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# Wave power conversion systems for electrical energy production

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## 1. Introduction

Wave power refers to the energy of ocean surface waves and the capture of that energy to do useful work. Sea waves are a very promising energy carrier among renewable power sources, since they are able to manifest an enormous amount of energy resources in almost all geographical regions. The global theoretical energy from waves corresponds to $8x10^6$ TWh/year, which is about 100 times the total hydroelectricity generation of the whole planet. To produce this energy using fossil fuels it would result an emission of 2 millions of tones of $CO_2$. This means that wave energy could contribute heavily for the attenuation of pollutant gases in the atmosphere, as defended by the Kyoto Protocol.
The global wave resource due to wave energy is roughly 2 TW and Europe represents about 320 GW, which is about 16% of the total resource. However, for various reasons, it is estimated that only 10 to 15% can be converted into electrical energy, which is a vast source of energy, able to feed the present all world. Eventually, wave energy could make a major contribution by yielding as much as 120 TWh/year for Europe and perhaps three times that level worldwide [1]
After a brief description of wave formation and quantifying the power across each meter of wave front associated to the wave, the paper describes several devices used presently to extract mechanical energy from the waves and their advantages and disadvantages are presented as conclusions. In particular, the modern Pelamis system is described in some detail.
Wave energy market is also discussed.

**Key words:** Wave Power; Devices to convert wave energy; Pelamis converter; Wave energy market.

## 2. World Resource of Wave Power

Wave energy is unevenly distributed over the globe. Figure 1 shows an Atlas of the global power density distribution of the oceans where the numbers indicate kW/m. The regions between the latitudes of 30° and 60° on both hemispheres, where winds blow with more intensity, have the best sites for capturing wave power.

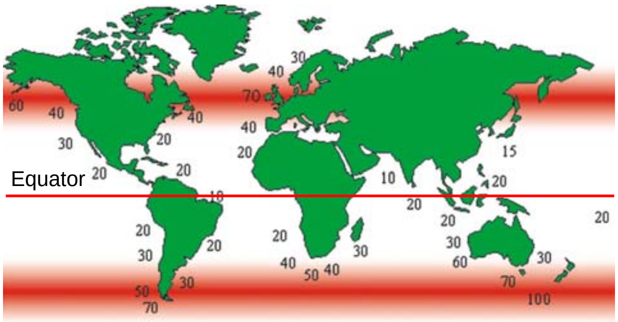


Fig.1 Global wave power distribution in kW/m

The oceanic wave climate (i.e. far offshore) offers enormous levels of energy. As waves approach the shore, energy is dissipated, leading to lower wave power levels on the shoreline. Therefore, the energy availability is sensitive to location and the distance from the shoreline [2]

## 3. Types of Wave Power Mechanisms

The sea wave's motion can be converted into mechanical energy by using proper wave power mechanisms. There are currently about 40 types of mechanisms for exploiting the energy available in waves, several of which are now being constructed. These devices are generally categorized by location installed and power take-off system.
Locations are *shoreline*, *nearshore* and *offshore*. Power take-off systems can be oscillating column of water, underwater pneumatic systems, wave dragon system and oscillating bodies system. Also these mechanisms can be lying on the bottom of the sea, on the shoreline and on sea level. Description of these systems is presented.

- **Shoreline Locations**

*A Oscillating Water Column*

This system consists of a chamber built in shoreline cost with the layout shown in figure 2. The motions of ocean/sea waves push an air pocket up and down behind a breakwater. Then the air passes through an air turbine. Next, when the wave returns to the sea, an air depression will circulate through the turbine in the opposite sense. However, this turbine has been designed to continue turning the same way irrespective of the direction of the airflow.

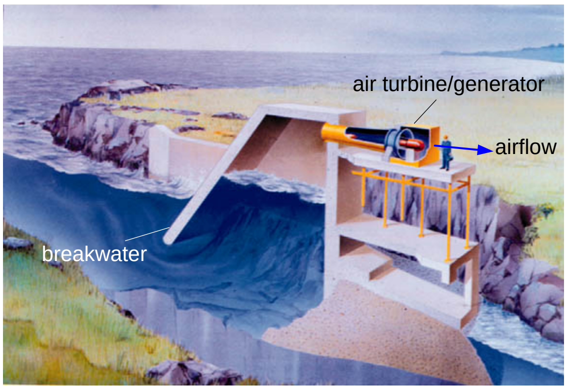


Fig. 2 Oscillating column of water system

This is a rectifier Wells turbine type, designed by Professor Alan Wells of Queen's University, which drives an asynchronous generator mounted on the same shaft. To control the air pressure inside the camera a valve in parallel (sometimes in series) with the turbine is used [3].

*B Pendulum System*

The Pendulum system is also installed in the shoreline and consists of a parallelepiped concrete box, which is open to the sea at one end.
A pendulum flap is hinged over this opening, so that the actions of the waves cause it to swing back and forth. This motion is then used to power a hydraulic pump and an electric generator.

- **Nearshore Locations**

*C Offshore Wave Dragon System*

Wave Dragon System is a floating slack-moored energy converter of the overtopping type that can be displayed in a single unit or in arrays. Groups of 200 Wave Dragon units result in a wave power park with a capacity comparable to a traditional fossil fuel based power plant.
The basic idea of this system consists of two large "arms" that focus waves up a ramp into a reservoir, as shown illustrated in figure 3.

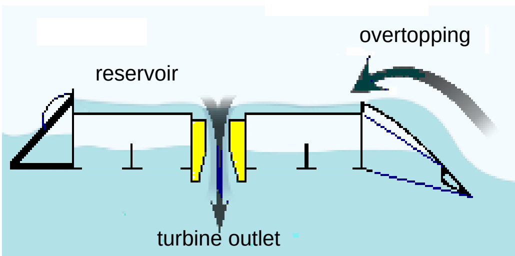


Fig. 3 Wave Dragon System Principle

The water returns to the ocean by the force of gravity via a low head hydro turbine driving an electric generator.
The water returns to the ocean by the force of gravity via a low head hydro turbine which drives an electric generator.

- **Offshore Locations**

*D Pelamis Wave Energy Converter*

The Pelamis Wave Energy Converter consists of six articulated cylinders of 3.5 m in diameter and 30 m in length (floaters) articulated connected to four cylinders of 3.5 m in diameter and 5 m in length (power modules)
This articulated structure with 140 m in a total length is placed 2/3 semi-submerged offshore in deep waters, as shown in figure 4.

Fig. 4 Pelamis Wave Energy Converter

Due to the waves, this structure up and down and side to side as a sea snake (Pelamis in Greek). Inside the power modules is installed a hydraulic motor driving an electric generator connected to the grid by means a power cable.
Another relevant offshore systems described in the full paper are *E) Salter's Duck System, F) Wave Roller System, G) Power Buoy, H) The Archimedes Wave Swing and I) Bristol Cylinder.*

## 4. Conclusions

Wave energy is not expensive to operate and maintain, no fuel is needed and no waste is produced. The MW cost installed to be competitive is situated between 0.5 to 0.6 M€/MW and the economic competitive is attainable when is installed at least a power of 6.8 GW. Presently, the world wave energy market is situated in $750 \times 10^{6}$ €. The European Union estimates a wave energy cost of about 5 €/kWh.

## References

[1] Bent SØrenfen: "Renewable Energy", Elsevier Academic Press, 2004 Edition.
[2] Wikipedia: Web site on Power Waves
[3] B. Weedy and B. Cory: "Electric Power Systems", Wiley, Fourth Edition, London 1998.