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Principles of wave energy

WAVE FARM DESIGNS **Wave energy is a relatively new RES (Renewable Energy Source), that is quickly gaining momentum. It has not yet reached a commercial stage, but many projects expect to launch wave energy as a viable RES alternative to wind energy and solar power within a few years.**

Björn Welander

Wave energy is a vast untapped source of energy and the potential for exploiting wave power around the globe has been calculated to be between 10-15,000 TWh per annum. It is, for example, expected that Europe will have an installed capacity of 3 – 4 GW by 2020. The world revenue potential is thought to be more than 40 B USD per year.

It is crucial to get familiar with the wave climate in the various areas around the globe. The wave climate contains more energy in places such as the west coast of Ireland, southern Chile and off the southwest coast of Austrailia (60–80 kW/m wavecrest) than in the Caribbean, the Baltic and the Mediterranean (10-20 kW/m wavecrest).

The energy contained in a wave is calculated as follows:

$$P = \frac{\rho g^2}{64\pi} H^2_{m0} T \approx (0{,}5 \frac{kW}{m^3 * s}) H^2_{m0} T,$$

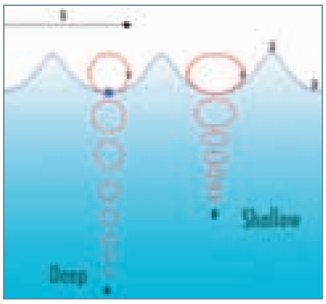
$$P \approx 0{,}5 H^2 T$$

where

P=Power (kW); H=wave heigh (m); T=wave period (seconds)

What matters is how much absorption can be achieved with a minimum of loss. Previously it was considered that it would only be possible to extract energy in wave climates with very high energy content, but recently some developers have been focusing on so called sheltered wave climates using devices with higher absorption rates.

Unlike wind energy, where a single wind turbine design has become totally dominant in the sector, there is a wide variety of Wave Energy Converter (WEC) designs available. One distinction between different designs is their location being either onshore, near shore or offshore. A further breakup is by looking at the various working principles of the designs.

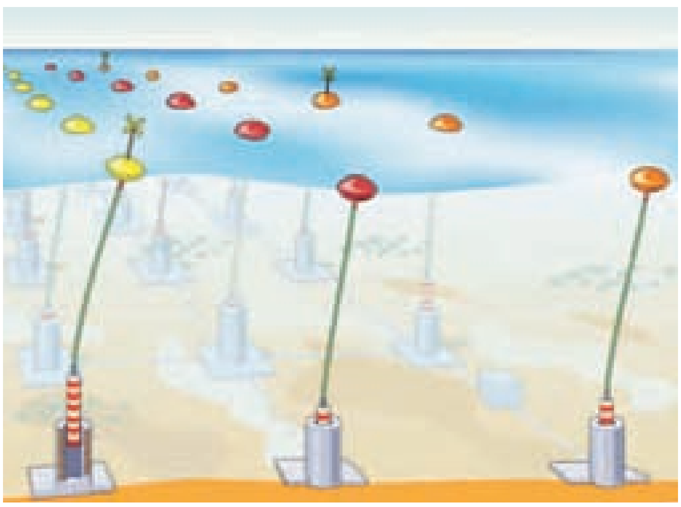


Particle movement of waves in deep and shallow water: Largest movement is at the surface

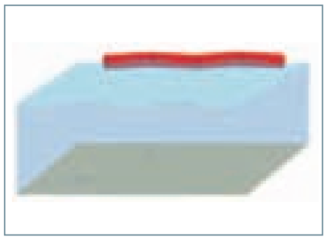
There are several reasons why it has taken longer for wave energy to mature than, for instance, wind power. Some of these are technological barriers, but many are not, such as the permission to use sea areas for wave energy parks and lack of investments. Both the EU and the US Department of Energy are trying to remedy this fact by setting up grant schemes and making partial funding available for R&D. The EU, for example, has been giving funding to the overtopping WEC in Kvitsöj, Norway, the SEEWEC project in Belgium, the AWS Ocean Energy and the Danish Wave Energy Star projects.

The technological barriers are primarily durability of the device to severe weather and long-term wear as well as the challenge to deliver energy at a competitive price. Another problem to overcome is the ability to deliver the energy in the form of electricity into an electric grid.

Reliability and serviceability are other issues that developers have tackled in different ways. The American company OWECO has developed a "point-absorber" type of WEC that doesn't need a bottom foundation and only needs slack mooring. The inventor Mr Foerd Ames has also come up with a new generator design that offers a more continuous motion and increases energy conversion efficiency.



Seabased uses Pointabsorbers with a linear generator situated at the sea bottom



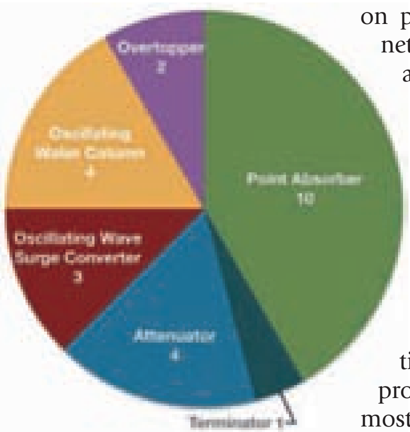
Attenuators ride the waves and generate energy by a folding motion

Non-technological barriers

Wave Energy Converters show great promises but there are several barriers. One of them is the permit required to gain access to sea areas that are needed to implement projects. Some countries, like the UK, have already designated certain areas to be used for wave energy extraction. There are also EU governed directives to conduct EIA (Environmental Impact Assessment) before exploitation. Localization of wave farms near shore have to take other interests into consideration, such as requirements by the shipping industry as well as by fishermen and, in some cases, there might be a conflict of interests with mining companies or the tourism industry. An assessment of risk will have to be carried out as well.

The OWEC wave energy generator is a point absorber that uses a neutral buoyancy as reference point. The generator is a counter rotating generator.

Many studies have already been carried out regarding the environmental impact of different types of WECs. Many of them point out the fact that there are several positive impacts, such as the artificial reef effect, which increases the biodiversity of a sea area by adding a substrate. Another effect is that wave farm areas will usually be out of bounds for industrial fishing, thereby providing potential nursery areas for fish.



Point absorber devices are the most popular designs

Areas that still need more studies are the effects of wave attenuation and the effects on ocean currents.

A life cycle analysis is needed to assess the environmental impacts and predict total carbon emissions through the lifetime of a device.

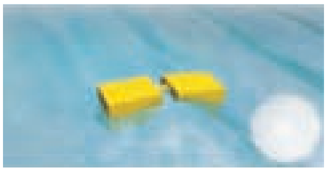
Cost effectiveness

The cost effectiveness of new wave energy devices has improved a great deal in the last few years. This is mainly thanks to the fact that materials like composites have become less costly and more efficient energy conversion mechanism have been designed, enabling better absorption of wave energy. For instance, new types of turbines and rotating generators based on powerful permanent magnets have recently become available.

To study the economic feasibility of industrial scale wave farms is still very difficult, as very few technologies have reached the commercial stage, yet. However, some reports have proposed estimations, but they often fail to provide specific information, mostly due to lack of data. The actual projected cost per kWh is today 0.10 – 0.25 EUR, targeting a cost level of 0.05 EUR by 2015 – 2020. (source: European Commission). Wave energy can be more reliable and, in many cases, has a higher capacity factor compared to wind energy, since it offers slower and more predictable drawdowns. Further, wave energy doesn't produce any noise and many devices have a very low visual impact.

The life span of wave energy devices is a critical issue. More ▶

testing will have to be done but it's considered that 25 years and above is a feasible life span for systems currently undergoing sea trials. Some developers, like OWECO, are placing the sensitive power generating parts under water in neutral buoyancy, which means they are not vulnerable to surface wave action.
The servicing of wave energy devices is an area which will become increasingly important in the future. Companies that specialize in this field will need to have vessels and trained personnel available.
There are a number of interesting ideas on how the produced energy should be converted, in order to be used most efficiently. One concept is to desalinate salt water on site and another one is to produce hydrogen by means of electrolysis.

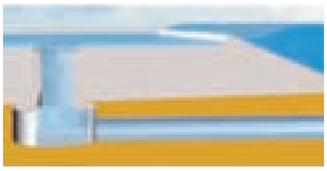


Attenuator

Point absorber

Oscillating Wave Surge Converter

Oscillating water column



Overtopping device

Submerged pressure differential

Images: © 2009 EMEC

Test sites

Several test sites have been set up in different parts of the world. In Ireland, there is the Galway Bay test site, in Norway, the Runde Environmental Centre and off the coast of Portugal a so-called Pilot Zone. The Danish site Nissum Bredning Test Station has tested about 30 different devices and enables developers to do first trials where the waves are not too powerful. A "wave hub" is planned off the coast of Cornwall where the efficiency and durability of different devices will be compared. Much of the research is currently carried out by universities in cooperation with wave energy developers.
WECs that have undergone a full-scale sea trial include:

- Pelamis: An attenuator, which is riding the waves. It has been deployed for 3 years off the coast of Portugal. The Pelamis is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. The wave-induced motion of these joints is resisted by hydraulic arms, which pump high-pressure fluid through turbines.
- Seabased: A point absorber based on a linear generator. In February it was decided to set up a wave farm with a capacity of 10 MW consisting of 400 – 550 WECs. Once deployed, this will become the world's largest wave farm to date.
- Ocean Linx: An Australian Oscillating Water Column design that uses the Denniss-Auld turbine that has variable pitch blades optimising the energy extraction. The designers have recently launched its latest generation of WEC.
- Wave Star Energy: After more than two years of testing a 1/10 scale model, which has successfully resisted many storms, a full-scale prototype of the Wave Star Energy is planned off the Danish coast. The full-scale prototype will be installed offshore and it will be connected to the grid through an existing offshore wind farm.

Oweco's design keeps the generator underneath the water surface and is able to connect all units into an array

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TYPES OF WAVE ENERGY CONVERTERS (WEC)

An **Attenuator** is a floating device, which works parallel to the wave direction and effectively rides the waves. Movements along its length can be selectively constrained to produce energy.

A **Point Absorber** is a floating structure which absorbs energy in all directions through its movements at or near the water surface. The power take-off system may take a number of forms, depending on the configuration of displacers/reactors.

Submerged Pressure Differential Devices are typically located near shore and are attached to the seabed. The motion of the waves causes the sea level to rise and fall above the device, inducing a pressure differential inside the device. The alternating pressure can then pump fluid through a system to generate electricity.

An **Oscillating Water Column** is a partially submerged, hollow structure. It is open to the sea below the water line, enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn compresses and decompresses the air column.

An **Overtopping Device** relies on the physical capture of water from waves, which is held in a reservoir above sea level, before being returned to the sea through conventional low-head turbines.

An **Oscillating Wave Surge Converter** extracts the energy caused by wave surges and the movement of water particles within them. The arm oscillates as a pendulum mounted on a pivoted joint in response to the movement of water in the waves.