Wave Energy in the Future

Waves are the result of interaction between winds and the surface of the sea, energy is transferred from the wind to the sea, so in effect wave energy is a stored form of solar energy, as winds are caused by pressure differences in the atmosphere, created by solar heating. The UK and West Europe is considered to have very good potential for wave power, as strong winds can blow across the Atlantic and create large waves which in turn can travel across the Atlantic gaining energy form the wind and losing little. Energy is lost when waves hit the shoreline. The amount of energy around the coast of the UK varies a can be seen in figure one.

Figure 1: European Wave Resource Chart
showing the annual average wave power in kW/m of crest width for various European sites. (Ocean Power Delivery Limited)

The energy of waves differs from off the coast to at the shoreline, for example 60-70 kW/m off the coast of Western Isles of Scotland in the deep water to energy of about 15-20 kW/m at the shore line[1]. Also there tends to be a variation in the amount of energy in the different seasons of the year, for example off the coast of Scotland to the west there is four times the amount of energy available from waves in the winter months than in the summer months[2]. The Department of Trade and Industry (DTI) have estimated the practicable amount of energy that could be obtained from the offshore waves is 50 TWh/year and 2.1 TWh/year from near shore (less than 20 miles from the coast)[3]. This is about 16% of the UK annual electricity consumption. Currently the UK is far from achieving this amount of energy from waves.

---

[1] Heath, T., Wavegen 2003, **Realities of Wave Technology**, http://www.wavegen.co.uk/pdf/art.1727.pdf, pp .2, (25-2-2005).
[2] ibid.
[3] House of Commons, Science and Technology Committee, 2001, **Wave and Tidal Energy Seventh report**, Stationery Office, London, pp. xiv.

There have been many attempts to harness wave power. The first wave energy device was patented, although not created, in 1799 under than name of Girard[4]. Other more modern devices have been developed but later failed, for example, the Osprey sunk in harsh weather conditions. However there have been few successful projects to date.

There are two devices, the Pelamis and the Limpet which are currently developed sufficiently so that they may be at a level to produce electricity commercially in the next 30 years. Other projects that are yet to be developed may possibly be small commercial contributors. However for the purpose of estimating projections for the future of electricity generation by wave energy only the Pelamis and Limpet devices have been considered to be sufficient suppliers and others have no been considered as they are likely to only contribute a few TeraJoules.

The Pelamis has been developed by Ocean Power Delivery Limited. There is currently a full scale device at the EMEC testing centre on Orkney. It has been described as snake-like structure; it is made up of a string of three steel cylinders of 3.5 metres in diameter measuring 150 metres in length, each with a 250 kW capacity. The semi-submerged cylinders are linked by a flexible hinged joint attached to hydraulic rams that pump oil through hydraulic motors which drive generators that produce 750 kW of electricity when they move with the motion of the waves. The device can be controlled to increase the amount of energy captured when waves are gentle. They also limit the movement and load on the joints in extreme conditions.

Figure 2: The Pelamis at Sea (Source: OPD, 2005)

It is proposed that wave energy farms would be developed as several devices can be connected together and linked to shore through a single seabed cable.

[4] Ross, D., 1981, **Energy from the Waves**, Pergamon Press Ltd, Oxford, pp. 1.

Figure 3: Artist's impression of a wave farm (Source: OPD, 2005)

A 30 MW installation of Pelamis devices would cover one squared kilometre[5]. Thus there would be 40 devices per 1 km^2 and they have a load factor of ~31% so 81.4 GWh would be produced annually per $1km^2$. It can also be assumed that 40 devices could be built every 3 months so 160 devices a year, so in five years it would be possible to build 800 devices producing 65.1 TWh annually and this would cover 20 km^2. This would only be possible with a very large amount of development and would definitely not be possible until 2015 at the very earliest. However, I think that this is very unlikely and therefore it will not be until after 2030 that this scale of development is possible.

Figure 4: Predictions for wave energy for the Pelamis taking into account the amount of development that would be needed and the problems associated with the device and wave energy.

Year	No. of Pelamis devices	Total energy available from Pelamis devices (PJ)
2010	2	0.0146
2015	10	0.072
2020	40	0.2923
2025	80	0.5846
2030	200	1.4616

However before wave farms become a reality Ocean Power Delivery Limited aim to reduce the capital costs and cost of energy to make it competitive with other alternative forms of energy. Once this is achieved it will be commercially viable to build wave farms and then there will be development into maximising the energy capture of the devices, so it is assumed in the table above that the load capacity will not increase because it is unlikely that these targets will be achieved by 2030.

[5] Ocean Power Delivery, 2004, **Offshore Wave Energy**, http://www.oceanpd.com/default.html. (21-2-2005).

The other device is the Limpet device has been developed by Wavegen and generates 500 kW per device. Inside it waves oscillate in the water column and the upward movement of the water forces air through the turbine which drives the generator producing electricity. The turbine also uses the air flowing back out into drive the generator. It is a shoreline device and one is installed on the isle of Islay, which is off the coast of west Scotland. Currently it is the only wave power station supplying electricity to the national grid but due to weak grid connection only 150-200 kW of its capacity can be used; it has a load factor of about 40%.

Figure 5: Picture of Limpet on the isle of Islay. (Source: New Scientist, 2003)

One of the major problems with the Limpet is that it requires a rocky coast, as they need to be built into hard rock this excludes the east and south coastline, and also a good wave climate with waves about 15-25 kW/m intensity. The coast of Devon and Cornwall has a good wave climate but have a large tidal range which increases the cost of building the device. The North Scottish coast is an ideal location as are the Hebridean Island but they are remote and further from the demand and thus there is the extra cost of connection to the grid. As the device has to be built on site the weather can slow down installation when the first device was installed building had to stop completely from December until late April, it took 2 years to build the device in total. For future projections it is assumed that each device takes on average two years to install, which would obviously increase the cost of the project. There is little likelihood of this being reduced as they is little that can be done to overcome the weather conditions as the device must be built on site

Figure 6: My predictions for wave energy for the Limpet taking into account the amount of development that would be needed and the problems associated with the device and wave energy.

Year	No. of Limpet devices	Total energy available from Limpet devices (PJ)
2010	1	0.0063
2015	2	0.0126
2020	4	0.0252
2025	7	0.0441
2030	10	0.063

Also the construction of a Limpet device involves a lot of rock being removed which is a long and costly process, it may also face opposition from locals as they may consider it to be ruining the natural environment and creating visual pollution. This would not be a problem with offshore device like the Pelamis as they would not be visible from the shore. However Pelamis wave farms could face opposition as they would require large areas of sea and therefore could interfere with existing shipping lanes and fishing regions as the wave farm areas would have to be closed to fishing and shipping activities. There are other environment impacts that have to be considered with the Limpet and Pelamis, and also with any other wave energy devices. Wave energy devices could have effects on marine life but there is little evidence that this is a problem and fauna may benefit because non-fishing environments may be created by wave farms and anchoring devices may new fish habitats. The wave patterns are likely to be effected by devices and this could effect the deposition of sediment amongst other aspects. However coastal erosion may be slowed by devices, the limpet would protect some of the rock cliffs and the shore side of offshore devices would be calmer with could help create more areas for water activities.[6] Although these aspects must be considered the adverse effects of wave energy devices is far less than those of other energy sources. Also no carbon is produced by the device other than in manufacture. For every 1% increase in market share by renewable technology there is a 2% reduction in carbon dioxide emissions[7].

A further problem is the connection of the device to the national grid as the best locations for the device are remote. There could be an impact on the local landscape by an increased number of transmission lines; this could create opposition from locals. It is also costly to build or strengthen existing transmission lines and they have to be paid for by the developers of the device, with is a barrier to development. It cost Ocean Power Delivery Limited £1million to strengthen connections to their Limpet device.[8]

As devices require high energy waves the ideal location is often in places that experience strong winds and storms. This can cause an extra cost not only as construction of devices on location can be inhibited and take a long time but also the materials need to very durable, for example the Limpet is made of concrete which has been reinforced with by high density steel[9]. It withstood the worse storms in living memory, according to locals, which is a good sign that it will continue to be productive. The Pelamis has been developed to withstand storms as the joints can be controlled to limit loads and motions during a storm when it is in survival mode to dive below waves.

---

[6] House of Commons, Science and Technology Committee, 2001, **Wave and Tidal Energy Seventh report**, Stationery Office, London, pp. xxii.
[7] ibid, pp.xxiii.
[8] ibid, pp. xvii.
[9] Heath, T., Wavegen 2003, **Realities of Wave Technology**, http://www.wavegen.co.uk/pdf/art.1727.pdf (25-2-2005).

The cost of electricity generated by wave energy range from 4-8 p/kWh this is much more costly than from fossil fuel generated electricity (about 2-3 p/kWh)[10]. This needs to be reduced to make wave power commercially viable. Wind energy was in a similar situation 20 years ago and received funding and subsidies to make it viable by lower the cost, if wave power receives similar subsidies it will be able to reduce its cost[11]. It estimated that £10 billion[12] would be needed to exploit wave power around the UK commercially.

The earlier UK Wave Energy Programme which began in 1974 was abandoned as wave energy was no longer considered prosperous in terms of economics, as it was more expensive (per kW) than other renewable technologies. However the programme was over ambitious as it planned to develop a 2 GW wave power station although this was then scaled down but eventually abandoned totally in 1994. For wave energy to become commercially successful another major programme would have to be initiated as serious funding is required. Wave angry is supported by the Scottish Renewable Obligations however more would be needed. It is unlikely that great deal more funding would be given to wave power as it can only contribute a very small percentage of the UK's electricity demand.

Figure 7: Maximum projections of electricity generated by wave energy until 2030

Year	Total energy (PJ)	Percentage of UK demand (399,820GWh[13]= 1439.352PJ)
2010	0.0209	0.001%
2015	0.0846	0.006%
2020	0.3175	0.02%
2025	0.6287	0.04%
2030	1.5246	0.1%

[10] House of Commons, Science and Technology Committee, 2001, **Wave and Tidal Energy Seventh report**, Stationery Office, London, pp. xviii.
[11] ibid.
[12] Vaughan, R., 1999, **Wave Power: Moving towards commercial viability**, Professional Engineering Publishing Limited, London, pp. 13.
[13] Department of Trade and Industry 2005, **Supply and Consumption of Electricity**, http://www.dti.gov.uk/energy/inform/energy_stats/electricity/5_2elecsupply-Q.xls, (27-2-2005)

References:

Dawson, J. K., 1979, Wave Energy: Energy Paper Number 42, Department of Energy, London.

Department of Trade and Industry 2005, **Supply and Consumption of Electricity**, http://www.dti.gov.uk/energy/inform/energy_stats/electricity/5_2elecsupply-Q.xls, (27-2-2005)

Heath, T., Wavegen 2003, **Realities of Wave Technology**, http://www.wavegen.co.uk/pdf/art.1727.pdf, (25-2-2005).

House of Commons, Science and Technology Committee, 2001, **Wave and Tidal Energy Seventh report**, Stationery Office, London.

Knott, M. 2003, Power from the waves, New Scientist, vol. 176, no. 2413, 20-9-2003, pp. 33-35.

Ocean Power Delivery, 2004, **Offshore Wave Energy**, http://www.oceanpd.com/default.html. (21-2-2005).

Ross, D., 1981, **Energy from the Waves**, Pergamon Press Ltd, Oxford.

Vaughan, R., 1999, **Wave Power: Moving towards commercial viability**, Professional Engineering Publishing Limited, London.