Supergen Offshore Renewable Energy

Delivering Net Zero: Forecasting Wave and Tidal Stream Deployment in UK Waters by 2050

A Supergen Offshore Renewable Energy Hub Policy Paper prepared by the Policy and Innovation Group at the University of Edinburgh.

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THE UNIVERSITY of EDINBURGH
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Policy and Innovation Group

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The Policy and Innovation Group (P&IG)

The Policy and Innovation Group exists within the Institute for Energy Systems (IES), one of the six research institutes within the School of Engineering, at the University of Edinburgh. The group combines expertise on offshore energy technologies, energy system organisations and institutions, and the wider policy and regulatory context for energy. The P&IG applies a range of quantitative and qualitative research tools and methods that includes innovation systems, energy system modelling and scenarios, supply chain capabilities, and transitions management. The P&IG has extensive experience of delivering strategy roadmaps and evidence-based policy for the offshore energy sectors, public and private investment and government departments.

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Find out more about the Policy and Innovation Group at
http://www.policyandinnovationedinburgh.org/

Supergen Offshore Renewable Energy Hub

The Supergen ORE Hub is a £9 Million Engineering and Physical Sciences Research Council (EPSRC) funded programme which brings together academia, industry, policy makers and the general public to support and accelerate the development of offshore wind, wave and tidal technology for the benefit of society. The Hub is led by the University of Plymouth, and includes Co-Directors from the Universities of Aberdeen, Edinburgh, Exeter, Hull, Manchester, Oxford, Southampton, Strathclyde, and Warwick. The Supergen ORE Hub is one of three Supergen Hubs and two Supergen Network+ created by the EPSRC to deliver strategic and coordinated research on Sustainable Power Generation and supply.

Find out more about the Supergen ORE Hub at
https://www.supergen-ore.net/

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Cover image: The Morlais Tidal Energy Zone (Source: Welsh Government)

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DELIVERING NET ZERO:
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CONTENTS

EXECUTIVE SUMMARY

This report aims to forecast the potential deployment of wave and tidal stream energy devices in UK waters by 2050, outlining how the ocean energy sector can meaningfully contribute towards national Net Zero targets. The emergence of a commercial wave and tidal stream sector can also strengthen our future national energy mix, which is particularly important given the ongoing concerns over national energy security, the volatility of foreign energy imports and the need for clean and secure domestic sources of energy. This report will therefore use energy system modelling to quantify and better understand the role of wave and tidal stream in a potential future UK low-carbon energy mix.

One of the main metrics that drives technology development and deployment is the present, and future, Levelised Cost of Energy (LCOE), the value of which will in turn dictate the market uptake of a given technology in any future energy mix. Due to the uncertainty in modelling future LCOE's, this report has opted to use the Strategic Energy Technology (SET) Plan LCOE targets, which have been set in consultation with the UK wave and tidal stream sector. The SET Plan, a policy-makers guide produced as a result of the sector-wide collaborative efforts of the ETIP Ocean Steering Committee and Technology Working Group, has set the following cost targets for ocean energy:

- 150€/MWh for wave by 2030;
- 100€/MWh for tidal stream by 2030.

By using these LCOE cost targets as the basis of our input into the Energy Systems Catapult (ESC) Energy Systems Modelling Environment (ESME) forecasting tool, we have been able to estimate the levels of deployment of wave and tidal stream energy, in a future UK energy mix that aligns with the UK government's 2050 Net Zero targets.

This report has produced the following results:

- Achieving the SET Plan targets of **150€/MWh for wave and 100€/MWh for tidal stream** by 2030 will result in the successful commercial deployment of wave and tidal stream devices by the **mid-2030s**;
- **Our forecasted 2050 UK energy mix will involve the deployment of at least 6GW of wave and at least6GW of tidal stream by 2050.**

The AR1500 tidal turbine (Source: SAE Renewables)

INTRODUCTION

The delivery of the UK's ambitious Net Zero targets is currently the most pressing challenge facing the UK government in their commitment to mitigate the worst extremes of the climate crisis. A critical step in achieving these targets is the delivery of a decarbonised energy system, with the ability to provide a reliable and affordable supply of secure, low-carbon electricity. To achieve this, the UK will need to transition to a diverse system of renewable energy generation and flexible low-carbon technologies, that can scale to meet the expected rise in demand of an increasingly electrified society.

This report will quantify the role of wave and tidal stream technologies, referred to collectively as ocean energy technologies, in contributing towards a technologically diverse and resilient Net Zero system. To date, the ocean energy sector has provided a relatively modest contribution towards national energy generation in comparison to other renewables. While a number of factors have contributed towards this position, this report is concerned mainly with the impact that the future Levelised Cost of Energy (LCOE)[1] will have on the associated deployment of wave and tidal stream devices.

While more mature renewable technologies, such as wind and solar, have benefited from a high cost reduction rate, in part due to support for early stage innovation through technology push policy support mechanisms and market led financial support for commercial deployment, nascent technologies, such as wave and tidal stream, require ongoing targeted support. By setting ambitious, but realistic LCOE targets, such as those laid out in the Strategic Energy Technology Plan (SET Plan) [1], coupled with effective technology innovation programmes, common research challenges can be addressed and innovation can be accelerated to deliver wave and tidal stream devices at a cost-effective price to consumers.

By analysing the SET Plan LCOEs established specifically for wave and tidal stream technologies, **150€/MWh for wave** and **100€/MWh for tidal stream**, both by 2030, this report will quantify the impact that achieving ambitious LCOE targets has on the penetration of ocean energy technologies in in a future Net Zero energy system.

AWS Waveswing deployed at EMEC (Source: EMEC)

[1] The LCOE is described as the "discounted lifetime cost of building and operating a generation asset, expressed as a cost per unit of electricity generated (£/MWh)" and can be considered as the life-cycle cost, encompassing the total costs faced by the generator from 'cradle to grave'.

ENERGY SYSTEM MODELLING AND SCENARIO DEVELOPMENT

Drone shot of Mocean Energy's Blue X wave energy converter (Source: Mocean Energy)

Energy System Modelling Environment (ESME)

ESME is a linear optimisation model of the UK energy system, where network optimisation generates the lowest-cost energy system possible, while still satisfying constraints such as the provision of energy service demands in buildings, transport, and industry, subject to CO2 budgets [2]. It is focussed primarily on the physical components of an energy system, such as infrastructure, energy flows and associated costs. Due to its long-term outlook, proxies are used to provide representations of supply and demand balancing, which are too granular for ESME to practically consider.

The philosophy within ESME is of modelling the UK as an energy island. This means that ESME designs do not rely on cross-border electricity infrastructure to absorb excess generation or import electricity when indigenous sources are not available. This philosophy reflects a conservative position wherein the energy system is designed to function without relying excessively on services from stakeholders outside the UK. In relation to this, whilst interconnectors between UK and Europe are represented in ESME in terms of capacity, it is assumed there is no net flow of electricity to or from the UK. This means that interconnectors contribute to the peak generation requirements of a system designed in ESME but not to the supply to end uses in industry, transport and buildings. Interconnector capacity in ESME is fixed, following current proposals for future connection with Europe out to 2050.

Scenario Development

Scenarios provide the primary tool by which to examine how decisions taken in the present day have the ability to shape the future. By underpinning scenario construction with unbiased modelling, focused on delivering a robust and cost-effective energy system, we can better understand how changes to one metric – LCOE for wave and tidal stream – can impact the composition of a future Net Zero energy system. While any scenario, regardless of how carefully it is constructed, is unable to predict the exact composition of our future energy system, by utilising sensible and prudent parameters we can interrogate the potential ramifications of any action we decide to take.

In order to investigate the impact of a changing LCOE on energy system composition, it is important to establish a common set of parameters upon which our scenarios can be applied. This report will present a national energy mix for the UK, based on the ESC's 96% Further Ambition (FA96) scenario, which in turn is aligned to the Committee on Climate Change (CCC)'s Further Ambition position defined in their Net Zero technical report [3] and used in the ESC's Innovating to Net Zero analysis [4].

Despite presenting a future where significant progress towards Net Zero has been made, the FA96 scenario falls slightly short of achieving full Net Zero, predicting that by 2050 overall emissions will reduce by 96% relative to 1990 levels. This is largely due to FA96 scenario being unable to predict with complete accuracy the progress of existing renewable technologies, the emergence of radical new alternatives or changes in societal attitudes. Regardless of Net Zero being achieved, the FA96 pathway will still produce a future energy mix where all available options to reduce emissions are adopted, whatever the cost.

In line with current UK government ambitions to increase the overall generative capacity represented by nuclear energy in the years to come [5], our energy mix has also accounted for a 2050 energy mix that includes three generation III nuclear plants: Hinckley Point C, Sizewell C and Bradwell C. The ESME model is designed to underpin a given amount of nuclear energy generation by deploying large quantities of renewable power, supported by combined cycle gas turbines (CCGT) with carbon capture and storage (CCS) and hydrogen turbines for periods of peak demand and anticyclone weather conditions. Due to renewable energy generators typically exhibiting a lower capacity factor than conventional thermal generators, such as gas and nuclear, an overall increase in the capacity of a largely renewables based energy system is required to meet demand during periods of peak energy consumption.[2]

With these parameters established and the composition of the future UK energy mix outlined, this report will now apply the SET Plan LCOE targets:

- 150€/MWh for wave by 2030;
- 100€/MWh for tidal stream by 2030.

This will enable us to forecast the levels of deployment of wave and tidal stream energy devices in the 2050 UK Energy Mix.

Orbital O2 operating at EMEC test site in Orkney (Source: Orbital Marine Power)

[2] Represented by a 1-in-20-year cold snap during an anticyclone period.

Shetland tidal array deployment at Bluemull Sound (Source: Nova Innovation)

Achievement of the SET Plan LCOE Targets

This report predicts that a 2050 UK energy mix will have a total generating capacity of 315GW and will be characterised as a highly electrified energy system. Due in part to the assumptions laid out in the FA96 scenario and the ESME models goals to minimise carbon emissions, this 2050 UK energy mix contains a high penetration of various complimentary renewable energy sources, amounting to 220GW as shown in Figure 1. Of this total, the majority of energy generation comes from variable and intermittent renewable sources, such as onshore wind, offshore wind and solar PV.

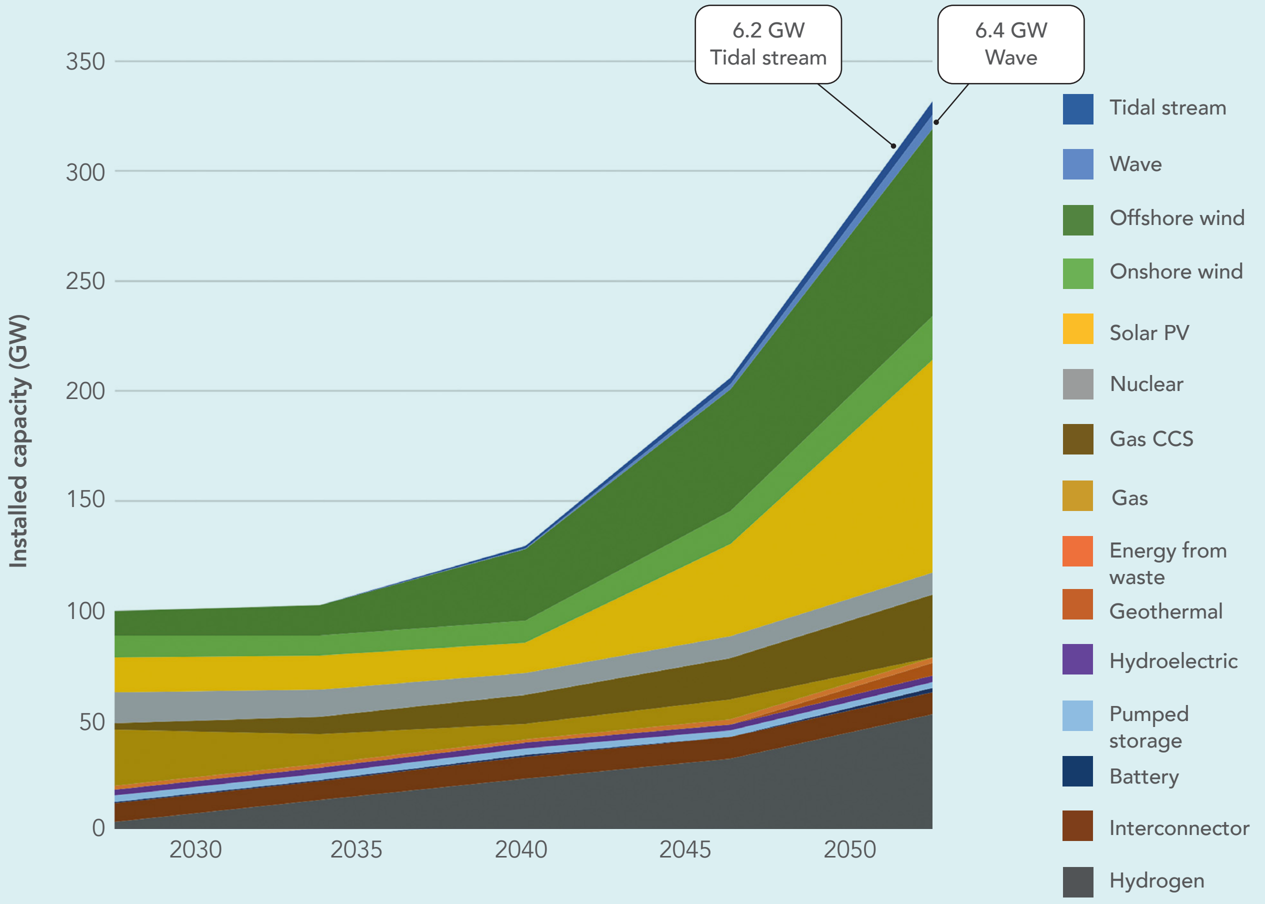

Figure 1 – 2050 UK energy mix under SET Plan LCOEs for wave and tidal stream

However, having met the SET Plan LCOE targets in 2030 and benefitted from subsequent cost reductions, this energy mix is also forecasted to contain:

- **6GW of wave** by 2050;
- **6GW of tidal stream** by 2050

While the initial rate of deployment for both wave and tidal stream will be slow as the sector continues to mature its technological, supply chain and consenting capabilities, the year on year cost reductions enabled by sustained technological innovation, will see the sector achieve commercial success.

As shown in Figure 2, by reducing the LCOE of tidal stream energy to that outlined in the SET Plan targets, the tidal stream sector is able to **achieve commercial deployment by the early 2030's** and goes on to deploy **around 1GW by the mid-to-late 2030's**. Tidal stream energy capacity then increases year on year, before culminating in the deployment of **6GW by 2050**.

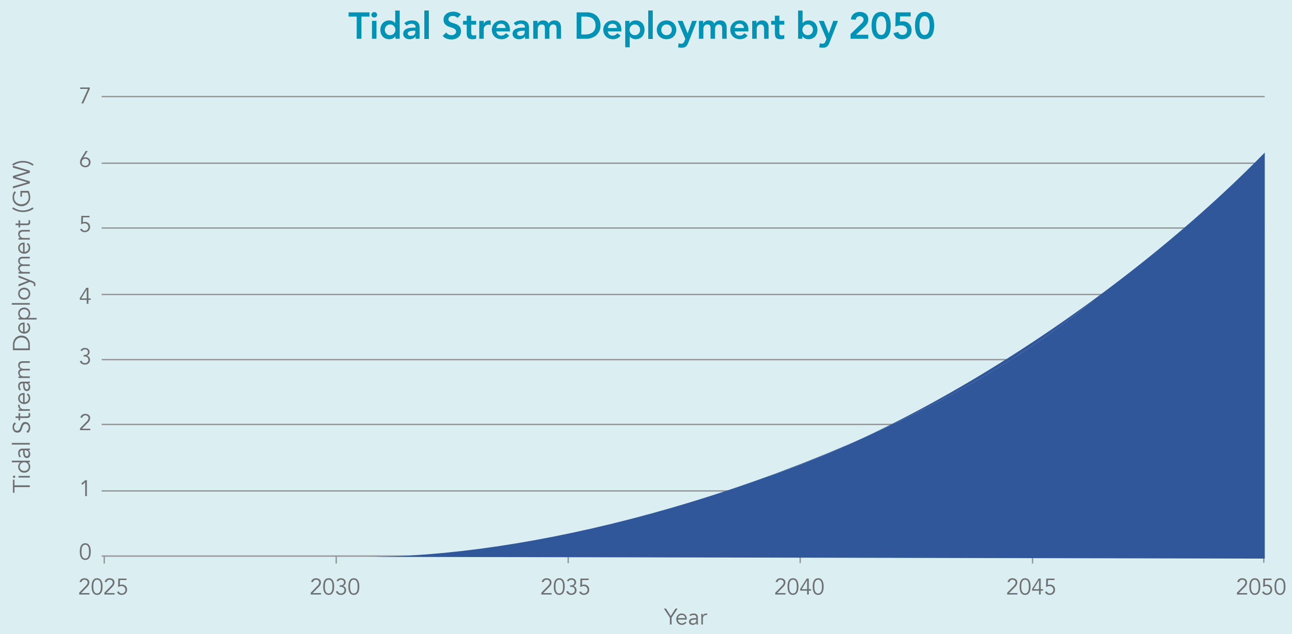

Figure 2 - forecasted cumulative tidal stream deployment by 2050

As shown in figure 3, by reducing the LCOE of wave energy to that outlined in the SET Plan targets, the wave sector is able to **achieve commercial deployment by the mid-to-late 2030's** and goes on to deploy **over 2GW by 2045**. Wave energy capacity then increases year on year, before culminating in the deployment of **6GW by 2050**.

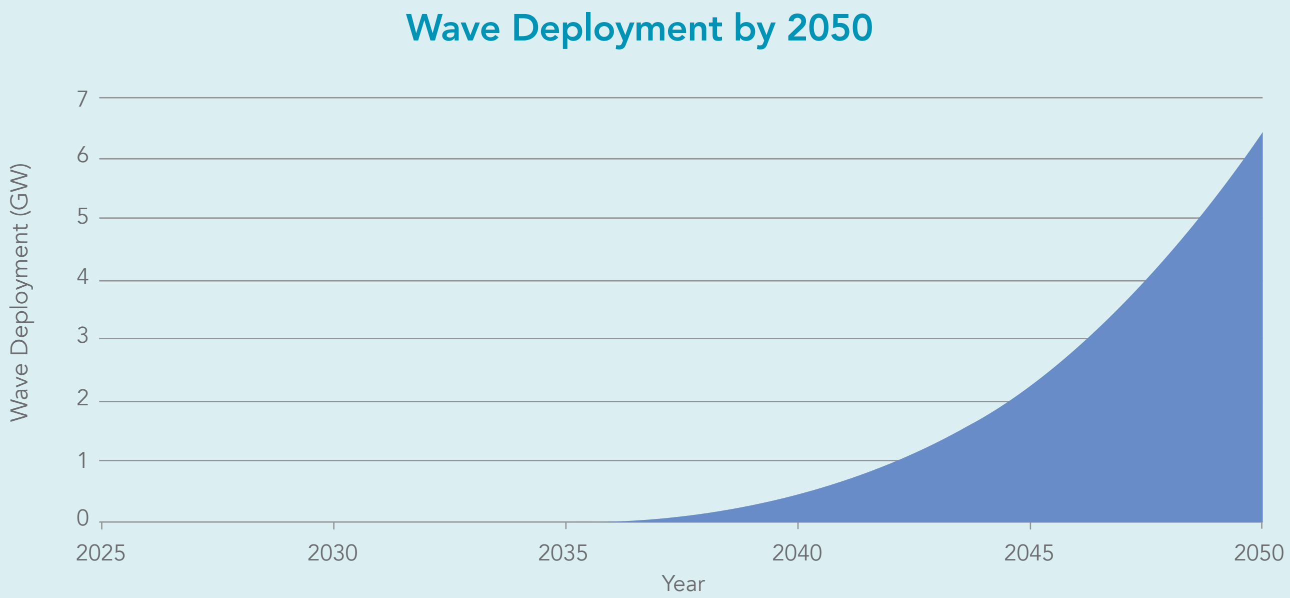

Figure 3 - forecasted cumulative wave deployment by 2050

KEY FINDINGS

Delivering Net Zero by 2050 will require a diverse and resilient energy system capable of meeting an increasingly reflexive national demand for electricity. While the composition of our future energy system is expected to be comprised of a number of low-carbon and renewable technologies, this report outlines that there is the potential for it to contain **at least 6GW of wave** and **at least 6GW of tidal stream.**

While current technology costs have, for now, limited the deployment of wave and tidal stream devices on a commercial scale, the ESME modelling tool has provided an opportunity to forecast the role that these sectors can play in helping to achieve a future energy mix that aligns with our Net Zero commitments. This potential increase in wave and tidal stream deployment in UK waters is indicative of the benefits of the cost reductions attained through increased levels of technology innovation spending and concurrent backing for market led financial support [6].

Despite representing a small percentage of the overall potential future energy mix, wave and tidal stream technologies have the potential to play an oversized role in helping to maintain a balanced and resilient national energy system [7]. While not considered to be baseload generation, wave and tidal stream benefit from being spatially and temporally offset from the generation profiles of more established renewable energy technologies, such as wind and solar, partially offsetting the need for fossil-fuel baseload energy generation.

While meeting the cost reductions outlined by the SET Plan LCOE targets may seem initially ambitious, these targets, which have been established as part of a collaborative process that has been informed and guided by a number of leading European wave and tidal stream energy countries, including the UK, should be viewed as realistic if the requisite levels of financial support for innovation and technology development, balanced by an optimal rate of market-led policy support, are applied.

This report has applied LCOE predictions that are consistent with industry-accepted reduction forecasts and has delivered the following key results:

- Achieving the SET Plan targets of **150€/MWh for wave and 100€/MWh for tidal stream** by 2030 will result in the successful commercial deployment of wave and tidal stream devices by the **mid-to-late 2030s**;
- Our forecasted 2050 UK energy mix will involve the deployment of **at least 6GW of wave** and **at least 6GW of tidal stream by 2050**;

Regardless of the final composition of the future national energy mix, this report has underlined that wave and tidal stream has a large and impactful role to play in helping to achieve our national Net Zero targets.

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FURTHER READING

Policy and Innovation Group and the Supergen ORE Hub

Our forecasted projections of 6GW of wave and 6GW of tidal stream by 2050 have also helped to inform and guide a number of reports released in collaboration with SuperGen ORE:

"What is the Value of Innovative Offshore Renewable Energy Deployment to the UK Economy?" [8]

This study quantifies the potential economic benefit, in gross value added (GVA) terms, that the UK stands to gain through the deployment of innovative offshore renewable energy (ORE) technologies (wave, tidal stream and floating offshore wind) in domestic and international waters.

"What are the UK Power System Benefits from Deployments of Wave and Tidal Stream Generation?" [7]

This study quantifies the potential power system benefits that the UK stands to gain through the deployment of ocean energy technologies (wave and tidal stream) in domestic waters. These system benefits can be attributed to wave and tidal stream generation being available at times of low wind and solar resource, helping to balance the overall renewable power profile. A national energy mix that contains ocean energy is consistently more available and better able to meet demand than an energy mix comprised predominantly of wind and solar.

"Ocean Energy and Net Zero: Policy Support to Achieve Cost-Effective Delivery of 12GW of Wave and Tidal Energy by 2050" [6]

This report outlines the policy support mechanisms, and the associated costs, that would be required to accelerate the commercialisation of the wave and tidal stream energy sectors. One of the primary challenges facing these technologies is the need to drive down the energy generation cost and achieve cost parity with the wholesale market price. This can be achieved in part through the targeted application of technology push and market pull policy support mechanisms to drive both sector innovation and market growth for wave and tidal stream energy devices.

"Research and Innovation for Wave and Tidal in the UK and EU: A 2023 Summary" [9]

This report aims to identify research and innovation opportunities in the wave and tidal stream sector by mapping the current research landscape against the recommendations of the Strategic Research and Innovation Agenda for Ocean Energy. In doing so, this report will help to guide the UK's policy-making decisions on future technology push funding for the wave and tidal stream sector.

Energy Systems Catapult

"Deployment of Offshore Renewable Energy" [10]

Although our scenario analysis has focussed exclusively on the future deployment of wave and tidal stream into the national energy mix, it should be noted that this will have further reaching impacts on the deployment of other renewable energy technologies. An expanded discussion on how the deployment trajectories of other renewable energy sources will change as the LCOE of wave and tidal is reduced, can be found in the ESC's report.

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[5] Department for Energy Security and Net Zero, "Shapps sets out plans to drive multi billion pound investment in energy revolution," 30 March 2023. [Online]. Available: https://www.gov.uk/government/news/shapps-sets-out-plans-to-drive-multi-billion-pound-investment-in-energy-revolution.

[6] P. W. Wong, K. Grattan and H. Jeffrey, "Ocean Energy and Net Zero: Policy Support for the Cost Effective Delivery of 12GW Wave and Tidal Stream by 2050," Policy and Innovation Group to Policy and Innovation Group and SuperGen ORE Hub, 2023.

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[10] Energy Systems Catapult, "Deployment of Offshore Renewable Energy," Energy Systems Catapult, 2020.

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EMEC Test Support Buoy (Source: EMEC)

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