



The first commercial wave power station in the UK - the LIMPET - is located on Islay. This device has a design generation capacity of 500kW. Another wave power device called OSPREY, located near Dounreay, was designed to provide 2 MW of power. The first OSPREY machine was damaged and sank, but a replacement is due to be tested soon. Both these machines are made by the same company, WaveGen, and both are based on an oscillating water column design. This uses a hollow shell, which extends to under the water line. The water in the shell rises and falls with the waves, compressing and expanding the air in the shell. The air then moves through a turbine, generating electricity. The turbine is a special design, called a Well's turbine. A Well's turbine has the property that it turns in the same direction whichever way the air is flowing, so gets powered by both rising and falling waves. WaveGen has also proposed adding a wind turbine to the OSPREY design to gather energy from two sources at once

### European Marine Energy Test Centre

Recently Highlands and Islands Enterprise commissioned a study into potential locations for a Marine Energy Test Centre (METC) in the Highlands and Islands region. This report was undertaken by John Griffiths of the UK Marine Foresight Panel and METOC, a marine engineering company. They considered four sites: Stromness, Crosskirk near Dounreay, Baghasdal in South Uist and Portnahaven in Islay. The report compared the sites on many properties, an obviously important one being the wave power resource available at each site:

| Distance       | Stromness | Crosskirk | Baghasdal | Portnahaven |
|----------------|-----------|-----------|-----------|-------------|
| Offshore, 100m | 76        | 75        | 71        | 67          |
| Nearshore, 40m | 51        | 36        | 52        | 29          |
| Nearshore, 20m | 45        | 22        | 30        | 22          |
| Nearshore, 10m | 44        | 29        | 16        | 22          |
| Shoreline, 0m  | 43.5      | 22.3      | 35.6      | 31.0        |

**Table 1: Average annual wave power resource (kW/m)**  
**Note: Other studies suggest these figures are slightly optimistic**

| Depth | Stromness | Crosskirk | Baghasdal | Portnahaven |
|-------|-----------|-----------|-----------|-------------|
| 10m   | <0.5      | <0.5      | 2.9       | <0.5        |
| 20m   | 0.6       | 1.1       | 5.5       | 0.9         |
| 40m   | 1.5       | 1.8       | 15        | 5.2         |
| 50m   | 1.8       | 2.8       | 19        | 10          |
| 100m  | 32        | 92        | 37        | 153         |

**Table 2: Distance (km) from shore to specified depth**

Another important criteria was the development cost differential: Crosskirk would have cost £80k more than Stromness to develop as a test centre, Baghasdal over £1 million more and Portnahaven would have cost nearly £2 million more. These and other reasons resulted in the selection of Stromness as the preferred location for the test facility.

The location of the testing area for wave devices is to the west of Billia Croo, on the west of Mainland, near Stromness. There are planned to be four berths, two on the 50m contour (about 2km out) and two on the 30m contour.

A study of the waves in these areas had to be performed before the site could be developed.

The UK Meteorological Office has kept data for the past 15 years of the waves at a point 59.00°N, 3.66°W. This data shows that February has the most active wave characteristics, with a median wave height of 2.9m. July is the most benign, with the median wave height being only 1.1m. Over the year the median wave height is 1.9m (at this point). The largest wave expected in a period of one year is 10m, and the largest expected in a period of 100 years is 15m.

This model was used to provide boundary conditions for a new model, based on the FELURAY refraction method. The model was then used to simulate the waves at the experimental sites. In general, the largest waves were found to come from the 300°N direction; this is useful in deciding the orientation of any devices. The following table shows the expected extreme wave heights encountered in one year at the different test sites:

| Site   | Extreme Wave Height (m) |
|--------|-------------------------|
| 50m, N | 10.6                    |
| 50m, S | 10.1                    |
| 30m, N | 9.0                     |
| 30m, S | 9.7                     |

**Table 3: Expected extreme wave height (m)**

It can be seen that the largest waves are present on the most northerly site on the 50m contour. This is also shown by the annual wave power resources at these sites (only a fraction of these powers can be extracted by a wave power machine).

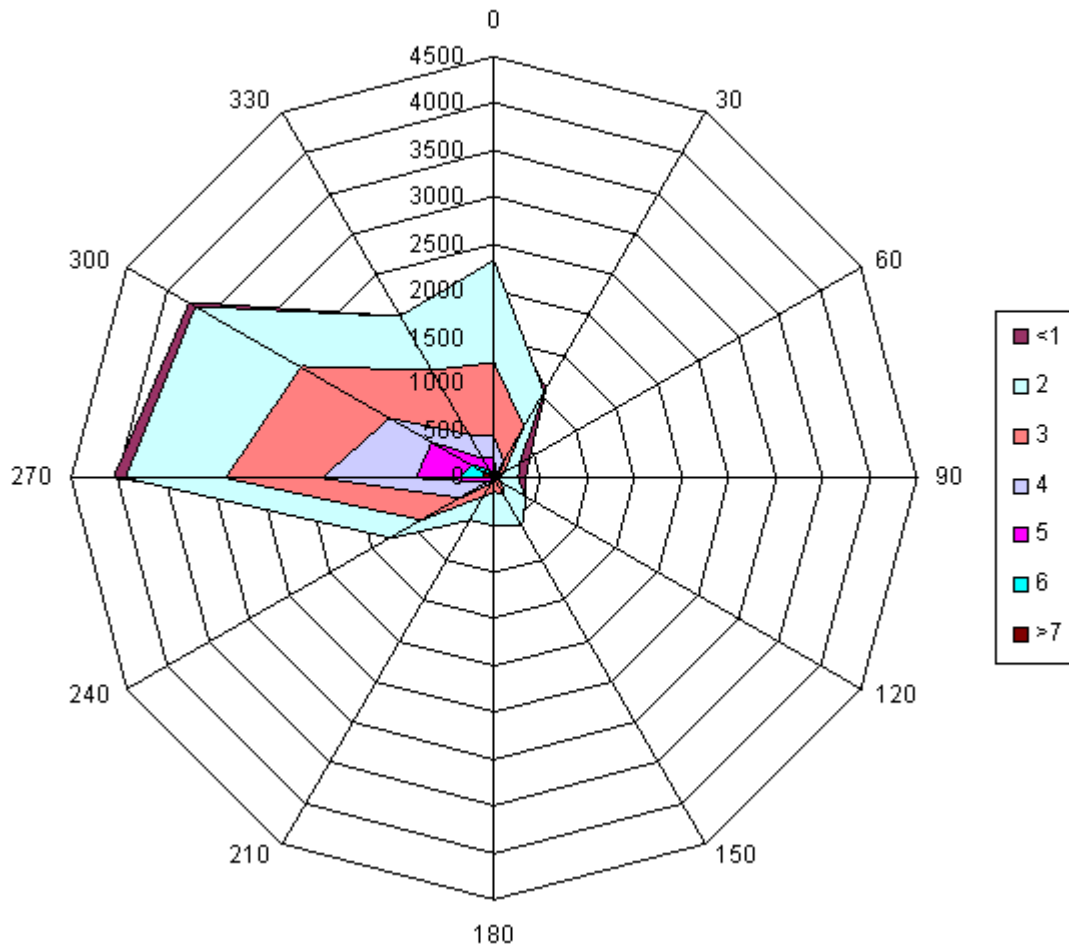
| Site   | Wave Power (kW/m) |
|--------|-------------------|
| 50m, N | 29.4              |
| 50m, S | 28.4              |
| 30m, N | 23.5              |
| 30m, S | 26.8              |

**Table 4: Average annual wave power resource (kW/m)**

The power in the waves changes slightly depending on tidal currents; this effect is less as you get closer towards the shore. It can be seen that the more recent estimates for power density are rather lower than those in the METOC report. At all sites the tidal current is relatively low, however, generally below 0.5 m/s. A low tidal current is desirable for wave power devices as strong tides decrease performance and strain moorings.

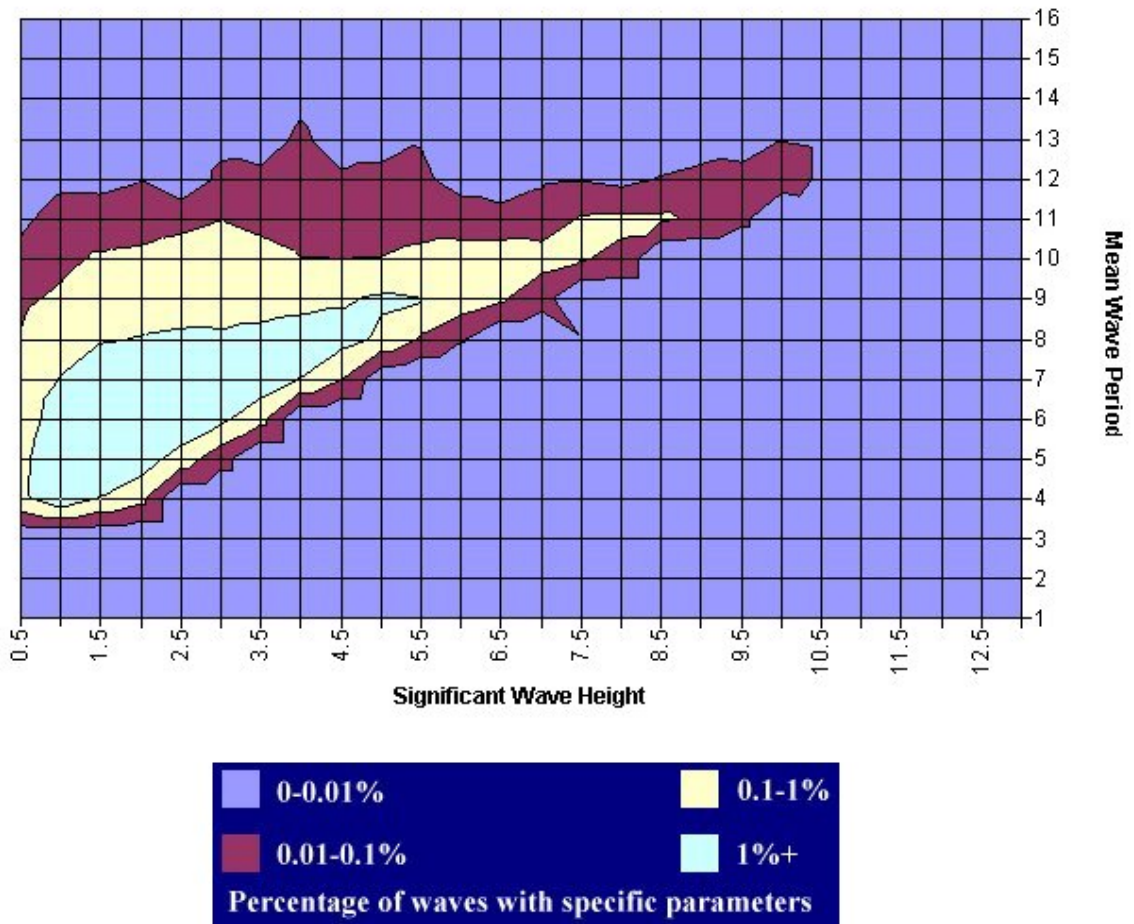
The next graph shows how the waves at the test area are distributed in direction, using data from a study commissioned by Highlands and Islands Enterprise<sup>3</sup>. The number of waves going in each direction is shown, taken from an overall sample of 100000 waves.

**Graph showing wave frequency for different directions and significant wave heights**



Another important property of the waves is the mean wave period. A study commissioned by Highlands and Islands Enterprise discovered that the majority of waves at Billia Croos fit into the 4-8s period with 0.5-3.0m significant wave heights. The plot below shows the percentage frequency with which waves are found with particular values for both properties.

**Frequency of waves of different mean wave periods and significant wave heights**



One of the latest generation of wave devices is the 'Pelamis' wave energy converter (see figure 2), made by a company called [Ocean Power Delivery](http://www.oceanpowerdelivery.com). This generator is a very long (~150m) articulated structure. Each section moves independently under the motion of the waves. Hydraulic rams between each section use this motion to pump fluid to hydraulic motors, which in turn drive electrical generators. The power is then fed through a cable to a seabed connection, and from there to shore. A 150m device will have a maximum output of 750 kW, which is comparable to a modern windmill.

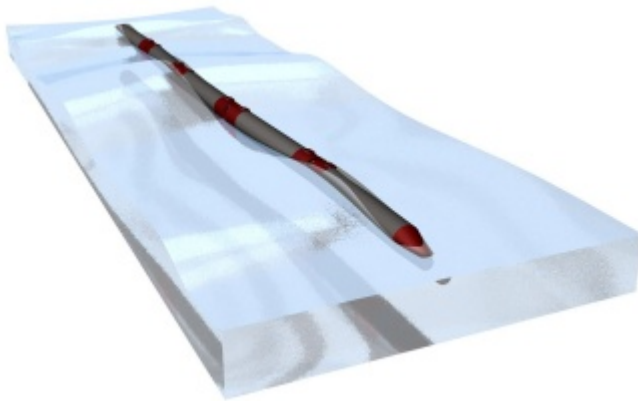


Figure 2: Pelamis wave energy converter

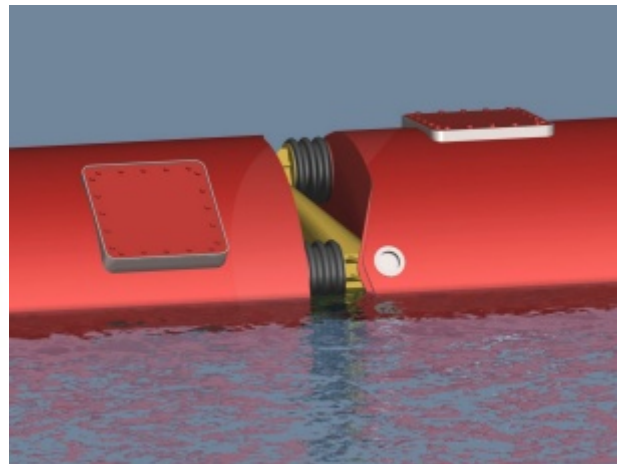


Figure 3: Pelamis hinge

An important part of the Pelamis design is the hinge between sections (shown in Figure 3). The hinge can be 'tuned' so as to extract more energy from the waves when they are small, or alternately to decrease the effect of the waves on the machine when the waves are strong enough to damage the machine. Another feature is the storing of energy in hydraulic accumulators, to smooth out the always varying energy input from the waves.

The technology should also prove very reliable. One of the problems of marine energy devices is that they must be able to survive the worst conditions. As the Pelamis device is arranged head on to the worst waves, it should be resistant to damage.

Table 5: Power output of Pelamis in different wave conditions (kW)

| Wave Height/Power Period | 5.0s | 7.0s | 9.0s | 11.0s | 13.0s |
|--------------------------|------|------|------|-------|-------|
| 1.0m                     | idle | 37   | 35   | 23    | idle  |
| 2.0m                     | 57   | 148  | 138  | 93    | 59    |
| 3.0m                     | 129  | 332  | 292  | 210   | 132   |
| 4.0m                     | -    | 540  | 475  | 339   | 213   |
| 6.0m                     | -    | 750  | 750  | 619   | 415   |

If the technology is proved successful it is hoped that eventually 'wave-farms' of 50 Pelamis devices could be established. One of these wave-farms would occupy a couple of square kilometres of sea space and produce enough electricity for 20 000 homes. It is expected that Pelamis, and wave energy in general, will be fully competitive with other forms of renewable energy in the next few years.

#### References

1"Wave Energy Technology Assessment for Grid-Connected Utility Applications", George Hagerman and Ted Heller, 1988

2"An Assessment of the State of the Art, Technical Perspectives and Potential Market for Wave Energy", Commission of the European communities, DG XVII, Prepared by ETSU and CCE, 1992

3"Marine Energy Test Centre, Stromness, Orkney", Report EX4471, HR Wallingford, November 2001