Wave and tidal energy: State of the industry summary

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Introduction

Despite substantial progress, the path to commercialisation for the wave and tidal industries is taking longer and proving more difficult than initially expected. In 2017, ClimateXChange commissioned a review of the current state and potential of the wave and tidal industries. The review was conducted by an industry consortium consisting of Caelulum Ltd., Aquatera Ltd. and Inflection Point Consulting and included a survey of industry developers.

There have been several reviews on wave and tidal energy development in recent years: these include UK reviews by Winskel (2007), Vantoch-Wood (2012), Jeffrey et al. (2013), Hannon et al. (2016) and Hannon et al. (2017). Of these, the latest Hannon et al. (2017) review is a comprehensive exploration of the UK's wave energy innovation support and industry development. There is also an EU review by Magagna et al. (2016), and recent comprehensive national and international data and country reviews published by Ocean Energy Systems (IEA OES, 2017) and the International Renewable Energy Agency (IRENA, 2017).

The ClimateXChange-funded project aimed to complement this existing work to chart recent activity and views in the sector; to investigate the deployment pipeline and the market; to explore recent policy and political signals from UK and devolved administrations and the availability of market-pull instruments; and to set UK development in the global context.

Key Points

- The UK currently has ~9MW of tidal stream capacity and less than 1MW of wave energy capacity installed, though substantially more has been deployed and recovered over time.
- Except for the commercially active 6MW MeyGen project, most of these projects are "first of a kind" demonstration projects, testing single devices
- None of the developers surveyed for this report believe they had achieved a fully proven system in an operational environment
- The tidal stream sector is more advanced than the wave energy sector in terms of installed capacity and convergence of design
- There remains a diverse development pipeline of tidal stream and wave energy devices, both internationally and in terms of technological approaches
- As Hannon et al. (2017) notes, the UK has now improved its approach to innovation with the aim of delivering commercial devices, largely as a result of strong Scottish Government and EU support
- The developers surveyed stated that they had attracted a mixture of public and private funding, with investments from tens of thousands to tens of millions of pounds. They also acknowledged that they will need to attract significant further investment to deliver commercially viable machines. The ability to raise that funding, particularly from private sector, will depend on a clear route to market
- The levelised cost of energy (LCOE) for wave and tidal has barely fallen over the past 10 years, while other renewables such as wind and solar photovoltaics (PV) have seen dramatic falls in their costs
- The aim of delivering commercial marine devices is likely to face severe disruption from wider political developments such as Brexit's impact on EU RD&D funding; the political focus on the overall

cost of energy; the UK Government's shift away from investing in marine renewables (other than offshore wind); and the absence of any "market pull" for wave and tidal stream projects in the UK

1. Recent Activity in the Sector

Active projects in the UK (meaning those installed or operating in the past 18 months) comprises approximately 9MW installed tidal stream capacity and less than 1MW installed wave energy capacity. Over 60% of this capacity has been installed over the past 18 months. Most of these projects are "first of a kind" demonstration projects, typically testing single devices; many are located at the European Marine Energy Centre (EMEC) in Orkney.

The exception to this is Atlantis Resource Limited's 6MW tidal stream MeyGen project, which is operating commercially, albeit with substantial EU and government funding support. Nova Innovation's 0.3MW turbine Shetland Array project and Scotrenewables Tidal Power (SRTP) 2MW twin rotor machine operating at EMEC are also notable for their recent operational outputs.

There are no commercial wave energy projects in operation in UK (and indeed only one in Europe: the Ente Vasco de la Energia (EVE) Mutriku breakwater project in Basque region, northern Spain).

Feedback from the survey of current tidal and wave energy developers indicates that none feel they have achieved commercially proven technology in an operational environment[1]. This is not surprising since the first multi-machine deployments for tidal stream energy have only occurred in the past 18 months. In contrast, this milestone was achieved for wave energy convertors in 2008, but there are currently no multi-machine wave projects operating in the UK.

In terms of performance, quantity of electricity generated provides a good indicator of technical progress (which was recognised in the Saltire Prize formulation). To date, in terms of total electricity generation, the leading tidal stream energy project in the world was the Marine Current Turbines SEAGEN project in Strangford Loch, Northern Ireland. This generated ~10GWh over a period of six years from a 1.2MW dual turbine installation. For wave power, the leading project is the Ente Vasco de la Energia (EVE) Mutriku breakwater project in northern Spain, which has generated 1.3GWh over a period of five years using 16 x 18.5kW (296kW capacity) turbines and continues to operate.

Of current tidal stream energy machines, the MeyGen project was reporting nearing 2GWh generation (August '17 figures) having been installed in Nov 2016, so has the strongest annualised electricity generation – of ~2.5GWh - to date, with monthly output figures increasing after turbines were optimised. The Scotrenewables Tidal Power (SRTP) energy converter being tested at the European Marine Energy Centre (EMEC) in Orkney took the record in November 2017 for the fastest 1 GWh generated at EMEC.

These generation amounts remain well below the Saltire Prize target of 100GWh generated over a continuous two-year period. However, prototype projects are not necessarily run to achieve maximum annual electricity yield; instead they seek to prove the power curve and other operating characteristics (such as ease of installation; control; reliability, etc.). We can expect to see improving electricity generation figures for currently operational projects.

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[1] Technology Readiness Levels (TRL) provide a short-hand estimate of technology maturity, though slightly different definitions of TRLs are often used contemporaneously in review literature. For technology developments projects in the EU, the Horizon2020 definition is useful: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf Under this nomenclature, TRL 7 implies a system prototype has been demonstrated in an operational environment; TRL 8 implies a technology system that is complete and qualified; and TRL 9 is an actual system proven in an operational environment. Feedback from developers suggest no wave or tidal stream energy system is at TRL9.

2. Deployment pipeline and the market

Over 100 companies have or are testing wave or tidal stream energy convertors globally. There is a detailed review of these activities in the recently published OES 2017 Annual Report on ocean energy activities. Of these, about 50 are relevant to Scotland (by undertaking or planning to undertake activities in Scotland/UK or because they are significant internationally) and are reviewed in more detail in the industry review for ClimateXChange. The wave or tidal stream energy convertors of these companies are at different stages of testing (i.e. tank test, scale test, full scale, electricity generation, prolonged electricity generation in operational environments). Despite well publicised setbacks, this and other recent reviews show that innovation activity remains high in both tidal and wave sectors, with Wave Energy Scotland (WES) stimulating activity in component development and EU research and development funding supporting several technology systems.

As well as energy technology challenges, for marine renewables there are also issues of survivability in the marine environment, reliability (also dependent on accessibility and maintainability), ease of installation, operability and cost-effectiveness. Solving these challenges requires design and systems engineering at a high level, along with components able to fulfil these requirements. While careful design can eliminate or militate against the impact of component failure, ultimately only through full system testing can these elements be verified and optimised over time. In terms of the development pipeline, there are more tidal stream energy developers who are either generating or expecting to be generating electricity soon, supporting the notion that the tidal sector is more advanced and vibrant than the wave energy sector.

Most of the developers surveyed stated that they have attracted a mixture of private and public funding, with investments ranging from tens of thousands to tens of millions of pounds. They also acknowledged that they will need to attract significant further investment to deliver commercially viable machines. Half of those interviewed are targeting their company being profitable (defined as making a margin on equipment or electricity sales) within one to three years with the remainder being three to five years or more than five years.

Hannon et al. (2017) argues that *wave energy's* failure to reach market can, in part, be attributed to weaknesses in government and industry strategy, most notably a premature emphasis on commercialisation, and over-confidence and poor exchange of knowledge within the industry. This has led to poor performance against key innovation indicators, such as a fall in installed and rated capacity of wave devices and a lack of convergence around a dominant device design, and a withdrawal of investors and major players from the sector. The recent concerted effort to learn from past policy mistakes, led primarily by the Scottish Government, has led to measurably better innovation performance.

Collectively, if all developers interviewed were to succeed, the estimated midpoint capital investment of those surveyed would be of the order of £300m in technology and project development, project build and operation, and other activities. Others argue much higher capital investment is required (e.g. Dickson and Winskel, 2018). However, the ability to raise such funding, particularly from the private sector, will depend upon there being a clear route to market.

3. Policy and political signals from UK and devolved administrations

Hannon et al. (2017) and the industry review for ClimateXChange note the continued positive signals from UK devolved administrations – and EU research and development funding - for wave and tidal energy development. But they warn that while the UK is now home to an innovation system much better placed to deliver commercial marine renewable devices, it is likely to face severe disruption from wider political developments. This includes Brexit's impact on EU RD&D funding; the UK's shift away from investing in wave energy; and the bundling of marine renewables with other, more mature and cheaper renewable technologies, such as offshore wind, in accessing the electricity market via Contracts for Differences.

Recent policy signals, such as the Scottish Government's Scottish Energy Strategy (2017) and the UK Government's decision to commission the Cost of Energy Review by Dieter Helm (2017), have also emphasised the increased political focus on (reducing) the cost of energy. Whilst significant progress has been made in both wave and tidal stream generation, the sector is still immature compared to other energy technologies, particularly onshore and offshore wind and solar PV energy generation.

Hannon et al. (2017), citing Bloomberg, show that the levelised cost of electricity[2] (LCOE) for wave and tidal energy has failed to fall over the past 10 years, while other technologies, such as offshore and onshore wind and solar PV, have seen dramatic falls in their LCOE. Solar PV has seen a fall of two thirds over this period and both wind and solar PV are increasingly cost-competitive against fossil fuel alternatives (even after noting system challenges of intermittent renewable electricity generation).

This industry review – drawing on a pre-defined list of answers – suggested that a major non-technical obstacle to progress wave and tidal stream energy was the "lack of an electricity market price that can sustain investments in projects", followed by lack of government prioritisation, strategy and support, and lack of investment. Developers surveyed here were disappointed in the decision to remove ring-fenced capacity of wave and tidal energy from electricity market auctions.

In contrast, recent debate about how to finance innovation in low carbon technologies (e.g. Mazzucato and Semieniuk, 2017) suggests that successful public policies that have led to radical innovations have been more about *market shaping and creating* through direct and pervasive public financing, rather than *market fixing*. In Scotland, a new Scottish National Investment Bank is planned, which could support such public financing (Dickson and Winskel, 2018). However, there is no clear "market pull" for wave and tidal stream energy projects in the UK at present or for the foreseeable future given current electricity market arrangements.

4. UK in a global context

The UK has the highest combined installed capacity of tidal and wave energy devices in the world, with over 60% of this capacity installed in the past year.

The picture presented in the development and deployment pipeline is diverse, both in its international nature and in terms of technological approaches to harness wave and tidal energy.

Scotland has factored in the plans of many of these companies; in part, this is due to:

- Scotland's wave and tidal resource availability
- WES funding programmes (for wave)
- The EMEC and other UK test infrastructure and the UK supply chain's strong track record
- Scottish academic facilities and capabilities
- EU funding available for testing (at EMEC or the Flowave testing tank in Edinburgh) from programmes such as Marinet and Foresea

However, this leading position may change if planned developments internationally come to fruition; or because of any loss of EU funding arising from Brexit; or in the absence of a clear strategy within Scotland/UK for a credible coherent pathway towards delivery of commercial devices (Hannon et al., 2017).

[2] Levelised cost of electricity (LCOE) is an estimate of the assumed lifetime costs of an energy generation asset divided by the energy generated – in other words, it is a proxy measure for the price the energy generating asset must receive to break even in the market. The inherent assumptions in calculating LCOE need to be treated with care, particularly network costs and (back-up) capacity costs.

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