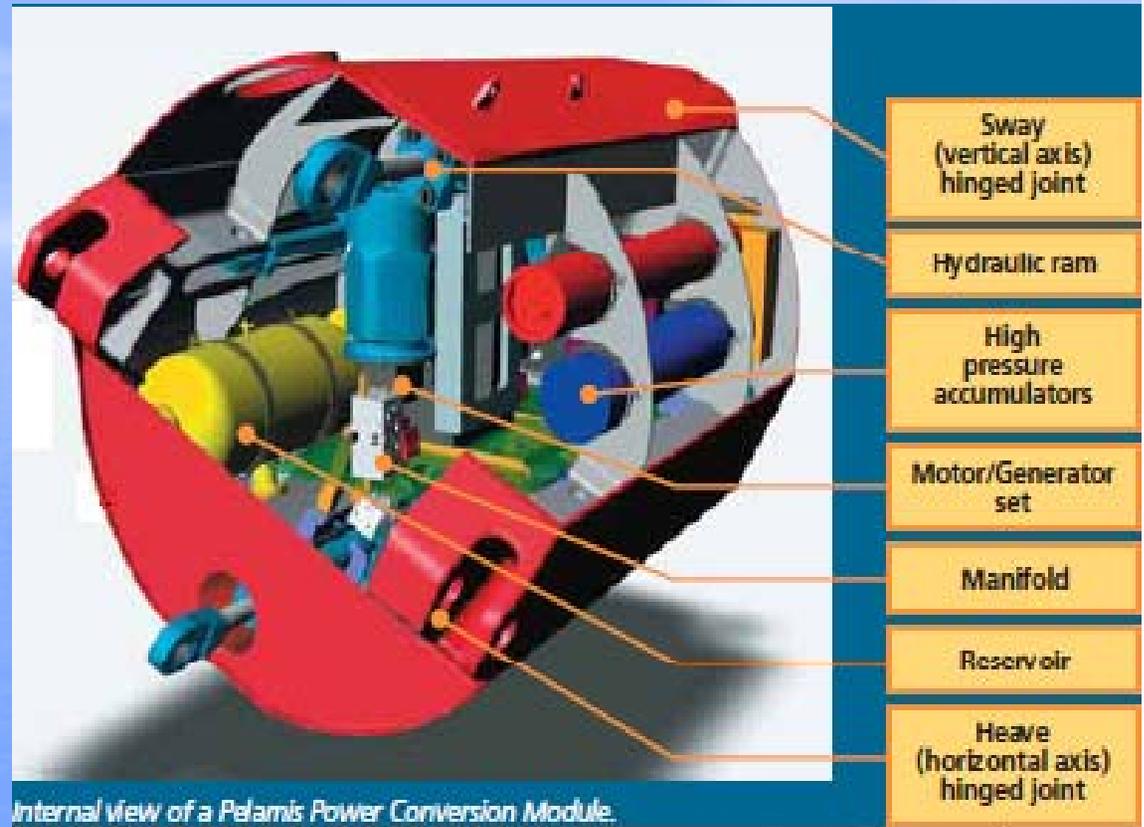
- Equivalent gas turbine – fuel 600 tonnes/year
- Equivalent gas turbine – CO2 emissions 2000 tonnes/year

[www.pelamis.com](http://www.pelamis.com)

<http://www.crses.sun.ac.za/oen/images/pdf/WaveEnergyConvertors.pdf>

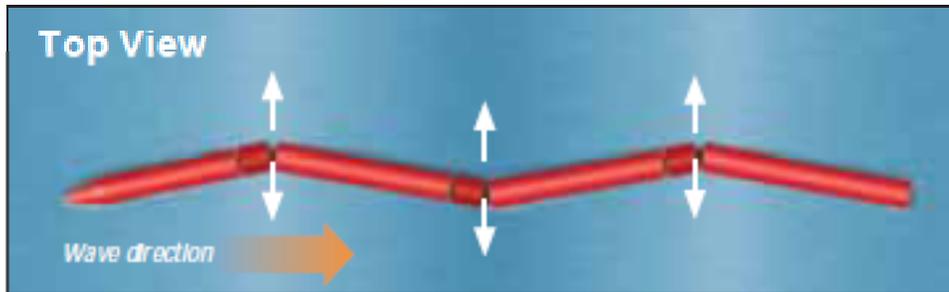
# Pelamis – Design & Mechanism

- Pelamis machines are 150m long and 3.5m in diameter with 3 power conversion modules per machine.
- Pelamis has four large Cylindrical Tube segments which have power Conversion Modules at the meeting point of two segments. These tubes are connected to each other by hinges.
- The waves cause the joints to move, thus causing the hydraulic rams to pump high pressure oil through smoothing accumulators to the motors.
- The motors rotate, thus generating electricity.
- A single cable carries electricity from the module to the junction on the sea floor.
- Several devices can be connected together and linked to shore through a single sea floor cable.

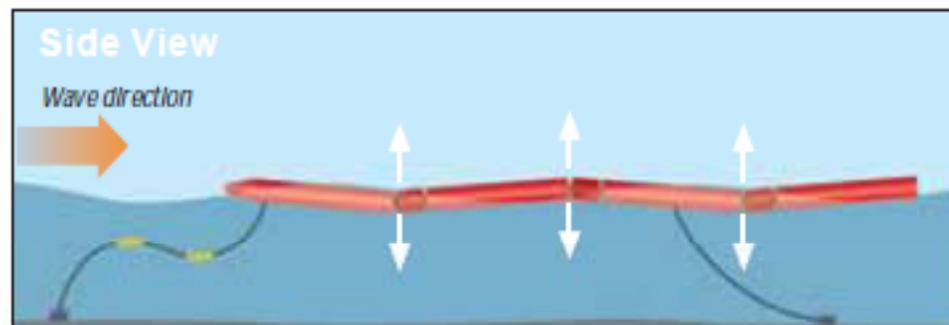


<http://www.pelamiswave.com/media/pelamisbrochure.pdf>

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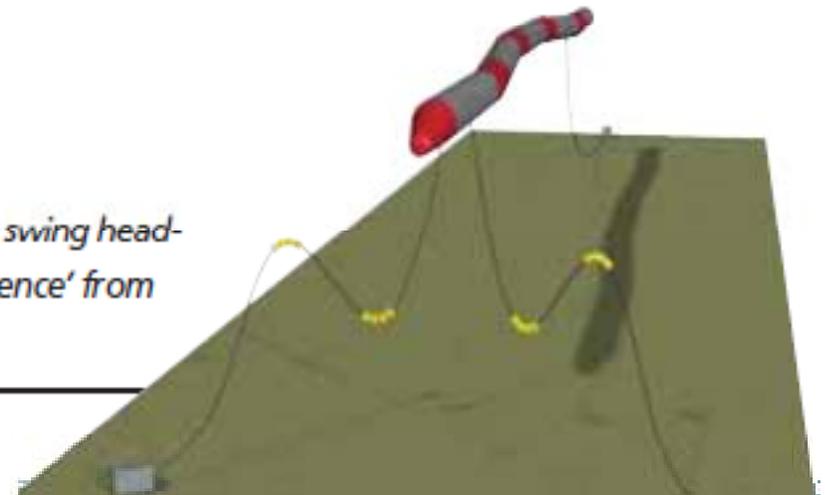


*The wave-induced motion of these joints is resisted by hydraulic rams which pump high pressure fluid through hydraulic motors via smoothing accumulators.*



*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 as to swing head-on to the incoming waves and derives its 'reference' from spanning successive wave crests.*



# Pelamis – Specifications

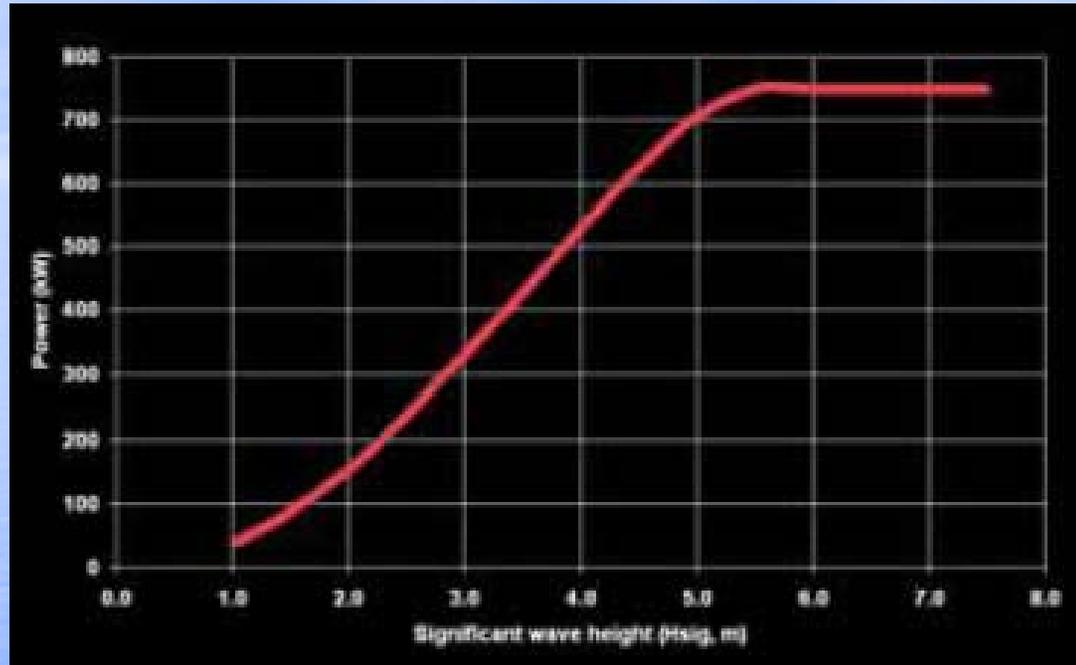
- Generator Specifications
  - Asynchronous
  - 2 x 157kVA / 125kW
  - Speed 1500rpm
  - Overall power rating 750kW
- System voltage 3-phase, 415/690Vac 50/60Hz
- Transformer 950kVA step up to 11kV or 33kV
- Annual output 2.7GWh
- Nominal wave power 55kW/m
- Hydrostatic power limiting >6 – 7m significant wave height

<http://www.pelamiswave.com/media/pelamisbrochure.pdf>

<http://www.crses.sun.ac.za/oen/images/pdf/WaveEnergyConvertors.pdf>



# Pelamis: Safety Mechanism

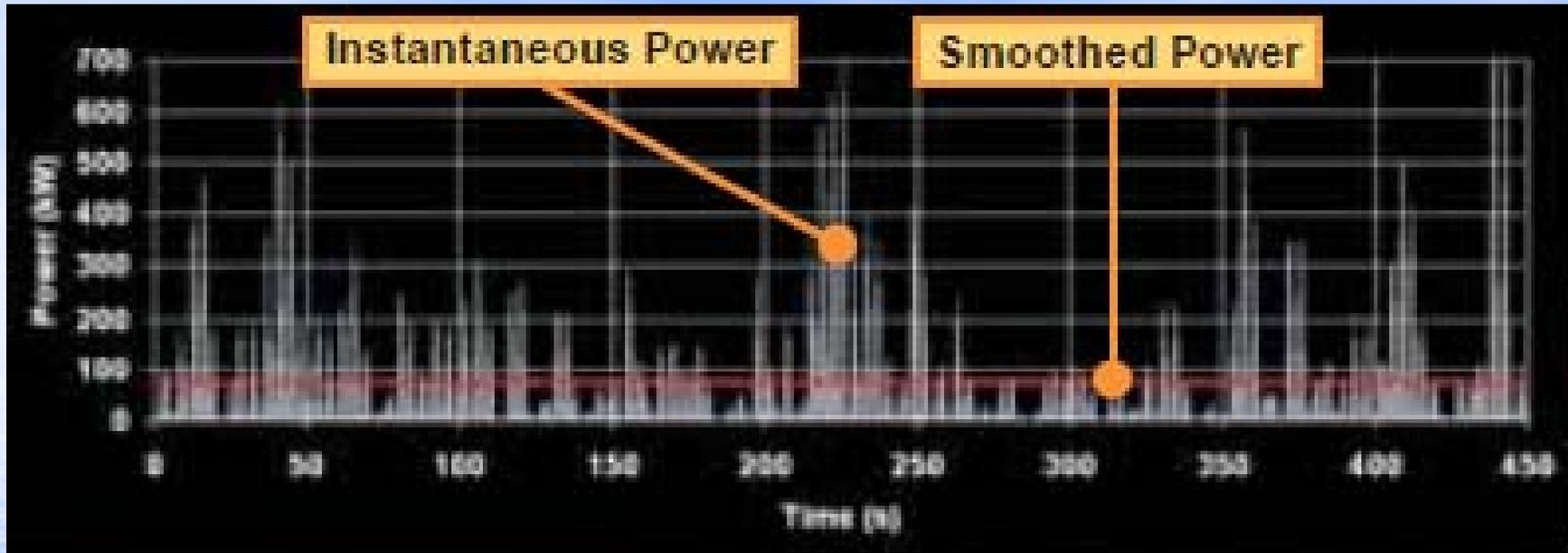


## Pelamis Hydrodynamic Power Limiting

- Wave period ( $T_{pow}$ ) of 8 seconds.
- Above a certain wave height, absorbed power is limited through the Pelamis inherent design characteristics.
- In this way, the danger of accidentally supplying more current than rated value and in the process damaging the transmission lines, the transformers or the device itself is eliminated.

<http://www.pelamiswave.com/media/pelamisbrochure.pdf>

# Pelamis - Smooth Output

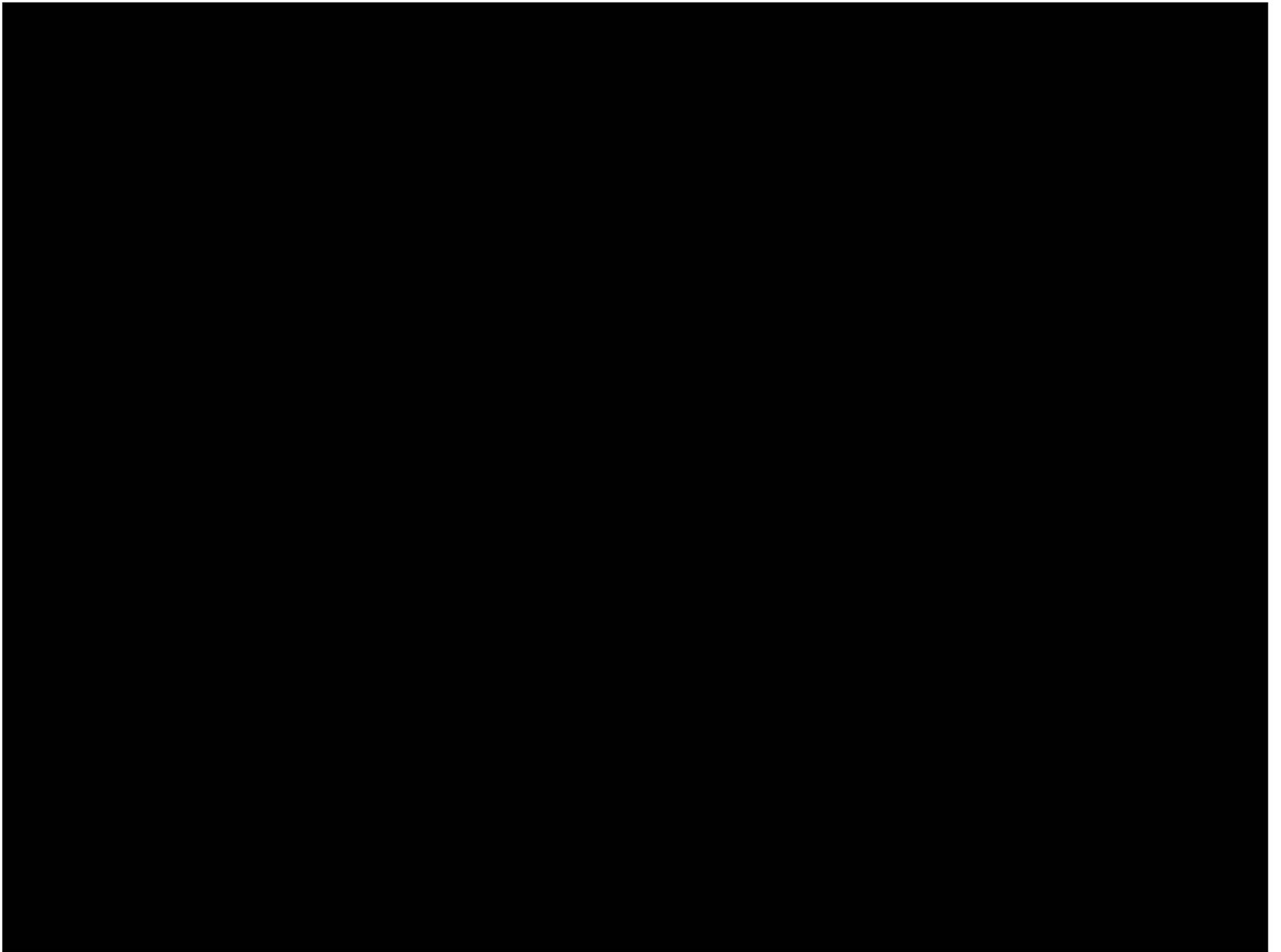


- Generally Waves produce a widely variable power input.
- The Pelamis stores energy in hydraulic accumulators to even out this unsteady input and provides a smooth flow of fluid to the variable displacement drive motor, and a steady power output from the machine's generators.

# Pelamis – Wave Farm Projects

- Aguçadoura, Portugal
  - World's 1st wave farm project.
  - 3 Pelamis deployed near the northern Atlantic coast of Portugal and supplying power to the grid.
- Shetland, Scotland
  - Project in development stage
  - Up to 26 Pelamis may be installed to produce 20MW.





# Challenges for Wave Power Devices

- There is an extremely large fluctuation of power in the waves. Thus the peak absorption capacity for the devices needs to be much (more than 10 times) larger than the mean power.
- The device has to be able to survive storm damage and saltwater corrosion. Hence, special technology has to be used to counter this problem, thereby increasing cost.
- The device has to efficiently convert wave motion into electricity. Generally wave power is available at low speed and high force, and the motion of forces is not in a single direction. Most readily-available electric generators operate at higher speeds, and turbines require a constant, steady flow.
- The total cost of electricity produced by Wave power is high thus making it less competitive in the power generation market.
- The current technology for wave power is still not as advanced as for solar or wind power.

[http://en.wikipedia.org/wiki/Tidal\\_power#Tidal\\_fences\\_and\\_turbines](http://en.wikipedia.org/wiki/Tidal_power#Tidal_fences_and_turbines)

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QUESTIONS ???