Shoreline and nearshore OWC wave energy devices

Oscillating Water Column (OWC) wave energy devices for shoreline and near-shore locations have been investigated for many years. The UK is host to a grid-connected demonstration project ('LIMPET' - on the island of Islay) and prototypes have been developed in other countries too. At the outset of the Marine Energy Challenge, the Carbon Trust invited Arup Energy and E. On Power Technology to undertake a comprehensive study of the potential for shoreline and near-shore OWCs and report on:

- The current state-of-the-art in shoreline/near-shore OWC device design; and
- The amounts of electricity that could be produced by shoreline and near-shore devices if they were installed in suitable locations around the UK.
- Furthermore, the Carbon Trust asked Arup/E.On to:
- Consider the scope for improvement in shoreline/near-shore OWC designs
- Identify potential reductions in the devices' costs of energy; and
- Recommend future research and development work.

The study was performed as a discrete work package within the Marine Energy Challenge and looked at the breadth of devices in the shoreline and near-shore OWC category rather than any specific device design.

This article gives a summary of the work and highlights some of its key conclusions. The full report can be downloaded here.

State-of-the-art

Shoreline and near-shore OWCs were identified in five countries: Scotland, Australia, India, Japan and Portugal (the Azores). Of these, presently operational shoreline units (including LIMPET) are built out of concrete, but steel has been proposed for near-shore devices. Developers of the Osprey and Port Kembla near-shore projects (Wavegen and Energetech respectively) have sought to minimise the structure size to reduce both the quantities of materials needed and the extreme wave loading. All structures have been bespoke designs for particular locations, with the collector geometry a function of the local water depth and wave climate.

Experience of constructing shoreline devices has been poor, with extended schedules and difficulties in providing adequate temporary construction works, (e.g. protection of personnel from waves). This has not been the case with near-shore devices that have been constructed largely off-site. To date, most shoreline and near-shore OWCs have had too great an installed generation capacity for the actual wave resource due to over-estimation of the resource. For this reason, 'wave-to-wire' efficiencies (where known) have been low.

Potential UK electricity generation

In a high level review intended to produce indicative results, Arup/E.On evaluated the wave energy resource, seabed bathymetry, tidal range, grid capacity and costs of construction/access for potential project locations around the UK. The findings included that:

- The coasts of north and west Scotland, the Outer Hebrides, Shetland and Orkney Islands, and north coast of south-west England are most promising for shoreline and near-shore OWCs;

- There is a potential frontage of 8km for shoreline devices and 141km for near-shore devices around the UK coast;
- Despite possible improvements in device design, shoreline OWCs are unlikely to supply a significant proportion of UK consumption; and
- Near-shore OWCs have the potential to supply ~7.8 TWh/annum, (approximately 2.3% of current UK electricity demand)

Scope for improvement
In the second stage of work, the consultants focused on improvements that might be made to near-shore OWC devices, incorporating lessons from work to date and by analysing/applying experience to the problems of design, fabrication and installation. The conclusions of this work are embodied in a new design of near-shore device that:

1. Is not bespoke but can be applied to a range of different sites;
2. Is built largely off-site in a controlled environment not susceptible to adverse weather conditions, and once on site requires little or no below-water working; and
3. As a result of 2) is constructed at minimum cost in its own right, and as a result of 1) and 2) can be mass produced and enjoy the associated economies of scale

The chosen structural material is concrete on the basis that this is marginally more cost-effective for UK projects (although steel should not be discounted from further investigations).

Figure 1: Solid model impression of generic near-shore OWC design. Images courtesy Arup/E.On.

The device's performance and costs were assessed, with allowances for:

- The efficiency of energy conversion at each stage of the power train (incident wave energy to pneumatic power, pneumatic power to mechanical power, mechanical power to electrical power); and
- The possible savings by producing batches of 10 units over one-off construction
- Headline results are a capital cost of £4.6M for a 2.25 MW rated device built as one of a batch of 10 (with productivity benefits) yielding 6.1 MWh/year.

Potential cost of energy reductions
Amongst the capital costs the cost of the structure dominates with >70% of the capital cost of the near-shore device mentioned above being structural costs. The wave resource, device size and overall device efficiency are also important to the cost of energy.
To assess the potential for cost reductions, Arup/E.On developed a NPV economic model and conducted a sensitivity analysis. The findings are that:

- Capture efficiency has the biggest impact on the economic viability of a development;
- The wave resource is the second most critical factor; and
- There are optimum sizes of shoreline and near-shore devices. Below 2 MW installed capacity, a shoreline device is preferable, but above 2 MW near-shore devices make more sense

The model was used to estimate the improvements needed in both energy conversion efficiencies and costs to achieve a competitive cost of energy and furthermore to consider how different learning rates would decrease the cost of energy over time.

Future research and development

There exist a number of technical uncertainties about OWCs, mostly to do with characterisation and estimation of performance. The consultants made a number of R&D recommendations in the contexts of:

- Increasing confidence in design for survivability;
- Increasing confidence in cost of energy estimates; and
- Decreasing the cost of energy

Conclusions

The overall conclusions of the study are as follows:

- The cost and performance improvements necessary for near-shore OWCs to become cost-competitive do seem achievable given the learning rates estimated;
- Near-shore OWCs can be expected to reach a point where they compete within the current economic framework for UK renewables generation when the cumulative level of installed capacity is such that the necessary learning to reduce the cost of energy has been achieved;
- For near-shore OWCs to have a long term future, the rate of technology development must be increased; and
- Shoreline OWCs seem unlikely to achieve a cost of energy as low as near-shore OWCs. Nonetheless they may play a niche role in serving isolated communities