# TIDAL STREAM AND WAVE ENERGY COST REDUCTION AND INDUSTRIAL BENEFIT

## Summary Analysis

AUTHORS Gavin Smart & Miriam Noonan

DATE // 23 April 2018

# 1. Key Findings

**GVA and Jobs Supported**

- With UK deployment of 100MW per year from 2021/22, and a realistic share of a growing global market, the tidal stream industry could generate a net cumulative benefit to the UK by 2030 of £1,400m, consisting of £1,600m GVA from the domestic market and £1,100m GVA from exports, offset by £1,300m of revenue support. This would also support a total of almost 4,000 jobs by 2030 and 14,500 by 2040.
- Assuming a 10 year lag behind tidal stream, wave energy will also add a net positive contribution to the UK economy, worth a net cumulative benefit to the UK by 2040 of £4,000m, consisting of £1,500m GVA from the domestic market and £3,700m GVA from exports, offset by £1,200m of revenue support. This would also support a total of 8,100 jobs by 2040.
- 50-60% of the economic benefit in terms of both GVA and jobs is expected to be generated in coastal areas, many with a need for economic regeneration, adding an additional value over and above what has been quantified in this report.

**Carbon Emissions Reduction**

- Marine energy technologies have the potential to displace coal and natural gas generation on the grid and to reduce $CO_2$ emissions permanently by at least $1MtCO_2$ per year after 2030 and at least $4MtCO_2$ per year after 2040.

**Cost Reduction**

- Tidal stream has potential to reach LCOE of £150 per MWh by 100MW installed, reducing to £90 per MWh by 1GW and £80 per MWh by 2GW. Further reductions are possible with additional focus on innovation and continued reductions in cost of capital towards levels coming through in offshore wind.
- Significant cost reductions are expected in the near-term as the industry takes the step from pre-commercial arrays to commercial projects.


# Acknowledgements

This report could not have been produced without critical inputs from a large number of sources. Offshore Renewable Energy Catapult would like to thank the project steering group for detailed inputs and feedback and the numerous supply chain companies for such willing and proactive engagement in the data gathering and analysis process.

## 2. Introduction

The UK's tidal stream and wave energy industries are at a key juncture. The momentum created by significant UK public support between c.2004 and 2014 has now visibly slowed, with a knock-on impact on private sector investor confidence. Despite a number of high-profile failures, 22 tidal device developers and 23 wave device developers remain active in the UK, and we observe a major difference between the status of the tidal stream developers who are progressing first farm projects, and the wave sector which is, in the main, still in the technology development phase. The aim of this study is to assess the value in further public support for the tidal stream and wave energy industries.

In order to assess the viability of new forms of renewable energy, the UK government's clean growth strategy has set out three tests:

- Can we see a clear cost reduction pathway for this technology, so we can deliver low cost solutions?
- Can the UK develop world-leading technology in a sizeable global market?
- Does this deliver maximum carbon emission reduction?

This study has been conducted to assess whether the UK's tidal stream and wave energy industries can deliver on these tests[1]

[1] Tidal stream has been assessed against all three test and wave energy against tests 2 and 3, due to the different maturities of the respective industries.

# 3. Current Industry Status

To date, the industry estimates it has invested around £508m of private capital in developing various marine energy technologies. These technology developers are estimated to have received £70m in direct public support[2] for technology development. In total more than £300m[3] of public money has been invested in marine energy in a broader sense (including academia and test centres). This combined investment has enabled the UK to position itself as a world leader, both in marine energy systems and project development.

The tidal stream and wave energy sectors have progressed at different rates, and these are now seen as two distinct sectors, all-be-it with strong cross over between many elements of the supply chain.

### 3.1. Tidal Stream

In the past decade, the tidal stream industry has made significant progress to the point where tidal energy devices can be deployed with a good degree of confidence as to their likely performance, following sustained periods of operation in test and at-sea conditions. A number of industry pioneers have successfully funded and deployed "first array" projects through a combination of public and private sources. Designs have also settled on floating and bottom mounted technologies, at least for first generation technologies, making it relatively easy for project developers to back core technologies, though other variants are in various stages of proof of concept and testing. A total of 22 tidal stream technology developers are currently active in the UK[4]. Tidal stream array deployments are now in place or under construction in Scotland by Atlantis at the Meygen site at Pentland Firth and Nova Innovation in Shetland.

### 3.2. Wave Energy

Wave energy is still at a technology development stage where several different concepts are being progressed, as far as funding allows. Wave energy has not yet seen technology convergence or reached consensus on optimal design and optimal platform type, offshore, nearshore, surface or seabed mounted. The main families of types are attenuator, point absorber, oscillating water column, overtopping/terminator, submerged pressure differential, bulge wave and rotating mass[5]. The pace of development varies between designs, with most testing single units but with plans to build a 10MW in Indonesia for one developer. A total of 23 wave energy technology developers are currently active in the UK[6].Current dedicated public R&D support has focused on a back to basics route; notably with Wave Energy Scotland, whose R&D programme is designed around a "rigorous process to reduce technical and commercial risk".

---

[2] https://c.ymcdn.com/sites/renewableuk.site-ym.com/resource/resmgr/publications/OER_inside_track_final_-_onl.pdf

[3] ORE Catapult analysis of public funding based on grant and other awards from 2006 - 2016.

[4] http://www.emec.org.uk/marine-energy/tidal-developers/

[5] http://www.emec.org.uk/marine-energy/wave-devices/

[6] http://www.emec.org.uk/marine-energy/wave-developers/

### 3.3. Capabilities

The UK marine energy supply chain is currently world-leading. Many companies offering site development services, offshore operations services, and bespoke engineering were established and grown off the back of EMEC's and Wave Hub's development, and subsequent publicly supported technology development projects. Major projects such as Meygen, Nova Innovation's Shetland Tidal Array, Scotrenewables Flotec turbine and Minesto's Holyhead Deep project have continued to provide work-flow which, together with overseas work, has allowed these companies to develop capabilities and further prove their credentials delivering arrays under FIDIC[7] commercial terms and conditions. Others have diversified or reverted to other sectors, but capability remains strong in several areas.

The UK has created and retains world leading expertise in academia where we continue to progress research into wave and tidal energy (largely funded through EPSRC, NERC, Wave Energy Scotland and ERDF funding through the Welsh government). The UK SuperGen Marine programme, formed in 2003 has been instrumental in fostering cross-institution collaboration. Universities such as Edinburgh, Heriot-Watt, Plymouth and Exeter continue to have strong and internationally well-regarded capability in areas including resource assessment, energy yield modelling, structural analysis and network integration.

### 3.4. UK Market

In total, the UK has in excess of 1,000MW leased tidal stream energy sites and 10MW of operational tidal stream capacity, including a number of multi-turbine arrays. There is a further 2MW currently under construction. Sites have been identified by the Crown Estate (many of which now sit with Crown Estate Scotland) totalling approximately 1,000MW.

In terms of wave energy projects, the UK currently has 137MW in operation or under various stages of development. This includes grid connected demonstration zones at EMEC, Wavehub, Pembrokeshire and West Anglesey.

### 3.5. Global Market

The International Energy Agency's 2012 Energy Technology Perspectives forecasts up to 337GW of marine capacity could be deployed across the world, with about 30% (101GW) coming from tidal sources and 70% (236GW) from wave by 2050. Key countries with high resource include Island communities such as Indonesia and the Philippines and those with remote, populated areas such as parts of Canada. The cost of generation in isolated areas can be up to £320 per MWh[8] and there is a clear logic to utilising marine energy. This presents a significant opportunity for technology and project developers who can be first movers in these markets.

Several countries stand out as key players in the global marine energy market, both as potential allies and competitors and there is increasing evidence that UK companies or companies which have used the UK's world-leading testing facilities are being attracted to these markets, with the resultant strengths

[7] Fédération Internationale Des Ingénieurs-Conseils (international standards organisation, which developed the FIDIC family of contract templates)

[8] http://www.islandedgrid.org/wp-content/uploads/2015/03/Brian_Hirsch_IGRC-Indonesiamarketupdate-FINAL.pdf

currently in the UK, including know-how, technology, economic value and jobs, leaving the UK and being drawn overseas. France has intentions to hold a tidal energy tender round with attractive financial support. Canada has five developers with berths at The Fundy Ocean Research Centre for Energy (FORCE) in Nova Scotia, receiving between CAN$385 and CAN$575 per MWh (Approx £220 and £330 per MWh). Canada is also conducting a large push for clean technology, and has recently announced a CAN$2bn Clean Technology Fund, and CAN$22bn planned investment in green infrastructure, including renewables, smart grids, reducing diesel use in remote communities and electric vehicle infrastructure.

Other countries actively building marine energy industries include Japan, Chile, USA, Indonesia, South Korea, China, Netherlands, Portugal and Australia. UK companies remain at the forefront of marine energy technology development and could be well-placed to capitalise on this opportunity, but this is uncertain and under threat given the level of activity and support on offer in other countries.

# 4. Cost Reduction Pathway

## 4.1. Current costs of tidal stream and wave energy

In order to assess the current and potential future cost for tidal stream energy, we have built, as far as possible, on the methodolgy employed in the Cost Reduction Monitoring Framework (CRMF). Technology and project developers provided data on current costs and estimates for future costs based on different levels of deployment. This allowed us to make our assessment of the commonalities and differences between developers as well as comparing assumed learning rates and areas highlighted for specific cost reductions.

The levelised cost of energy (LCOE) for tidal energy projects installed to date shows a wide range as these have been installed over a variety of types of sites, using different devices at different stages of technology development (eg. single prototypes vs small arrays). Giving more weighting to the most recently deployed sites, we calculate that the representative current LCOE is approximately £300 per MWh[9].

The key cost reductions achieved in recent years relate mainly to economies of volume (producing and deploying multiple devices), saving time and cost through learning by doing, process optimisation, engineering validation and improved commercial terms.

For wave energy it is hard to quantify the LCOE due to the stage of development. Recent one-off prototype devices indicate an LCOE in excess of £300 per MWh. A lack of data, particularly energy generation, makes it difficult to accurately estimate costs, and for this reason we believe it is more appropriate to focus on how we gain confidence in designs and performance rather than cost reduction.

## 4.2. Near-term cost reduction potential

With the right support giving a route to market, we expect significant cost reduction to be achieved in the near-term, followed by ongoing incremental reductions with growth in the industry. The industry will benefit from cumulative global deployment and, as deployment volumes increase, cost will decrease. The following analysis considers cost reduction from the perspective of cumulative deployment as it is hard to focus on specific time period given market uncertainty.

Significant cost reduction is expected to be achieved through: initial accelerated reductions; learning by doing and innovation; and cost of capital (Figure 1).

[9] All figures are quoted in 2012 real terms, consistent with the current base year for strike prices

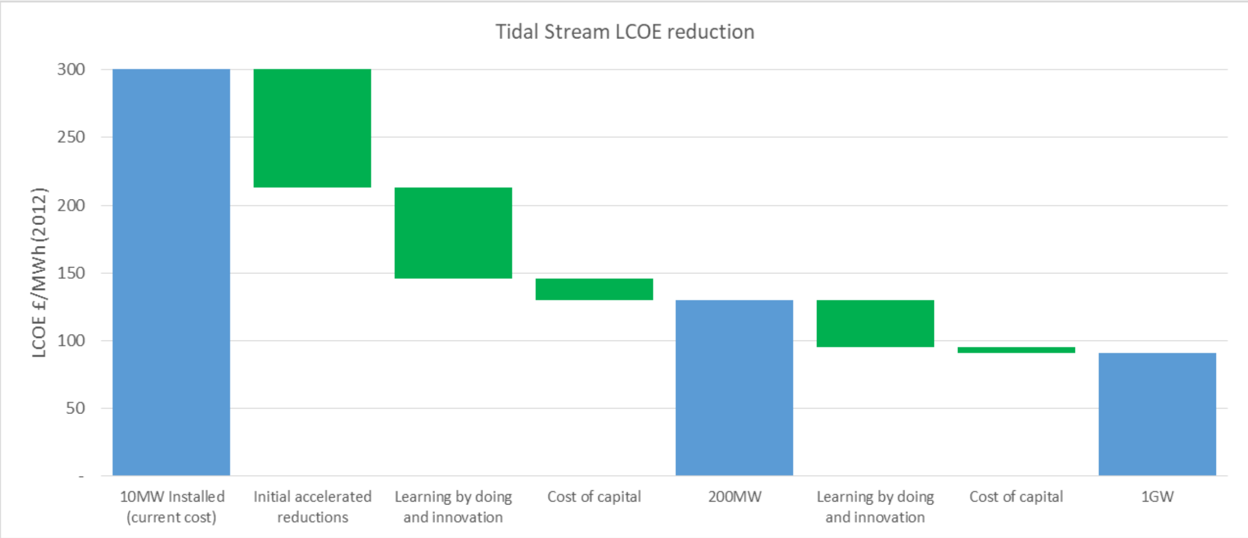


Figure 1: Tidal stream LCOE reduction

#### 4.2.1. Initial Accelerated Reductions

The move to commercial and, in some cases, utility-scale arrays, will bring a number of immediate cost reductions, which will also have ongoing impact to some degree. These reductions will manifest themselves in three key ways and will apply in different proportions to different developers and sites.

**Economies of Volume**

Economies of volume will play a large part in bringing down the cost of tidal energy. This is intuitive and observable from other industries through bulk order discounts, reduced production cost per unit and standardisation of common components. This will have a significant impact initially with the first move from one-off and small production runs to standardised production. The ongoing impact will also be important as design optimisation and serial production takes place.

**Economies of Scale – Site Size and Turbine Rating**

To date, tidal energy has been deployed in the UK at small scale. The largest array is the 6MW MeyGen 1A in the Pentland Firth. A utility scale, grid-connected site would overcome several inherent diseconomies of scale currently borne in constructing and operating smaller projects such as export to shore; installation and project management. In a larger scale project these items will not scale linearly, allowing for significant cost saving over the initial small capacity project.

A number of developers are now deploying turbines with capacity in the range 1MW – 2MW and this development allows more output per unit, which has a positive knock-on impact on balance of plant and fixed costs.

**Accelerated Learning**

A number of technology developers are continuing to develop and deploy devices in the sub-1MW range. While these will not benefit from device scaling and are unlikely to be deployed at utility-scale in the near future, this does open the opportunity for accelerated learning as each doubling of capacity, which underpins learning-driven cost reduction, is achieved quickly with smaller capacity per unit.

### 4.2.2. Learning by Doing and Innovation

As project developers repeat operations, processes become better understood, procedures optimised and performed more quickly. This has been seen first-hand at EMEC, where developers have improved with experience and time and costs fall from operation to operation. There are historically observed learning rates from a number of industries, where costs reduce by a certain % with each doubling in cumulative capacity. Since capacity can doubles quickly at the beginning of an industry's development, the cost reductions achievable in the near term are significant.

- With real life operational and weather data, operators can better forecast how frequently inspections and maintenance should take place and develop a proactive O&M strategy which minimises expensive reactive repairs and maximises turbine uptime.
- Supply chain companies can optimise manufacturing processes to construct multiple units quickly and at a lower cost, through assembly lines or automation.
- Becoming familiar with a site is often a reason for accelerating operations and reducing downtime. Operators get first-hand experience of the range of tidal, wind and wave conditions they can operate in – eg. Time required to mobilise a vessel, daylight requirements and marine environment operational windows for specific operations.

It is crucial that industry works together in an increasingly collaborative way in order to capitalise fully on the learning opportunities across increases in global capacity. This has not always been the case, as individual companies have focused on protecting intellectual property and perceived competitive advantage.

### 4.2.3. Innovation

Based on our experience in marine and wind there are a number of key areas where cost reduction is expected to be achieved in both the near-term and the longer-term relating to improving performance and reliability of individual components. Key innovations in this sector are incremental, using experience gained in the offshore oil and gas and wind sectors, meaning that, rather than carrying any risk premium, their application may well reduce the level of perceived risk for investors. Innovations are underway in a number of areas including:

- Improved reliability and availability
- Improved structures and moorings
- Reduced offshore operational costs
- Improved electrical connectors

A dedicated programme to identify further innovation and encourage collaboration between developers and supply chain could accelerate cost reduction in this area.

#### 4.2.4. Cost of Capital

Projects are currently financed through a combination of grant support and private finance. Our estimated cost of capital for 10MW is 10%[10], which effectively represents a cost of equity. As the industry matures and is considered less risky by financial institutions, this is envisaged to move to a model where commercial debt begins to form a portion of project financing, following the route of offshore wind. We have modelled cost of capital reducing to 8.4% by 100MW, 8.0% by 200MW and 7.1% by 1GW. These reductions can be achieved through a combination of increasing debt finance and reducing equity premiums. Illustratively, 7.1% by 1GW could consist of 25% debt at an interest rate of 4.5% and 75% equity at 8% return.

Some industry players consider this to be conservative and aim to introduce higher portions of debt even at the 100MW and 200MW stages. When the Offshore Wind Pathways study[11] was published in 2012, it set a target for 2016 of 20% debt in construction of projects and 40% in operations. The Cost Reduction Monitoring Framework[12] (CRMF) 2017 reported that it was common for offshore wind projects to attract 70% debt in the construction phase and more than 75% during operations. Similarly, equity risk premiums were found to have reduced more than expected. This gives an indication of the extent to which debt and institutional investors can be attracted to infrastructure projects with increasingly familiar technology and stable revenue mechanisms. These reductions in financing cost are being achieved in spite of offshore wind projects continuing to push the boundaries in terms of new technology (eg. larger turbines) and more difficult sites (deeper water, higher wind resource, further from shore).

We note the significant part which cost of capital has played in reducing the bid prices of Offshore Wind, but also acknowledge that it has taken multiple gigawatts of installed capacity to achieve this level of investor and lender comfort. It is worth noting that each 1% reduction in discount rate (eg. from 7.1% to 6.1%) is worth roughly 6% in LCOE and that achieving a cost of capital of 5% (75% debt at 4% interest rate and 25% equity at 8%) would reduce our 1GW LCOE estimate of £91 per MWh to £80 per MWh.

### 4.3. Long-term cost reduction potential

#### 4.3.1. Long-term Learning Rates

In addition to the near-term developments highlighted above, there are a number of opportunities for further cost reduction in the longer term. Key areas where we can expect learning will lead to innovations that reduce lifetime costs are: reduced cost of offshore operations; improved device reliability and availability; and longer service intervals. The Review of Renewable Electricity Generation Cost and Technical Assumptions[13], produced by Arup on behalf of DECC estimates the learning rates to be expected in tidal stream power following the doubling of installed capacity at 19% for OPEX costs and 13% for CAPEX costs. This is consistent with precedence from commercial development of other

[10] All return figures are quoted on a pre-tax real basis
[11] https://www.thecrownestate.co.uk/media/5493/ei-offshore-wind-cost-reduction-pathways-study.pdf
[12] http://crmfreport.com/
[13] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566718/Arup_Renewable_Generation_Cost_Report.pdf

renewable technologies. Solar PVs have achieved a learning rate of 18-22%[14], onshore wind 15% and offshore wind approximately 20%[15] which continues to drop rapidly. In this context, our overall effective learning rates (which include the impact of initial significant cost reductions from scale and volume effects, ie. We have ensured no double-counting) of 13% for capex and 11% for opex are on the conservative side. However, we have assumed that improvements in design and O&M strategies will result in increased capacity factors and prolonged operating life.

Combined with ongoing reductions in cost of capital, this ongoing learning by doing could bring LCOE down to £90 per MWh with 1GW of deployment.

### 4.4. Relevance of cost reductions in offshore wind to tidal stream technology

The offshore wind industry in the UK and key markets in Europe, have experienced significant reductions in costs in recent years. In the Cost Reduction Monitoring Framework (CRMF) 2017 report, the industry aggregate LCOE of projects taking Final Investment Decision (FID) in 2015-2016 (commissioning between 2017 and 2020) was estimated at £97 per MWh, showing a 32% decrease from £142 per MWh for projects taking FID in 2010-2011 (as shown in the CRMF 2015 report)[16]. Further anticipated cost reduction for projects to be commissioned beyond 2020 is evidenced by the strike prices of £74.75 per MWh (projects commissioning in 2021/22) and £57.50 per MWh (projects commissioning in 2022/23) awarded to three UK windfarms in the September 2017 Contracts for Difference (CfD) allocation round. These strike prices imply LCOE (in 2011 real terms) of roughly £69 per MWh and £54 per MWh, marking an anticipated total reduction in UK offshore wind LCOE of 60% in roughly ten years.

Our assessment of tidal stream LCOE shows a 70% cost reduction from today to 1GW installed – the anticipated reductions in offshore wind provide good context for achieving this ambition.

Analysis of recent UK Offshore Wind auction bid prices highlights the key drivers of cost reduction. We estimate that the most significant reduction has come through cost of capital, with debt proportions and margins and, at least as significantly, cost of equity, having reduced dramatically. In time, this type of reduction should also apply for tidal stream (as referenced in Section 4.2.4 of this report).

Similarly, increases in capacity factors through improvements in blade aerodynamics, control systems, forecasting and maintenance strategies are all applicable to some degree to tidal stream. We have reflected this in an increasing capacity factor profile over deployment.

The move to even larger-rated turbines in Offshore Wind (with 12-15MW turbines expected for projects from ~2023) is one which we do not see applying to tidal stream to the same degree. A number of developers either have or are developing turbines up to 2MW, but the scope for going larger is limited by environmental factors including water depth, which limits blade length.

---

[14] IRENA 2017, Renewable Power: Sharply Falling Generation Costs

[15] http://www.gwec.net/wp-content/uploads/2016/06/160603-FINAL-Offshore-wind-cost-reduction-statement-with-annex.pdf

[16] https://ore.catapult.org.uk/app/uploads/2018/02/CRMF-Quantitative-Assessment-report.pdf

### 4.5. Cost Reduction Summary

The cost reductions above will lead to a path as shown in Figure 2. Initially, significant cost reduction will come with modest deployment as supply chain and developers can confidently commit to investing in the industry and overcome early design and operational challenges. As the technology matures, cost will continue to fall with incremental innovation and continuing learning. Based on our analysis and industry engagement, we see ongoing reductions will be achieved over a relatively modest volume of deployment. We forecast LCOE of £150 per MWh by 100MW installed, £130 by 200MW and £90 by 1GW.

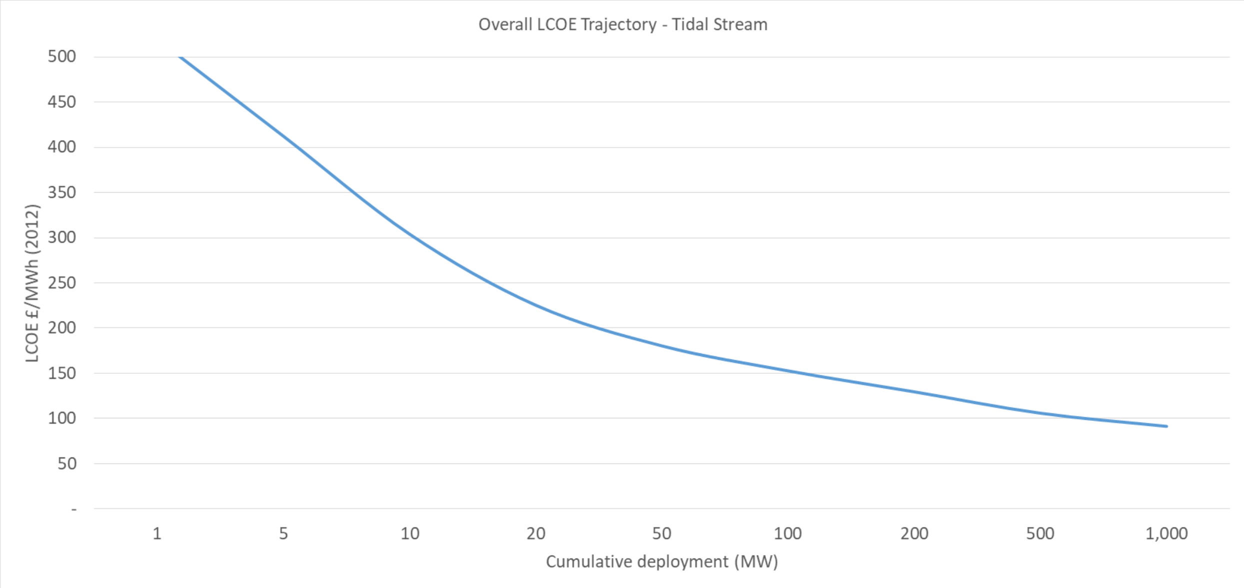


Figure 2: Tidal stream estimated LCOE trajectory to 1GW

As noted in the preceding sections, the overall learning rates are by no means aggressive and applying an overall learning rate on both capex and opex of 15% would result in LCOE by 1GW of £80 per MWh. There is also potential for cost of capital to reduce further, closer to the reductions implied by offshore wind auction bids and achieving a 5% cost of capital would also result in 1GW LCOE of £80 per MWh.

# 5. UK Wave & Tidal Stream Supply Chain Comparative Advantage

The UK has some of the best marine energy resource in the world, and many of the technology concepts have originated from the UK. The UK's 23 tidal stream technology developers already referenced is currently rivalled only by the USA with 19, while there are growing numbers in France, Canada, Australia and Norway. In wave energy, the USA has the greatest number of technology developers in various states of technology readiness.

UK companies have highly relevant existing skills in offshore industries such as oil & gas and offshore wind, as well as other industries with transferable skills, such as aerospace and shipping. The Marine Energy Supply Chain Gateway (MESCG)[17] lists in excess of 850 companies, spread throughout the UK, currently active or able to participate in the sector. However, the UK is not unique, and several other countries have identified wave and tidal stream energy as a major opportunity for energy supply and economic growth.

### 5.1. Deployment potential

The UK's practical resource[18] has been estimated at 15GW for tidal stream and 23GW for wave energy. With the right policy support, in the near term we should expect to see up to 1GW of tidal stream deployed by 2030 at an average rate of 100MW per year and up to 1GW of wave energy deployed by 2040. This deployment profile for tidal stream has been informed by developer expectation and Renewable UK's project intelligence database and takes into account our assessment of the ongoing level of activity needed to unlock supply chain investment which enhance capabilities.

Our understanding of global deployment has been informed by the IEA Energy Technology Perspectives (ETP) 2012 study[19]. The ETP model combines analysis of energy supply and demand to provide a technology-rich, bottom-up analysis of the global energy system. This study takes the High renewable

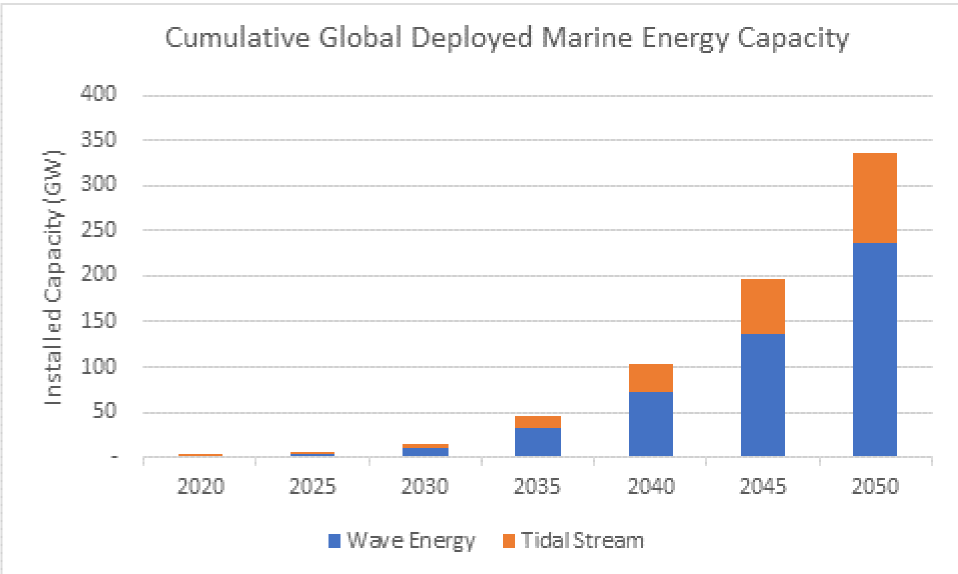


Figure 3: ETP ocean energy capacity forecast to 2050

[17] https://www.mescg.co.uk/
[18] ETI ESME modelling
[19] http://www.iea.org/etp/etpmodel/

variant of the IEA's 2 degree scenario (with delayed CCS and low nuclear variant) as a basis. This was chosen to reflect the significant cost reduction seen in recent years across a number of mature renewables technologies, which has increased investment in solar power, onshore and offshore wind. At the same time, several countries are making a conscious move away from nuclear for reasons of policy and/or due to actual costs being higher than previously forecast. This forecast gives a prize in capacity of 101GW of tidal stream and 236GW of wave energy by 2050.

## 5.2. UK GVA & Jobs Supported

A 2016 analysis by economic development agencies in the South-West, Wales and Scotland estimated that around 1,700 people currently work in the UK wave and tidal sectors, with roughly £445 million spent to date in the UK supply chain. The UK has existing skills in subsea engineering, offshore foundation design and manufacture and marine operations. There are substantial crossover skills in electrical grid connection and the UK is a global leader in technology development and project development for both tidal stream and wave.

### 5.2.1. GVA creation

Based on existing strengths, how UK marine energy contracts have been placed to date, and developer expectations going forward, UK companies are expected to retain a majority of the domestic supply chain activity. There is more logic for export potential in some segments of the supply chain, such as small, high-value, easily transportable electrical components, wave and tidal device design and expertise in installation techniques, O&M strategies, environmental surveying, project development and management. Both tidal stream and wave energy can add a net positive contribution to the UK economy.

Assuming 100MW UK deployment per year from 2021/22, up to 3GW deployed in the rest of the world and a cost reduction trajectory as already described, by 2030 tidal stream could generate a net cumulative benefit to the UK of £1,400m, consisting of £1,600m GVA from domestic market, £1,100m GVA from exports, offset by £1,300m of revenue support[20], as illustrated in Figure 4.

With the same UK deployment profile but a lag of 10 years, and up to 10GW deployed in the rest of the world, and a cost reduction trajectory as already described for tidal stream, by 2040 wave energy could generate a net cumulative benefit to the UK of £4,000m, consisting of £1,500m GVA from domestic market, £3,700m GVA from exports, offset by £1,200m of revenue support, as illustrated in Figure 5.

While we see the economic benefits from tidal stream accruing earlier, the size of the prize for wave energy is great when considering the potential size of the global market. For both energy sources, we have assumed costs reduce in line with global deployment and so the UK benefits from globally-led cost reduction, while paying for UK-installed capacity. UK revenue support paid for wave energy deployment comes out slightly lower than modelled for tidal stream as the global (non-UK) deployment is higher and so the UK can potentially benefit even more from faster cost reduction.

---

[20] We have assumed a 15-year index-linked CfD in line with the cost trajectory documented in this report

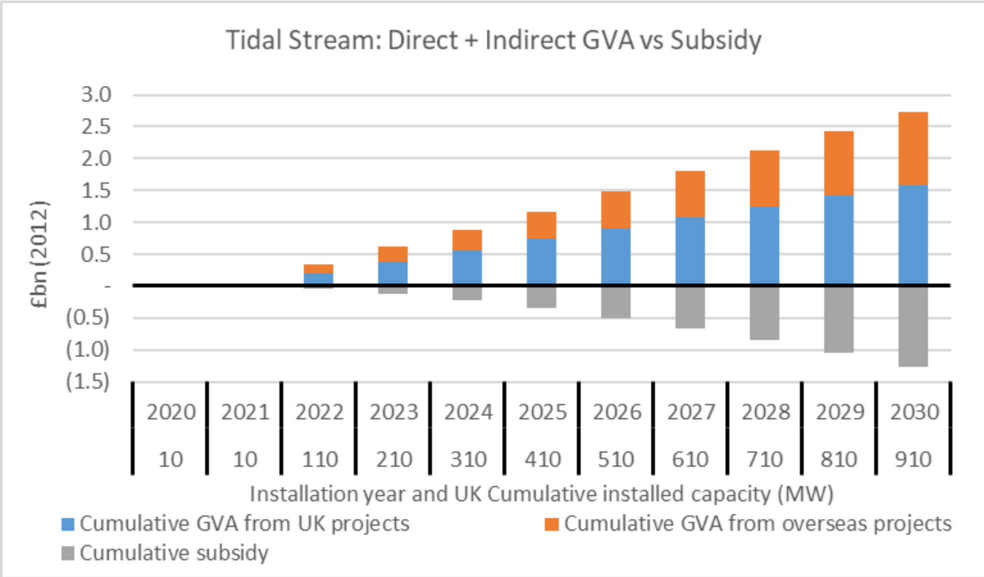


Figure 4: Tidal Stream: GVA vs Revenue Support

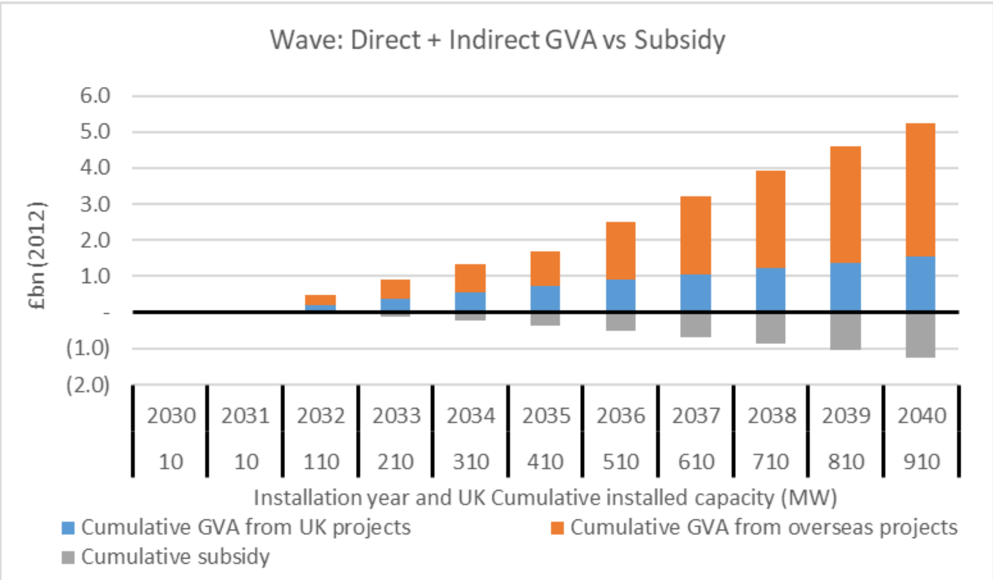


Figure 5: Wave Energy GVA vs Revenue Support

### 5.2.2. Jobs Supported

New jobs will be supported and will continue to be concentrated in distinct regions, and will grow primarily from existing UK industries where there is strong absorptive capacity, especially offshore wind, oil & gas, steel, and maritime, through companies diversifying into marine energy. Our modelling shows that, in tidal stream energy, this could grow to 4,000 by 2030 and to 14,500 by 2040. In wave energy, this could grow to 8,100 by 2040, giving a total of almost 22,600 jobs supported by the sector by 2040.

Supply chain clusters are forming in the UK, primarily in areas local to deployment. There is evidence of these developing into strong regional supply chain nodes in South West, Solent/Isle of Wight, Wales, Shetland, Orkney, North-West Scotland and Northern Ireland. The fact that much of the activity is focused in peninsula, coastal regions, many in need of economic regeneration adds an extra layer of value to the GVA and jobs supported by the sector. A significant benefit of marine energy is the ability to create a sustainable domestic market and supply chain in the UK. Early investment in the UK marine energy sector will anchor the industry in the UK, just as investment by Denmark in the early days of wind energy has created a thriving wind industry that now supports 32,000 jobs with €7bn in annual exports[21].

Our estimates of GVA creation in 2030 for tidal stream and 2040 for wave energy are shown in Table 1 and Table 2.

| Component | UK Projects UK Content | UK Projects 2030 spend £m | UK GVA from UK projects in 2030 £m | Non UK Projects 2030 spend £m | UK GVA from Exports £m | Total UK GVA creation in 2030 £m | FTE supported by 2030 |
|---|---|---|---|---|---|---|---|
| **Tidal Platform** | 65% | 111 | 53 | 403 | 59 | 112 | 1,210 |
| **Foundations/ Moorings** | 80% | 23 | 11 | 85 | 5 | 16 | 160 |
| **Electrical** | 70% | 42 | 23 | 153 | 15 | 38 | 460 |
| **Installation** | 60% | 21 | 12 | 78 | 7 | 19 | 450 |
| **Other Capex** | 72% | 21 | 15 | 77 | 20 | 35 | 330 |
| **O&M**[22] | 75% | 80 | 56 | 247 | 13 | 69 | 1,240 |
| **Development** | 75% | 7 | 5 | 24 | 10 | 15 | 130 |
| **Total** | **70%** | **307** | **175** | **1,066** | **129** | **304** | **3,970** |

Table 1: Tidal stream annual UK GVA in 2030 and jobs supported by 2030

[21] http://www.windpower.org/en/knowledge/statistics/industry_statistics.html
[22] Operating & Maintenance costs are applied to cumulative installed capacity to 2030

| Component | UK Projects UK Content | UK Projects 2040 spend £m | UK GVA from UK projects in 2040 £m | Non UK Projects 2040 spend £m | UK GVA from Exports £m | Total UK GVA creation in 2040 £m | FTE supported by 2040 |
|---|---|---|---|---|---|---|---|
| **Wave energy converter** | 65% | 101 | 48 | 1,549 | 226 | 275 | 2,970 |
| **Foundations/ Moorings** | 80% | 21 | 10 | 327 | 19 | 30 | 280 |
| **Electrical** | 70% | 38 | 21 | 587 | 58 | 79 | 940 |
| **Installation** | 60% | 20 | 11 | 299 | 27 | 37 | 910 |
| **Other Capex** | 72% | 19 | 14 | 297 | 76 | 89 | 830 |
| **O&M**[23] | 75% | 73 | 51 | 773 | 42 | 93 | 1,820 |
| **Development** | 75% | 6 | 5 | 92 | 37 | 42 | 380 |
| **Total** | **70%** | **280** | **159** | **3,924** | **486** | **645** | **8,140** |

Table 2: Wave energy UK annual GVA in 2030 and jobs supported by 2030

[23] Capex-related jobs relate to in-year spend; Operating & Maintenance costs are applied to cumulative installed capacity

## 6. Secure, Reliable Clean Energy Supply

Every kWh of power generated by a wave or tidal saves 394g $CO_2$ compared to the same power from CCGT, 937g $CO_2$ compared to coal or 120g $CO_2$ compared to biomass[24]. It is also worth noting that diesel generation, often used in remote island communities, has a carbon intensity of 250g/kWh which, when coupled with the relevant plant efficiency of 25% gives an effective carbon intensity of 1,000g/kWh, which is in line with the estimate for coal.

By 2030 the power sector needs to be almost completely decarbonised. Meeting the Fifth Carbon Budget will require ambitious action across the whole of the UK economy. Electrification will be one of the keys to reducing emissions from other sectors, which will have an impact on power demand and supply dynamics. At the same time, many old nuclear and gas power stations will be coming to the end of their working lives, and the UK Government committed to the phase out of unabated coal power by 2025.

Marine energy technologies have the potential to displace natural gas generation on the grid and to reduce CO2 emissions (compared to CCGT) permanently by at least 1MtCO2 per year after 2030 and at least 4MtCO2 per year by 2040. Its potential is even greater than that of other less established renewable technologies such as biomass and advanced conversion technologies. Tidal energy has the added benefit of predictability: the tides can be predicted decades in advance. Combined with energy storage, this creates the potential for a predictable dispatchable renewable energy source to support the low-carbon grid.

[24] Referring to operational stage of life only.

# 7. Conclusions

| | Tidal Stream | Wave |
|---|---|---|
| **Is there a clear cost reduction pathway for the technology, so it can deliver low cost solutions?** | <u>Yes</u><br>Cost has reduced significantly already with minimal deployment. Further reduction will come: economies of scale; learning by doing; maturing market and innovation.<br>We expect LCOE to reduce from £300 per MWh to £90 per MWh by 1GW of deployment. | <u>Too early to analyse</u><br>Wave cost reduction has not been modelled in this study. The technology is still at an early stage and there is high uncertainty in design and energy yield potential, but we recognise there is huge potential for read across from both offshore wind and tidal supply chains. |
| **Can the UK develop world-leading technology in a sizeable global market?** | <u>Yes</u><br>The UK is an early leader in marine energy. Companies with existing skills in marine technologies are diversifying into tidal stream technology. Almost 4,000 jobs could be supported by 2030 and 22,600 by 2040, focused in Scotland, Wales, and the South West.<br>There is growing interest from global markets which the UK can access through existing supply chain links. | <u>Yes</u><br>Wave has an abundant global resource. Many of the same companies are moving into wave as well as tidal, however the technology is at an earlier stage.<br>WES is playing a huge role in accelerating development through their competitive stage gate process which have used 71% UK content on average to date. |
| **Does the technology deliver maximum carbon emission reduction?** | <u>Yes</u><br>Tidal energy is an abundant resource with low operational $CO_2$ emissions. It could reduce emissions by over 1MtCO2 per year in 2030 and over 4MtCO2 per year in 2040. | <u>Yes</u><br>Wave energy is an abundant resource with low operational $CO_2$ emissions. It could reduce emissions by over 1MtCO2 per year in 2040. |

Table 3: Clean growth strategy tests

The UK is ready to make big strides in tidal stream energy, securing the UK market and securing a significant share of global exports. The industry requires a positive signal from UK Government to unlock the private investment necessary to enable initial commercial arrays to grow and pave the way for additional development in UK waters.

Whilst wave is still in early development, there is obvious cross over from both offshore wind and tidal, particularly in supply chain and best practice that will enable wave to very quickly flourish once the primary mover and PTO interface challenge has been overcome.

Marine energy presents a significant opportunity for UK technology developers and supply chain companies given the UK's current position, worth an estimated £95m[25] per year by 2030, or £1,400m cumulatively. Underpinning the UK's ability to capitalise on this significant export opportunity is the need to build deep expertise in the relevant fields through a vibrant domestic market.

However, there is a very real danger that as global momentum grows in these countries, the UK risks handing over its global lead to other countries. To benefit from this growth, the UK needs to present a clear success story of technology and project development in the UK, where UK companies can develop and showcase their expertise.

[25]Calculated as sum of GVA from UK and non-UK projects minus the cost of revenue support in that year

The UK is currently a world leader in the development of marine energy technologies but policy support is required to provide a market mechanism that enables commercial projects. For tidal stream developers this means providing an immediate route to market to enable volume deployment, standardisation and the application of existing innovation activity as well as ongoing R&D funding to further enhance the technology and solutions available. For wave energy, continued support is required to achieve the current journey towards technology convergence and proving survivability and reliability. The provision of a route to market for tidal energy today will also provide comfort to investors in wave technology that there is a viable business case for continuing development programmes.

With 10MW currently deployed, we estimate the LCOE for tidal stream energy being deployed in the UK today to be approximately £300 per MWh. Based on our analysis and industry engagement, we see that significant cost reduction is possible in the immediate term and that ongoing reductions will be achieved over a relatively modest volume of deployment. We forecast LCOE of £150 by 100MW installed, £130 by 200MW and £90 by 1GW. These reductions will be driven initially by economies of scale and volume enhanced by specific innovations and ongoing learning by doing.

Tidal Industry participants require visibility of a steady project pipeline and we estimate that an average of 100MW per year from 2022 up to at least 2GW would provide the right signals to mobilise the supply chain investment required. Given the decreasing profile of revenue support required and the increasing profile of economic value and jobs supported with the volume deployed this would support by 2030 total GVA of £2.7bn and 4,000 jobs at a cost via CfD-type revenue support of £1.3bn.

With the appropriate continued support of technology development programmes wave energy will also reach the point of requiring a policy-driven route to market. In our modelling we have assumed this will be 10 years later than for tidal stream, with 100MW per year deployed from 2032. Assuming the same price trajectory, UK content, deployment and share of global market as tidal energy, this would support by 2040 total GVA of £5.2bn and 8,100 jobs at a cost via CfD-type revenue support of £1.2bn.

Given the size of the global opportunity, the investment required through policy support is relatively modest and outweighed by the GVA generated from domestic and global markets. This will create UK global advantage and support sustainable jobs in a growing industry. 50-60% [26] of the economic benefit in terms of both GVA and jobs is expected to be generated in coastal areas, many with a need for economic regeneration, adding an additional value over and above what has been quantified in this report.

There could be a shortfall of low carbon electricity generation of 100TWh by 2030 and marine energy technologies have the potential to displace natural gas generation on the grid and to reduce $CO_2$ emissions permanently by at least 1Mt$CO_2$ per year after 2030 and at least 5Mt$CO_2$ per year after 2040.

The UK has the lead in a huge potential global marine energy market. Policy action will allow the UK to maintain this lead, and build the foundations for a global sustainable energy sector.

[26] Based on analysis of regional supply chain activity in the Marine Energy Supply Chain Gateway database, with uplift on installation and O&M activity to reflect increased activity near site.

# Contact


**GLASGOW**
Inovo
121 George Street
Glasgow
G1 1RD

**T** +44 (0)333 004 1400
**F** +44 (0)333 004 1399

**BLYTH**
National Renewable Energy Centre
Offshore House
Albert Street, Blyth
Northumberland, NE24 1LZ

**T** +44 (0)1670 359 555
**F** +44 (0)1670 359 666

**LEVENMOUTH**
Fife Renewables
Innovation Centre (FRIC)
Ajax Way, Leven
KY8 3RS

**T** +44 (0)1670 359 555
**F** +44 (0)1670 359 666

**Info@ore.catapult.org.uk**
**Ore.catapult.org.uk**