THE UNIVERSITY of EDINBURGH
School of Engineering

Policy and Innovation Group

# Future Economic Potential of Tidal Stream & Wave Energy in Scotland

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Results and recommendations presented here are a summary of two separate studies conducted by the Policy & Innovation Group at the University of Edinburgh for **Scottish Enterprise** and **Wave Energy Scotland.**

- Economic Review of Tidal Stream Energy in Scotland [1],
- Economic Impact Assessment – Value of Wave Energy Deployment to the Scottish Economy [2].

## Policy and Innovation Group

The Policy and Innovation Group is part of the Institute for Energy Systems (IES), which is one of the seven research institutes within the School of Engineering at the University of Edinburgh. The Policy and Innovation Group combines expertise in offshore energy technology, energy system organisations and institutions, and the wider policy and regulatory landscape. They apply a range of quantitative and qualitative research tools and methods including energy system modelling, future transition scenarios, techno-economic analysis and innovation pathways. This leads to the development of policy guidance reports, energy system roadmaps and economic and energy system analysis for technology developers, public and private investment and government departments.

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

## Scottish Enterprise

Scottish Enterprise (SE) is Scotland's national economic development agency and a non-departmental public body of the Scottish Government. It supports businesses to innovate and scale to transform the Scottish economy, by focusing on new market opportunities through targeted investment, innovation and internationalisation. Scottish Enterprise takes a mission-based approach to concentrate efforts and target support on those areas and businesses that will realise Scotland's economic potential and address structural weaknesses. These missions are aimed at creating an internationally competitive energy transition industry in Scotland; scaling the impact of Scotland's innovation strengths into high-growth industries of the future; and driving capital investment to deliver a step-change in Scotland's productivity.

Find out more about Scottish Enterprise at **https://www.scottish-enterprise.com/**

## Wave Energy Scotland

Wave Energy Scotland (WES) is driving the search for innovative solutions to the technical challenges facing the wave energy sector. Through a competitive procurement programme, they support a range of projects focused on the key systems and sub-systems of Wave Energy Converters. The aim is to produce reliable technology which will result in cost effective wave energy generation. WES was formed in 2014 at the request of the Scottish Government and is a subsidiary of Highlands and Islands Enterprise. The aim of WES is to ensure that Scotland maintains a leading role in the development of marine energy.

Find out more about Wave Energy Scotland at **https://www.waveenergyscotland.co.uk/**

Suggested citation: D. R. Noble, K. Grattan, and H. Jeffrey, *'Future economic potential of Tidal Stream & Wave Energy in Scotland'*, The University of Edinburgh, Jan. 2025.

# Contents

# Executive Summary

**Scotland is at the forefront of the global development and deployment of tidal stream and wave energy devices.** In addition to significant resource in Scottish seas, Scotland is also home to several leading tidal stream and wave energy device developers and possesses the underpinnings of a suitably equipped supply chain to support them.

Commercial domestic tidal stream and wave energy sectors have the potential to provide a meaningful contribution to Net Zero, the Just Transition, energy security and economic growth commitments and ambitions, both in Scotland and the rest of the UK.

Scottish tidal stream technologies and projects have won Contracts for Difference in the last three auctions (to be delivered 2026–2029). **A competitive Scottish supply chain, capable of producing devices and key subsystems at volume, is now needed.** Investment in this supply chain, coupled with ongoing market support for the tidal stream and wave energy sectors, is essential to ensure that Scotland capitalises on its position as a pioneer of these technologies.

If Scotland is successful in achieving device commercialisation, there could be a potential combined market for almost **9 GW of tidal stream and wave energy in Scotland by 2050**, feeding into potential deployments of 12.6 GW in the UK and 300 GW across the globe in the same timescale.

**Tidal stream and wave projects in the UK could generate over £8bn in economic benefit to the Scottish economy by 2050, and support over 15,000 high-value jobs in 2050.**

To ensure that these deployments are led by Scottish companies and organisations, **establishing a highly competitive and modernised domestic supply chain is increasingly important.** This will help to ensure that Scotland remains the location of choice for prospective tidal stream and wave energy developers to develop, build, deploy and maintain their devices.

To achieve these step-changes in supply chain capabilities and deliver the GVA and jobs potential for both sectors, this summary report provides the following set of policy recommendations.

Firstly, targeted recommendations are required to **support both device developers and their supply chains**, focusing on the need for:

- **Long-term market support:** Discussions with both UK and devolved governments around the continuation and growth of comprehensive market pull policies.
- **Sustained technology innovation:** Enabling sustained sources of both public and private innovation funding for technology developers.
- **Increased supply chain competitiveness:** Delivering a step-change in the capabilities of a modernised and highly competitive supply chain.

Secondly, recommendations are needed **to develop essential sector infrastructure**, focusing on:

- **Develop skills for a Just Transition:** Development of soft infrastructures, such as preparing a pipeline of workers with relevant skills and training.
- **Cross-sector collaboration:** Opportunities to collaborate with, and share, the supply chain and infrastructures of other established offshore sectors, including offshore wind.
- **Prioritise infrastructure upgrades:** The build out of hard infrastructure, such as ports, harbours, and national grid capabilities.

Finally, this summary report provides the following recommendation **to support the smooth delivery of previous recommendations:**

- **Delivering innovation support in Scotland:** Scotland should utilise the extensive experience of its well-established enterprise and innovation support organisations, to deliver on the complex task of sustained device development and the modernisation of domestic supply chain capabilities.

If successful, Scotland stands poised to become the nation synonymous with leading the successful development and deployment of innovative tidal stream and wave energy devices and farms.

# 1 Introduction

**Scotland is currently leading the world in the development and testing of tidal stream and wave energy technologies.These closely linked sectors could thus form a significant emerging market for Scotland.**

As a result of the success of the Contracts for Difference (CfD) scheme, there is now a pipeline of commercial tidal stream farms set to be built in Scotland and Wales, with the first phases to be commissioned in the next three to five years. This presents an imminent need to develop the supply chain to support these projects, since developers are already placing orders for long lead time items.

Wave energy offers a similar and complementary future deployment and supply chain opportunity, with longer term potential to co-locate with wind farms as they move into deeper waters and more energetic wave environments.

These two emerging technologies offer an additional source of domestic renewable energy to contribute to energy security and meet Net Zero targets. Incorporating tidal stream and wave energy into the generation mix also offers additional power system benefits, as summarised on page 6.

This summary document brings together the learnings from two in depth reports [1,2] that highlight the potential economic benefits available to Scotland from developing tidal stream and wave energy technology and projects. These ocean energy farms may be domestic projects in Scotland or elsewhere in the UK, and the global export market is also considered.

The economic benefits to a country or region can be quantified using two common metrics:

- **Gross Value Added (GVA)**

  This is the economic metric used by treasuries worldwide to measure impacts within a country. It is the value produced by an industry or sector, analogous to Gross Domestic Product (GDP).

- **Full-Time Equivalent (FTE) jobs**

  These are jobs at device and project developers, and within the wider supply chain, to develop, build and operate tidal stream and wave energy farms.

The supply chain required in Scotland to successfully develop both domestic projects and potential export opportunities is also reviewed.

Although previous studies have quantified the benefits of ocean energy at an international, European and UK level [3–5], presented here are the results of the first studies focused on the benefits of tidal stream and wave energy to Scotland specifically.

# Ocean energy technology status and resource

**Although quite different technologies, and at different stages in their path to commercialisation, tidal stream and wave energy are often grouped together under the term ocean energy. Both technologies harness the relentless movement and energy within the oceans.**

## Tidal stream

Tidal stream turbines capture the kinetic energy from predictable tidal currents flowing around the coast. These mostly operate in a similar manner to wind turbines but submerged in the water, mounted on the seabed or beneath floating platforms.

The world's first pre-commercial tidal stream farms have been operating in Scotland since 2016, and the sector is now moving to early commercial projects supported by the UK CfD revenue support mechanism for low-carbon electricity.

At the time of writing, there is almost 10 MW of tidal stream turbines installed in the UK, all in Scottish waters. Beyond this is a pipeline of projects to be installed over the next five years, supported by CfD; 122 MW in the UK, with nearly 84 MW in Scotland.

A recent review of the practical tidal stream energy resource in the UK and British Channel Islands broadly supported previous estimates of around 34 TWh/year, or approximately 11% of the annual electricity demand [6]. Building on an earlier Carbon Trust study [7], this equates to about 11.5 GW of installed capacity, with around 60–70% of this resource in Scottish waters.

The exploitable tidal stream resource is spatially concentrated at headlands and in channels between islands, where the flow is fastest. A significant proportion of the Scottish tidal resource is located in the Pentland Firth and Orkney waters.

## Wave energy

Wave energy converters (WEC) capture energy from the motion of water particles. The greatest energy is available in open seas and oceans where wind generated waves can develop over great distances. Although a wide variety of WEC concepts have been developed to harness this energy, further demonstration is required to build confidence in their ability to produce significant amounts of power, consistently, over multiple years of operation.

While at an earlier stage of development than tidal stream, there has been consistent progression of the development and demonstration of WEC technologies, including significant commitment of resources on research in Scotland. This is bringing the sector closer to being commercially viable. Wave energy farms are expected to be demonstrated in Europe in the next five years.

The practical UK wave resource could be significantly larger and more geographically distributed than tidal, with the potential for over 100 TWh/yr, or around 24 GW of installed capacity. More than 60% of this wave resource is in Scotland, distributed around the coast, with the most energetic swell along the exposed Atlantic Coast to the north west [8–10].

Future wave energy arrays have the potential to be co-located with offshore wind farms, which are beginning to consider locations having an energetic wave climate. This would enable further opportunities for smoothed, combined power export and for improved economics by sharing infrastructure, services and supply chain [11].

Fabrication of Orbital O2 device. Credit: Orbital Marine Power

# Scotland leading in ocean energy

**Scotland is leading in the development, testing, and demonstration of tidal stream and wave energy technologies.**

The European Marine Energy Centre (EMEC) was established in Orkney in 2003 to help support the development of the ocean energy industry. It provides pre-consented test berths for testing tidal stream and wave energy devices. To date, 34 devices from 23 developers have been tested at EMEC, many of these companies coming from overseas.

Two of the world's first tidal stream arrays have been built and operated in Scotland since 2016, the Shetland Tidal Array by Edinburgh-based Nova Innovation, and the MeyGen project by SAE. Another leading Scottish tidal developer, Orbital Marine Power, launched their O2 tidal turbine in 2021; at 2.0 MW this is the largest tidal stream device built to date.

Building on a long history of developing and testing wave power in Scotland, Wave Energy Scotland has supported a range of projects to develop both novel devices and key subsystems. These were competitive stage-gated programmes, open to companies in Europe. Within them, Scottish companies AWS Ocean Energy and Mocean Energy successfully tested their devices at EMEC in 2021/22. Mocean then demonstrated their technology over a further 13 months in 2023/24 in the Renewables for Subsea Power project, supported by private sector finance.

European Marine Energy Centre


Nova Innovation M-100D


SAE MeyGen project/Proteus AR1500


Orbital Marine Power O2

AWS Ocean Energy WaveSwing


Mocean Energy Blue-X

# Benefits of ocean energy

Ocean energy offers an additional source of domestic renewable energy to help meet energy security, decarbonisation, and Net Zero targets. Additionally, there are power system benefits which result from the timing of the resource being offset from both wind and solar [12-17]. The tides are entirely predictable years in advance, and the annual pattern of wave energy resource is well matched to electricity demand in Scotland.

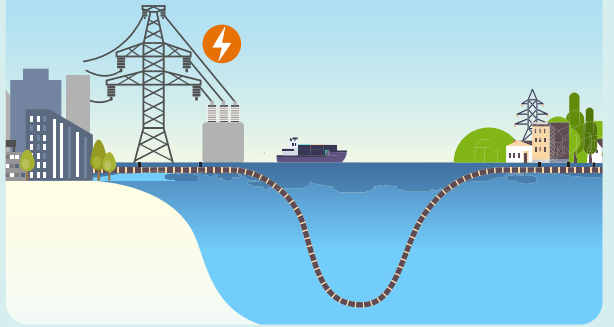
**£1bn reduction in annual dispatch costs from 6.2 GW tidal stream and 6.4 GW wave energy deployed in UK by 2050 [17]**

There are also economic benefits, both in terms of value added by the supply chain, and the jobs supported, some of which will be in coastal communities, or around the Highlands and Islands.

The remainder of this report will outline the economic benefits and jobs resulting in Scotland from developing and deploying tidal stream and wave energy in all markets.

## CARBON SAVINGS


## POWER SYSTEMS BENEFITS



## ECONOMIC BENEFITS

## JOBS

# 2 Methodology

## Overall methodology

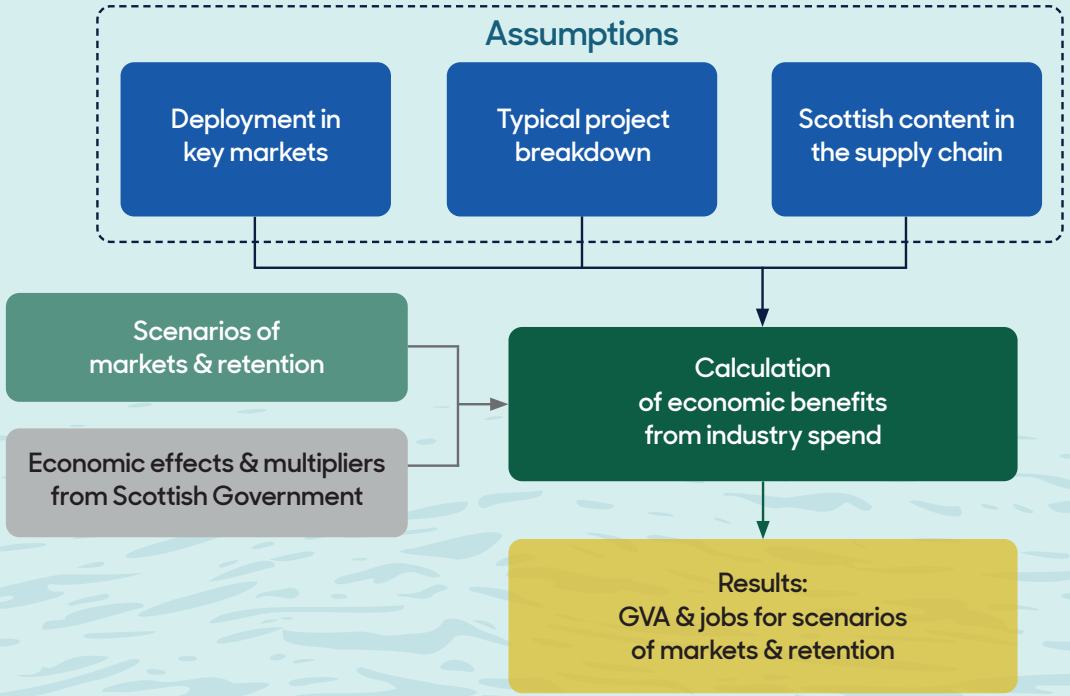
**The economic benefits considered in this study are those resulting from developing, building and operating tidal stream and wave energy projects. These are within three markets: projects in Scotland, the rest of UK, and global exports.**

The future is reliant on various external market factors, therefore practical and credible assumptions were made for a range of inputs:

- Deployment in key markets
- Typical project cost and industry breakdown
- Scottish content in the supply chain

Scenarios are used to illustrate the results, in terms of both GVA and FTE jobs. These are calculated using multipliers from the Industry-by-Industry Input-Output (IO) tables, developed by the Scottish Government [18], that represent how different sectors of the national economy interact.

The assumptions are outlined on pages 8 and 9, followed by a description of the scenarios used.



# Deployment in key markets

## UK & Scottish deployment

Previous energy system modelling [19] shows a potential economic market for **UK deployments by 2050** of:

- **6.2 GW tidal stream**
- **6.4 GW wave energy**

It is presumed 70% of this could be in Scotland, for both wave and tidal stream projects, based on the geographical spread of resource, the project pipeline awarded a CfD, and the UK Marine Energy Council's proposed 2035 targets [20,21].

This gives **Scottish deployments by 2050** of:

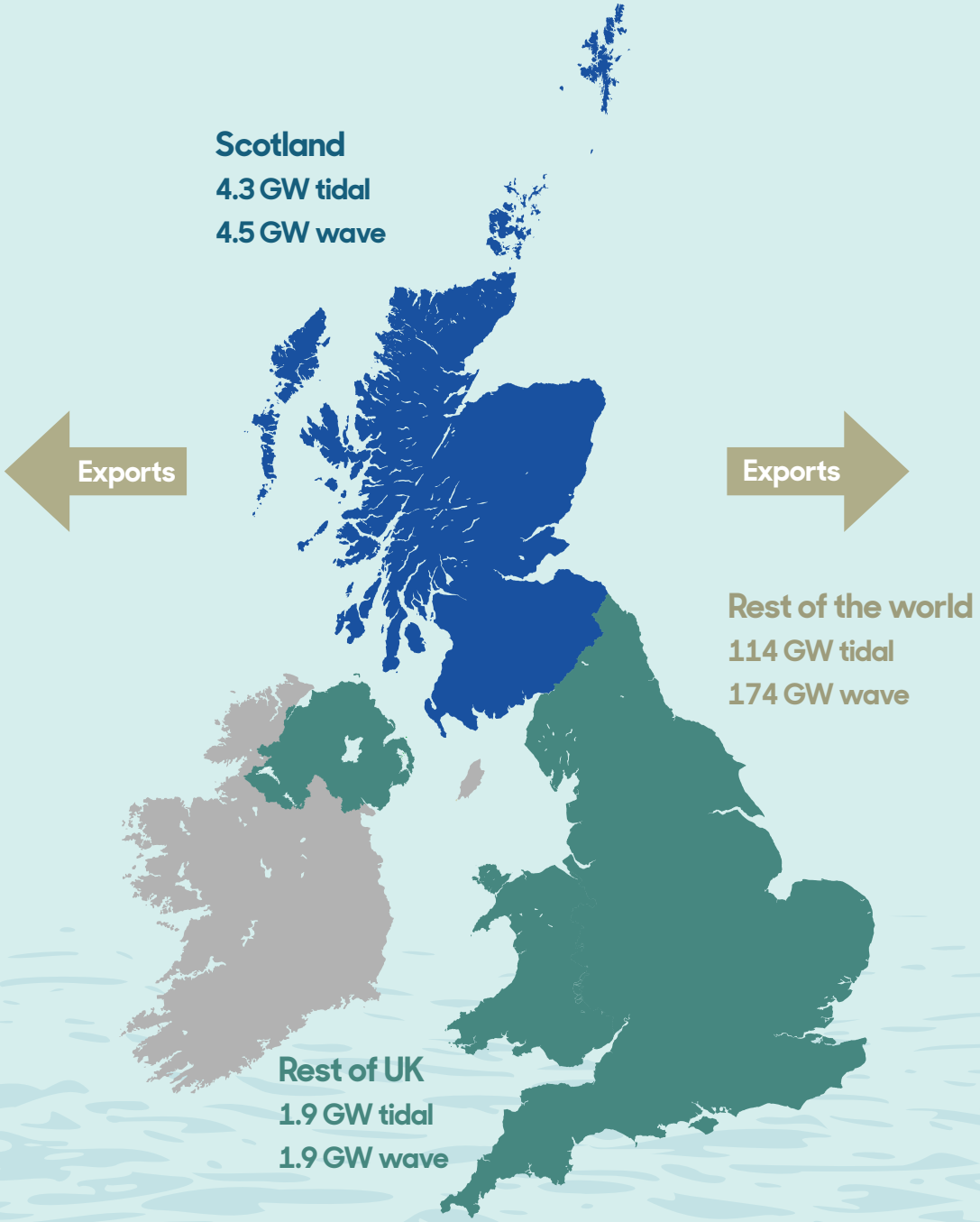
- **4.3 GW tidal stream**
- **4.5 GW wave energy**

## Global deployment

The global market for tidal stream and wave energy is much larger, with significant potential for export of Scottish expertise. Our analysis is consistent with the recent International Roadmap to Develop 300 GW of Ocean Energy by 2050, published by the International Energy Agency's technology collaboration programme on Ocean Energy Systems (IEA-OES) [3].

This **global total by 2050** comprises:

- **120 GW tidal stream**
- **180 GW wave energy**



## Project cost breakdown

Typical breakdowns of project costs and supply chain industrial sectors were developed for tidal stream and wave energy, based on previous work and internal assumptions [22–24].

Project costs cover development, capital, operational and decommissioning expenditures (DEVEX, CAPEX, OPEX, DECEX), split into 6 stages as shown in Table 2.1. A 25-year operational lifetime is assumed, in line with industry expectations. Construction of the device and balance of plant is assumed to take two years, with the bulk of development costs expected in the 5 years prior to commissioning.

Costs were allocated to supply chain sectors using standard industry classification (SIC) codes, which align with those used in the IO tables. These are used to determine the future economic benefits, including direct, indirect, and where appropriated induced effects.

## Scottish content

Very high levels of Scottish content have been reported for some recent ocean energy projects [25]. However, it is assumed this will drop as the industry rapidly gears up to manufacturing 10–100 MW/year, since the supply chain does not yet exist to support this volume. With suitable interventions the supply chain should develop, with Scottish content increasing over time for domestic projects.

A set of low, medium and high levels of Scottish content were developed for key project cost-centres, as shown in Table 2.1. The weighted averages across all project stages are 15%, 48% and 80% respectively. These are consistent with previous sector analyses plus local content commitment and ambitions for the ScotWind leasing round [5,10,26–30].

This represents an average for all projects in each market, although it is acknowledged that there will be significant differences between projects in reality.

## Deployment & cost reduction

As observed with other renewable technologies in various regions, deployments in the UK and overseas are expected to grow year-on-year, although the rate of growth slows over time. The levelised costs of both tidal stream and wave energy technologies are projected to reduce with an ambitious but achievable learning rate of around 15%. The deployment trajectories are smooth over time, with the implicit assumption that market support continues, and any supply chain and infrastructure barriers are overcome in a timely manner.

**Table 2.1. Project breakdown by stage, timeline, share of cost, and Scottish supply chain content**

| Project stage | Timeline | Share of cost | | Scottish supply chain content |
|---|---|---|---|---|
| | | Tidal | Wave | 0% 25% 50% 75% |
| Development & project management | Year -4 to 0 | 8.0% | 5.6% | |
| Generating device supply | Year -1 and 0 | 54.0% | 58.0% | |
| Balance of plant supply | Year -1 and 0 | 19.5% | 17.5% | |
| Installation | Year 0 | 12.0% | 12.0% | |
| Operations & maintenance† | Year 1 to 25 | 3.0%† | 4.0%† | |
| Decommissioning | Year 26 | 6.5% | 6.9% | |

† annual O&M costs as % of fixed costs

Low Medium High

## Scenarios used to illustrate benefits

**For each of the three markets, varying levels of Scottish developer and supply chain ambition have been considered, ranging from moderate ambition up to leaders in the field.**

For **Scottish projects**, it is assumed there is some level of Scottish content in all projects; the economic benefit is only limited by how much.

For projects in the **Rest of the UK**, some projects may have no Scottish content; they could be developed by a non-Scottish company, with the supply chain entirely from outwith Scotland. Similar supply chain content assumptions to projects in Scotland are used.

For the **Global export market**, scenarios show Scottish involvement in either 5% or 20% of global projects, with low or medium Scottish supply chain content, since the supply chain in other countries will also develop and many projects will happen without any Scottish content at all.

The Scottish and Rest of the UK markets are collectively referred to in this report as the Domestic market.

While two levels of ambition are presented, the true figure could fall between these.

**It should also be stressed that to achieve even the Moderate ambition scenarios will require significant effort and investment across the sector, including focused policy interventions.**

It should also be highlighted these are not predictions of what will happen, but credible scenarios to illustrate the potential benefits. Within these, the deployment of tidal stream and wave energy, both in the UK and the rest of the world, is predicted to grow year-on-year with corresponding reduction in costs, similar to what has been achieved with other renewable energy technologies.

Table 2.2. Scenario details

| Market | Level of Scottish ambition | Projects with some Scottish content | Scottish supply chain content within those projects |
|---|---|---|---|
| Scottish | Moderate | 100% | Medium* |
| | Leaders | 100% | High* |
| Rest of UK | Moderate | 50% | Medium* |
| | Leaders | 75% | High* |
| Global exports | Moderate | 5% | Low |
| | | | Medium |
| | Leaders | 20% | Low |
| | | | Medium |

* reaches this level over time

# 3

# Results: economic benefits

## Economic benefit to Scotland

**The economic benefit to Scotland, from all involvement of developers and supply chain companies in the different projects, is quantified using gross value added (GVA) using the assumptions outlined in previous sections.**

These results show the total GVA between now (2024) and 2050, discounted to present day value using the UK Treasury Social Time Preference Rate of 3.5%, consistent with previous studies.

The benefits accrue from 4.3 GW of tidal stream capacity and 4.5 GW of wave energy being installed in Scotland by 2050, with a further 1.9 GW of each in the rest of the UK.

The global export market by 2050 is projected to be around 114 GW of tidal stream and 174 GW of wave energy. It is expected that more countries will be involved in the development and deployment of wave energy projects worldwide, given the larger global resource and wider geographical distribution.

There is potential for tidal stream and wave energy deployments of **nearly 9GW by 2050 in Scottish waters**, contributing to 12.6 GW in the UK and 300 GW globally.

Turbine re-installation at the MeyGen tidal array. Credit: Glen Wallace, Flickr, CC-BY-2

## Domestic scenarios: projects in Scotland and the rest of the UK

**The GVA from domestic projects, in Scotland and the rest of the UK, accrued between 2024 and 2050 is shown in Figure 3.1. Given the expected deployment trajectories the benefits from tidal stream accrue earlier.**

For the Moderate ambition scenario, both tidal stream and wave energy could result in over £2.1bn each from domestic projects; around £1.7bn from projects in Scotland and a further £400m in the rest of the UK.

For the more ambitious Leaders scenario, this increases to £4.5bn from tidal stream and £4.2bn from wave energy, both with a slightly greater share coming from projects in the rest of the UK.

**Tidal stream and wave energy farms in Scotland and the rest of the UK have the potential to generate almost £8.7bn in GVA to Scotland by 2050**

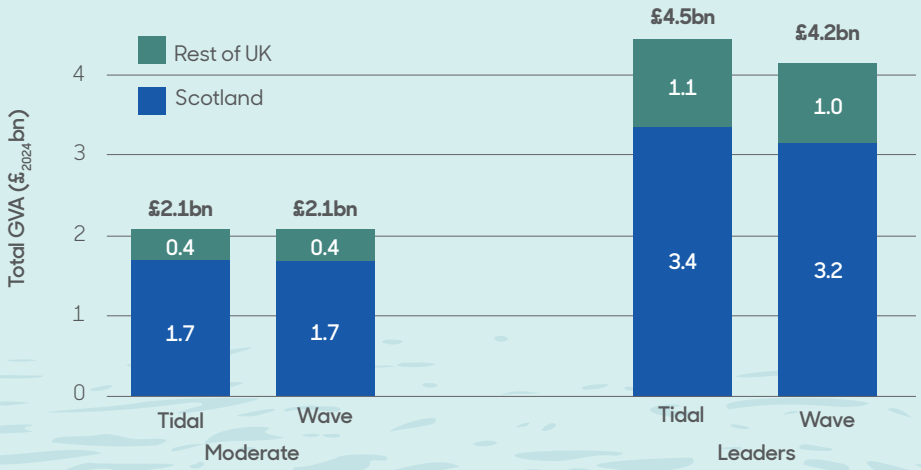



Figure 3.1. GVA from projects in Scotland and rest of the UK by level of Scottish supply chain ambition and technology

## Global export scenarios: GVA from overseas projects

**Scenarios for global exports of tidal stream and wave energy are shown in Figure 3.2, broken down by percentage share of the global market that Scottish companies are involved with and by the level of Scottish content achieved within those projects. Although lagging tidal stream now, by 2050 the global market for wave energy is expected to be considerably larger.**

These show the combined export markets for tidal stream and wave energy could be worth around £2.1bn to Scotland in the Moderate ambition scenario, and potentially up to £28bn in the Leaders scenario. While there are uncertainties over deployment targets in countries across the world, or the development of their local supply chains, there is a huge market available to tidal and wave companies.

**The global export market could be worth up to £28bn by 2050, if Scotland becomes World Leaders in producing devices and their subsystems**

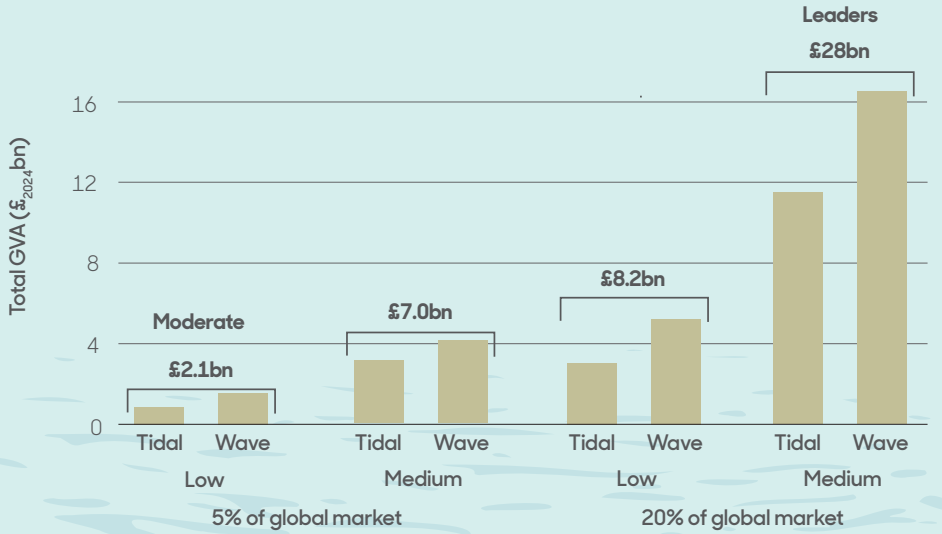



Figure 3.2. GVA from exports, by Scottish share of the global market, supply chain content (Low/Medium) and technology

# Results for combined scenarios

**The total GVA from tidal stream and wave energy projects in all markets is explored using four combinations of the previous scenarios, with results shown in Figure 3.3.**

- **Moderate Ambition in all Markets** – the combined total of the Moderate scenario in the three markets, with lower Scottish content and a smaller share of non-Scottish markets. This has a total GVA to Scotland of just over £6.2bn.
- **Scottish Focus** – has higher Scottish content in Scottish projects, as Scottish companies are Leaders in this market, but still Moderate in other markets. This has a total GVA of almost £9.4bn.
- **UK Focus** – has higher Scottish content and market share in all the UK, with Scottish companies Leaders in this whole market, but still with limited global exports. This has a slightly larger GVA than the Scottish focus, at nearly £11bn.
- **Scottish Leaders in all Markets** – is the optimal scenario, with Scottish companies involved in a larger share of all markets and with higher Scottish content. With considerable exports, this could see almost £37bn in total GVA to Scotland.

Orkney supply chain vessels (Credit: EMEC)

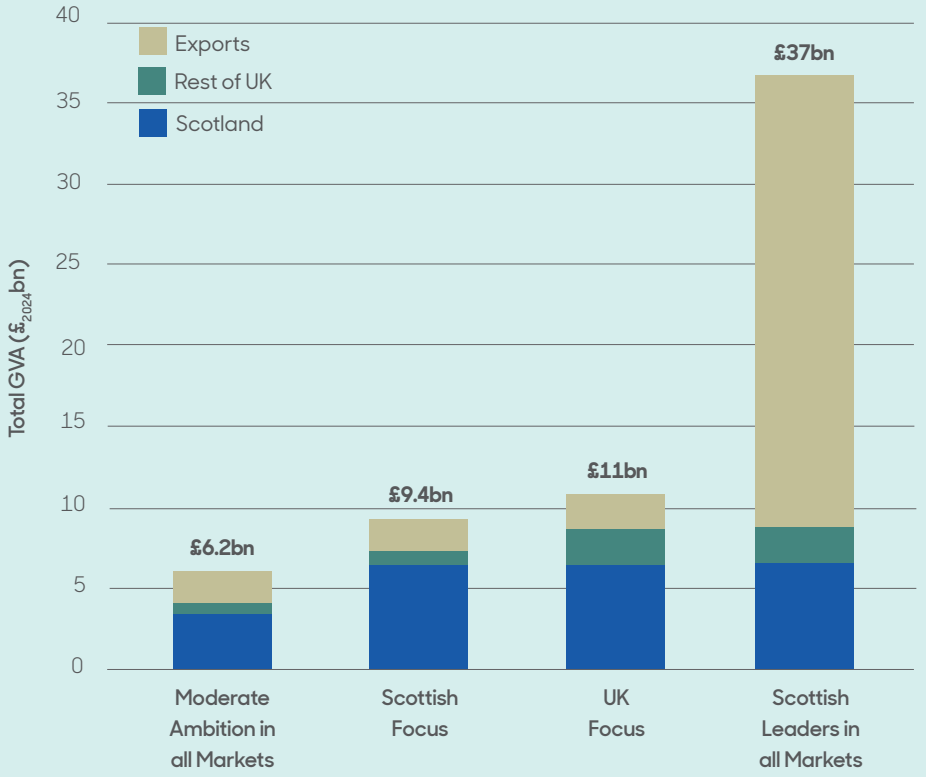



Figure 3.3. Combined scenarios for all three markets of total discounted GVA from 2024 to 2050 for both tidal stream and wave energy

**Tidal stream and wave energy could generate £6bn to £37bn in GVA to Scotland by 2050. All scenarios require intervention, but where Scottish companies are Leaders in all Markets there could be a six-fold increase in the prize.**

## GVA by project cost centre

Within this work, six main project cost centres are considered:

- **Development & project management**
- **Generating device supply**
- **Balance of Plant supply**
- **Installation**
- **Operations & maintenance**
- **Decommissioning** (albeit limited by 2050)

The split of GVA by these cost centres is shown in Figure 3.4. By far the largest component is the generating device supply, at almost half the total GVA. Ongoing O&M is then almost a quarter of the total. The remaining third is split between balance of plant supply, installation, and development and project management.

Given the 25-year project lifetime assumed in line with industry ambitions, there is limited decommissioning by 2050, and thus it is not shown.

These results are for the 'UK Focus' scenario for tidal stream; however the other scenarios have a similar split, based on the input assumptions. All wave energy scenarios are also similar, albeit with device manufacture increased to around 50%.

Mooring in tidal flow at EMEC tidal test site, Orkney (Credit: Colin Keldie/EMEC)

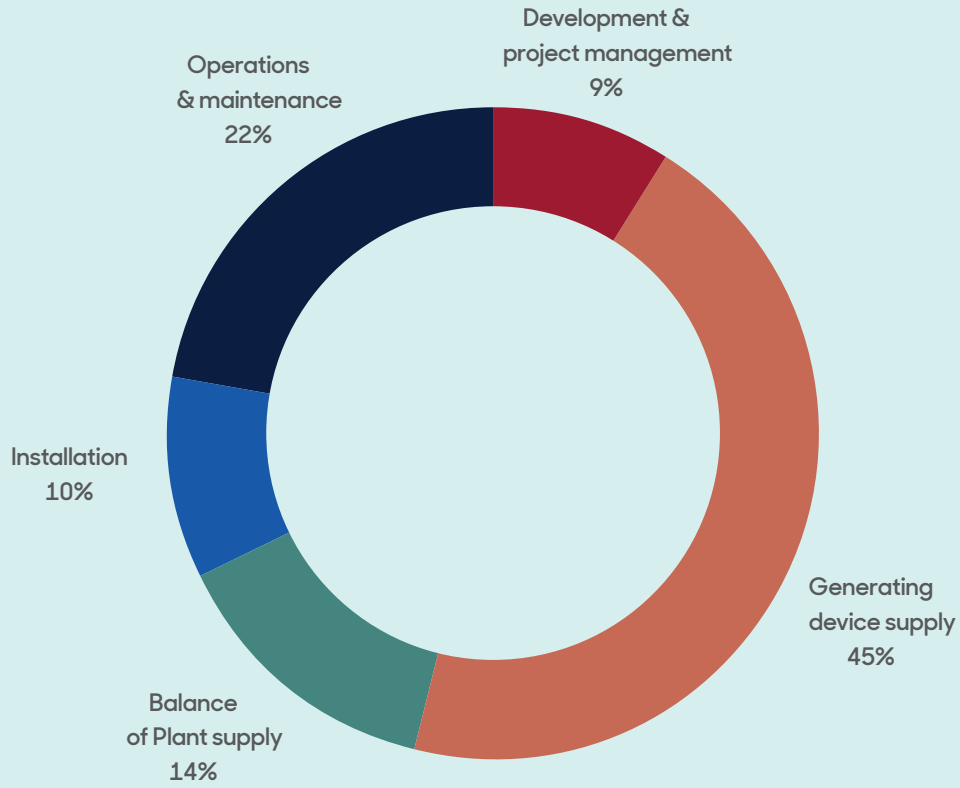



Figure 3.4. Example share of GVA by main project cost centres (tidal stream UK Focus)

Around **half the gross value added** comes from the **device manufacture** with the **operations and maintenance** accounting for **nearly a quarter** of the overall economic benefit

# 4

# Results: jobs supported

## Jobs by market

**In line with the GVA results on page 13, the total FTE jobs in 2050 from both tidal stream and wave energy for the combined scenarios of all markets are shown in Figure 4.1.**

- The **Moderate Ambition in all Markets** scenario has over 12,400 jobs; over 7,000 of these from projects in Scotland, 1,500 from projects in the rest of the UK, and nearly 4,000 from export markets.
- The **Scottish Focus** scenario has nearly 12,000 jobs from Scottish projects, bringing the total to over 17,000.
- In the **UK Focus**, projects in the rest of the UK make up 3,800 jobs, with over 19,000 in total.
- Finally, the most ambitious **Scottish Leaders in all Markets** scenario could see over 46,000 jobs from the export markets. Combined with the 15,600 jobs from domestic projects, this brings the total to over 62,000 jobs.

These are FTE jobs in Scottish companies, resulting from developing, building and operating both tidal stream and wave energy projects in Scotland, the rest of the UK, and from global exports. This includes those directly employed by developers and Tier 1 suppliers, plus indirect jobs in the supply chain.

Some jobs, especially O&M, may require workers to be based near the project site. Alternatively, Scottish experts might travel to the project sites to undertake specific maintenance.

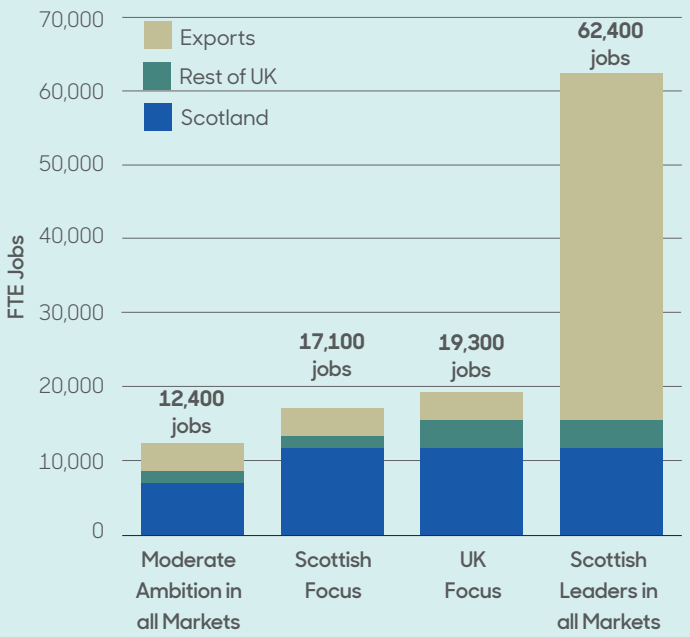



**Figure 4.1. Combined scenarios for all three markets of FTE jobs in 2050 for both tidal stream and wave energy**

**Depending on ambition, tidal stream and wave energy could support between 12,000 and 62,000 jobs from projects in all markets in 2050. Within this, farms in the UK could support over 15,000 jobs in Scotland**

For context, in 2021 the wind sector employed almost 20,000 people in Scotland, with nearly 11,000 in offshore wind and over 8,000 onshore [31]. This is expected to continue to grow, with offshore wind jobs in the UK potentially tripling by 2040 [32].

## Jobs by cost centre

**The share of jobs can also be broken down by the five main project cost centres. These are shown for the medium-term (jobs in 2035) and the longer term (jobs in 2050). Again, these are from the UK Focus tidal stream scenario, but the distribution is similar for all scenarios, including wave energy.**

In Figure 4.2, construction of the device is the biggest share, making up over half the jobs in the medium term. Installation represents the smallest share, and initially O&M also quite a small share at around 10% of all jobs, given the deployment trajectory assumptions.

By 2050, the number of jobs in the sector could triple from 2035, shown by the increased size of the pie. Figure 4.3 shows construction of the device is still the biggest share, at just under half of all jobs in 2050, and it is the biggest growth in number of jobs over this timescale.

The largest change is the share of jobs from O&M, this increases significantly, comprising more than a quarter of all jobs in 2050. This is a direct result of there being more devices in the water over time. By 2050, there could be over 12 GW of tidal stream and wave energy projects in UK waters.

Around **half the jobs are associated with building devices.** By 2050 over a quarter of all jobs are in operation and maintenance of tidal stream and wave energy devices and farms

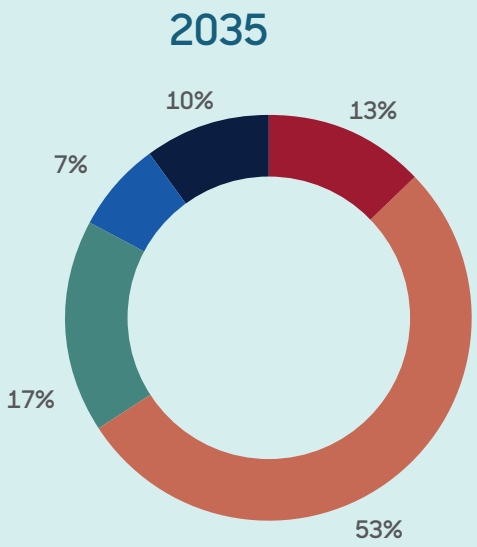



Figure 4.2. Share of FTE jobs in 2035 by project cost centre

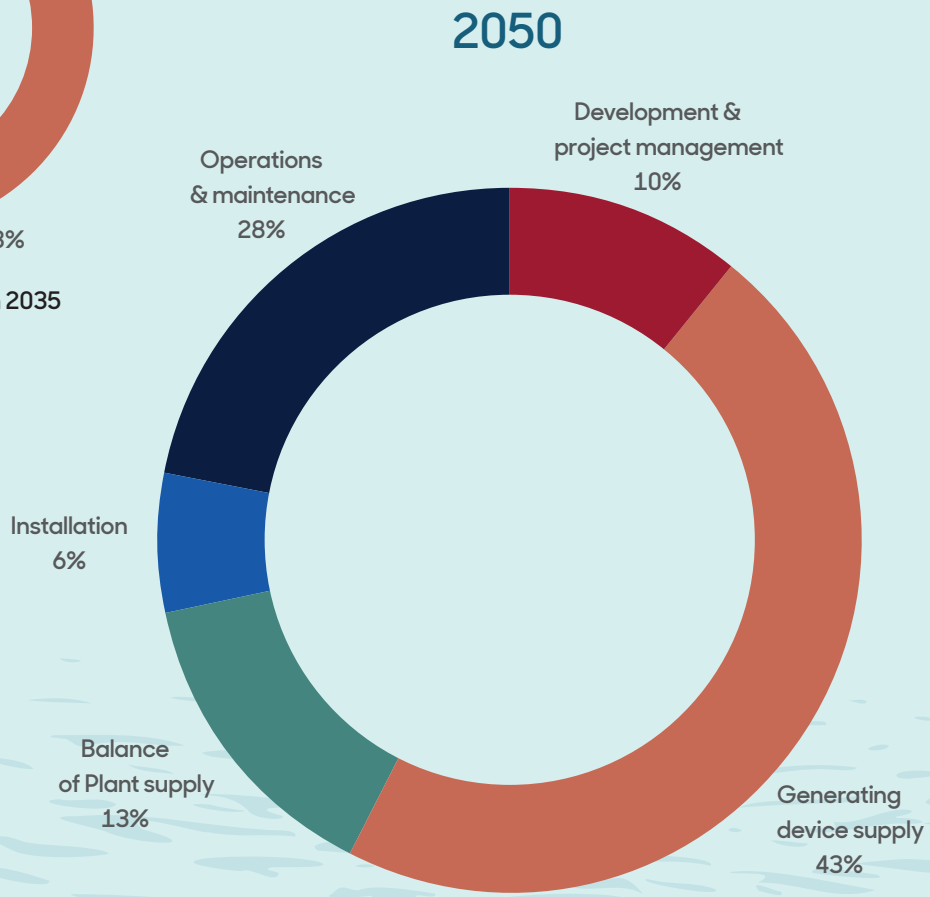



Figure 4.3. Share of FTE jobs in 2050 by project cost centre

# 5

# Supply chain competitiveness

## The Scottish supply chain

**As the tidal stream and wave energy sectors grow to meet the deployment trajectories outlined in this report, investment in supply chain capabilities and capacities must scale accordingly. This will ensure that the domestic supply chain that serves these closely linked sectors is well-equipped to provide solutions to their overlapping needs and challenges. This will also enable them to competitively produce key subsystems and components at the volumes required. This serves two purposes:**

1. It helps to ensure that in the long-term, both sectors continue to be led by Scottish companies and developers.
2. The socio-economic benefits associated with commercial tidal stream and wave energy sectors, such as GVA and jobs, are retained within Scotland.

**To grow Scotland's supply chain capabilities and increase the overall competitiveness of the companies that underpin it, it is important to establish who needs to be competitive.**

**Technology developers:** Responsible for driving the **deployment** of innovative tidal stream and wave energy devices. These organisations ensure that Scottish companies continue to win contracts here in Scotland and across the world.

**Commercial manufacturers:** The companies expected to **build** these projects, from SMEs to larger manufacturers, all of whom will be responsible for producing the components and subsystems competitively and at volume.

**Research organisations:** Helping to underpin the **accelerated innovation** of new materials, manufacturing processes and testing to ensure that Scotland maintains its position at the forefront of both sectors.

# Device subsystems & areas of expertise

As the tidal stream and wave energy sectors move closer to commercial deployment, the Scottish supply chain must also evolve, enhancing its manufacturing capabilities, production capacities, and underpinning expertise to remain competitive with other nations. To deliver this outcome, the Scottish supply chain has to identify key areas where policy support and innovation funding can be strategically targeted for maximum impact and cost-effectiveness. For this, there are two general areas of focus:

- To identify which key **device subsystems** should be a manufacturing priority in order to support the volume production of tidal stream and wave energy devices.
- To identify the overarching **areas of expertise** that are required for device development and deployment, which is necessary to ensure the sustained progression of the sector.

The following lists identify key device subsystems and areas of expertise that are common across both tidal stream and wave energy devices.

## Device subsystems

1. Device hulls and sub-structures
2. Blades (for tidal turbines)
3. Power take-off and electrical systems, including generators, gearboxes, pitch systems, and power conditioning systems
4. Subsea electric cables
5. Anchors and moorings

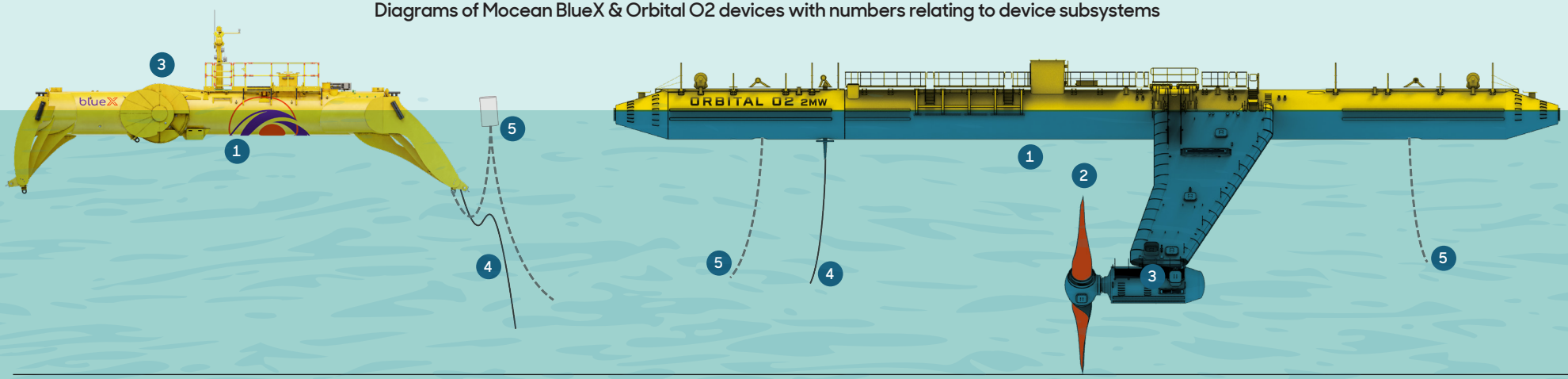
In addition to requiring manufacturing expertise in a range of device subsystems, device developers and their shared supply chains will also be required to grow their expertise in a range of supporting areas. A sophisticated service sector, based on Scotland's decades of project development expertise, is essential for domestic projects and also provides an opportunity for Scottish companies to access and establish a presence in overseas markets. This is all essential to ensure that Scotland maintains its world-leading reputation and remains the location of choice for prospective device developers to develop, build, deploy and maintain their devices.

## Areas of expertise

- Development and testing of devices
- Overall device manufacture/assembly and sub-system integration
- Project development
- Installation, operations and maintenance

As the rest of this section will outline, it is important for Scotland to ensure the correct balance of manufacturing capabilities, production capacities and underpinning expertise across its domestic supply chain. By quickly identifying the device subsystems and areas of expertise that its supply chain is well positioned to provide in coming years, Scotland can potentially maximise the GVA and jobs associated with commercial tidal stream and wave energy sectors.

Diagrams of Mocean BlueX & Orbital O2 devices with numbers relating to device subsystems



# Assessing supply chain competitiveness

**To determine future competitiveness, it is important to first understand both the current status of the supply chain and where the opportunities for Scotland lie.**

## Current supply chain competitiveness

To fully assess Scotland's supply chain strengths in the present day, a classification system that enables decision-makers to view Scotland's current competitiveness for each of the key subsystems is required. By plotting Scotland's current supply chain strength and capability against the potential supply chain opportunity, the following classifications are established:

**Leading the Sector** – Scotland possesses established supply chain capabilities that should be maintained and if possible, strengthened through modernisation.

**Matching the Sector** – Areas with skills and facilities in line with other competing countries. Emphasis should be to support and grow these areas to remain competitive.

**Following the Sector** – Areas where other countries have a significant technological lead. Scotland should carefully assess if this a viable future supply chain opportunity.

**All To Play For** – Areas where no one country holds a significant technological lead or has an established supply chain. With careful strategic investment this area of the supply chain could be moved towards a Leading the Sector position.


Two supply chain subsystems have been selected to explain the reasoning behind their classification:

### Leading the Sector – development and testing of devices

Scottish expertise in the development and testing of devices is recognised across the ocean energy sector. Given the guidance provided by established innovation and support agencies, combined with world-renowned domestic testing facilities, Scotland is well-situated to maintain this position.

### All to Play For – tidal blades

Currently, no single nation holds a definitive lead in the development and manufacture of tidal turbine blades. However, as one of the pioneering nations in the sector, Scotland possesses much of the necessary expertise in composites research, manufacturing and testing to seize this market.

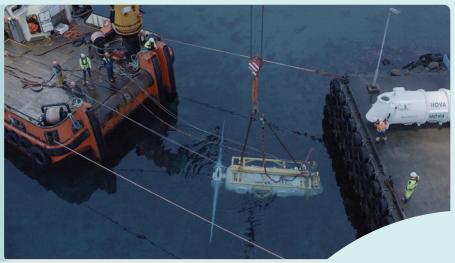
Scotland needs **strategic investment into the manufacture of devices and key subsystems** for tidal stream and wave energy, particularly for those subsystems where Scotland is **Leading the Sector** or has identified an **All to Play For market.**

## Future supply chain competitiveness

Providing support to the companies and organisations identified as holding responsibility for the delivery of key subsystems is a complex task. It requires a combination of innovation funding and financial mechanisms to be carefully delivered to maximise value, impact and overall cost-effectiveness.

To ensure the delivery of comprehensive policy programmes we have considered six underlying factors that are key to increasing the competitive performance of both sectors:

**Markets:** Providing a highly visible and supported route-to-market for underpinning innovations, from technical equipment to new manufacturing processes, is essential to increase sector and investor confidence.



**Research & Innovation:** Ensuring that device developers are supported to deliver sustained innovation, so that the Scottish tidal stream and wave energy sectors maintain their world leading position.

**Regulation & Legislation:** Designing a fit-for-purpose regulatory and legislative landscape, that helps not hinders the accelerated development and deployment of new technologies and employs appropriate financial tools to support and protect the sectors.

**Tidal Stream and Wave Energy Supply Chain Competitiveness Framework**

**Supply Chain Sophistication:** Modernising the entire Scottish supply chain, focusing policy and financial support towards areas such as automation and digitisation, to ensure competitive and volume delivery of key subsystems .

**Collaboration:** Facilitating knowledge exchange and collaborative working between different sectors and stakeholders, combined with the development of innovation clusters.

**Workforce:** Assessing the availability of a skilled future workforce across all education levels, with training to maximise potential impact and ease transition from other sectors.

Developing a **modern and competitive Scottish supply chain** for tidal stream and wave energy is a **complex but achievable challenge.** Policymakers should consider different **interconnected and underlying metrics** when designing policy actions

# 6

# Overview of the prize and recommendations

## The potential for Scotland

Scotland has historically been, and continues to be, at the forefront of the global development and deployment of tidal stream and wave energy projects. In addition to the significant resource, **Scotland is home to several leading tidal stream and wave energy device developers and possesses the underpinnings of a suitably equipped supply chain to support them.**

With a clear pipeline of tidal stream projects already fuelling the steady expansion of the sector, and the development of its underlying supply chain, there is an increasingly attractive prize on offer, should Scotland be able to capitalise on this position. Domestic commercial tidal stream and wave energy sectors have the potential to **provide a meaningful contribution to both Scotland and the wider UK commitments and ambitions on Net Zero, Just Transition, energy security, and economic growth.**

### Net Zero

Nearly 9 GW of tidal stream and wave energy could be deployed in Scottish waters by 2050, contributing to Net Zero and energy security.

### Economic Growth

Projects across the UK could generate over £8bn in economic benefit to the Scottish economy by 2050, with the potential for this value to increase via exports.

### Just Transition

These deployments could contribute over 15,000 jobs in 2050, with high-value jobs located in coastal communities around Scotland..

## An end to business as usual

The benefits highlighted within this report are **not indicative of a business-as-usual approach to technology development and deployment. Significant effort, financial support and policy interventions will be essential** to achieve any of the scenarios outlined in this report. Without taking **urgent and targeted steps**, there is the real possibility that the socioeconomic benefits associated with the tidal stream and wave energy sectors could be led by, or even lost to, overseas competition.

To ensure that Scotland secures these socioeconomic benefits, it is essential that national government, enterprise agencies, device developers and the supply chain are able to access and utilise an appropriate balance of coordinated policy support and long-term public and private finance. This is essential to ensure that **Scottish tidal stream and wave energy device developers continue to develop innovative and cost-competitive technologies**, both in Scotland and across the globe.

# Targeted recommendations to enable the tidal stream and wave energy sectors

**Delivering policy recommendations with the capability to progress both the tidal stream and wave energy sectors is a complex and urgent task.** Tidal stream projects are being built now, with the first phases to be commissioned in 2026/27, and a growing pipeline beyond. To ensure that Scotland is ready for these deployments, and for future wave energy capacity, decisions must be made now to account for both the unique and overlapping development challenges and deployment timelines facing each sector.

Policymakers should consider three equally important and interconnected areas to promote sector progression at a device and supply chain level:

- Discussions with both UK and devolved governments around the continuation and growth of comprehensive market pull policies.
- Enabling sustained sources of both public and private innovation funding for technology developers.
- Delivering a step-change in the capabilities of a modernised and highly competitive supply chain.


## 1. Long-term market support

Continuation and expansion of a **well-funded UK market support mechanism**, such as the CfD, is the foundational step to **ensuring a market for Scottish tidal stream** developers to supply and deploy their devices. It also provides a **potential long-term funding source for the wave energy sector.**

This should be coupled with a **highly visible future deployment ambition for both technologies**, which will bolster the growth of the domestic market, provide clarity over supply chain requirements and increase investor confidence.

## 2. Sustained technology innovation

**Targeted and sustained research and innovation support for both tidal stream and wave energy technology developers is essential.** This will ensure that Scotland builds upon and maintains the competitive edge that it has already established in these sectors.

This focused support is vital to ensure that **Scottish companies continue to innovate, reduce costs, win projects, and deploy their devices** in both domestic and international markets.

## 3. Increase supply chain competitiveness

**Modernisation of Scottish supply chain capabilities** should be **implemented at all levels** to support the imminent pipeline of tidal stream and future wave energy projects.

In areas where **Scotland already possesses a world-leading status** or is **matching the competitive performance of other nations**, policy and financial support should aim to **nurture, strengthen and maintain this position.**

For areas with **no clear market leader**, Scotland should position itself to maximise investments into supply chain sophistication and capabilities, with an aim to **seize these all-to-play-for markets.**

# Underpinning recommendations to develop sector infrastructure

As part of the considerations being made for the wider energy transition in Scotland, important decisions must be taken now to ensure that suitable underpinning infrastructure is in place for the tidal stream and wave energy sectors to continue their rapid development. The needs and benefits of these emerging technologies should be considered alongside those of other energy sectors.

This will include:

- Soft infrastructures, such as preparing a pipeline of workers with relevant skills and training.
- Identification of opportunities to collaborate with energy sectors already established within Scotland.
- The build out of hard infrastructure, such as ports, harbours, and national grid capabilities.


## 4. Develop skills for a Just Transition

Investment into device innovation and supply chain capability should be coupled with an **equal investment into domestic workforce capacity and skills.**

This should not solely target higher education graduates from a STEM background, who are an important consideration of any future skilled workforce. It should also consider apprenticeships and existing workers transitioning from the oil & gas and other relevant sectors, who often have transferable skillsets and exposure to the challenges of working in a marine environment.

## 5. Cross-sector collaboration

The maturity of the offshore wind sector, in terms of fabrication facilities and supply chain depth, should serve as both an inspiring template and **a serious opportunity for collaboration with the tidal stream and wave energy sectors.**

**Active collaboration between tidal stream and wave energy developers and their supply chain**, where competition allows, could also lead to the **creation of innovation clusters.**

## 6. Prioritise infrastructure upgrades

**Significant grid upgrades will be required alongside the continued development of renewable energy in Scotland,** to avoid transmission bottlenecks and potential curtailment of renewable output.

**These planned upgrades must factor in the requirements, and potential energy system benefits of tidal stream and wave energy.**

**Port and harbour infrastructure upgrades** across the country, currently being planned for offshore wind, should also factor in the additional requirements from the growing pipeline of tidal stream projects and potential for wave energy.

## Delivery of recommendations

The goals of sustained development of highly innovative tidal stream and wave energy devices and the modernisation and enhancement of domestic supply chain capabilities are a complex task that will require well-structured and coordinated delivery. Scotland should utilise the extensive experience of the well-established enterprise and focused innovation support organisations. They have already demonstrated multiple successful instances of managing the delivery of innovative technologies and devices, both in the tidal stream and wave energy sectors and their underpinning supply chains.

### 7. Delivering innovation support in Scotland

Tasking and funding **existing innovation and support organisations** to oversee the **well-coordinated and accelerated delivery** of recommendations, in particular innovations in tidal stream and wave energy device development, and improvements in Scottish supply chain capabilities. This will help to ensure that **Scotland maintains its position as a world leader in the delivery of tidal stream and wave energy projects** with high Scottish supply chain content.

# Closing message

Scotland is one of the leading nations driving progress of the tidal stream and wave energy sectors. As such, it is well positioned to accelerate the development and deployment, both domestic and exports, of tidal stream turbines and wave energy converters. In doing so, it can seize the significant socioeconomic benefit, in terms of GVA and jobs, associated with their manufacture and operation. This outcome presents Scotland with a significant opportunity to leverage home-grown technology sectors into the advancement of Net Zero, Just Transition, energy security and economic growth.

Achieving these outcomes will require significant shared responsibilities across the entirety of the supply chain, from technology developers and commercial manufacturers to the organisations and government departments tasked with overseeing sector delivery. Without providing significant coordinated investment and guided policy support to Scottish technology developers, accompanied by strategic investment into high-value areas of the domestic supply chain, there is a clear danger that Scotland's lead will be eroded. This could ultimately result in tidal stream and wave energy sectors overseas overtaking Scotland's present advantage, as has happened in other energy sectors. This situation must be avoided if Scotland wishes to capitalise on GVA and jobs figures outlined within this report.

Scotland has come far in the last decade, leading the transformation of an emerging technology into sectors that stand on the brink of large-scale commercialisation. It is therefore vital that in the coming years Scotland maintains this position. In doing so it can establish a reputation as the premier location for the tidal stream and wave energy sectors to develop, build, deploy and maintain their devices, utilising sector-leading innovation capabilities, a highly skilled workforce and a robust Scottish supply chain.

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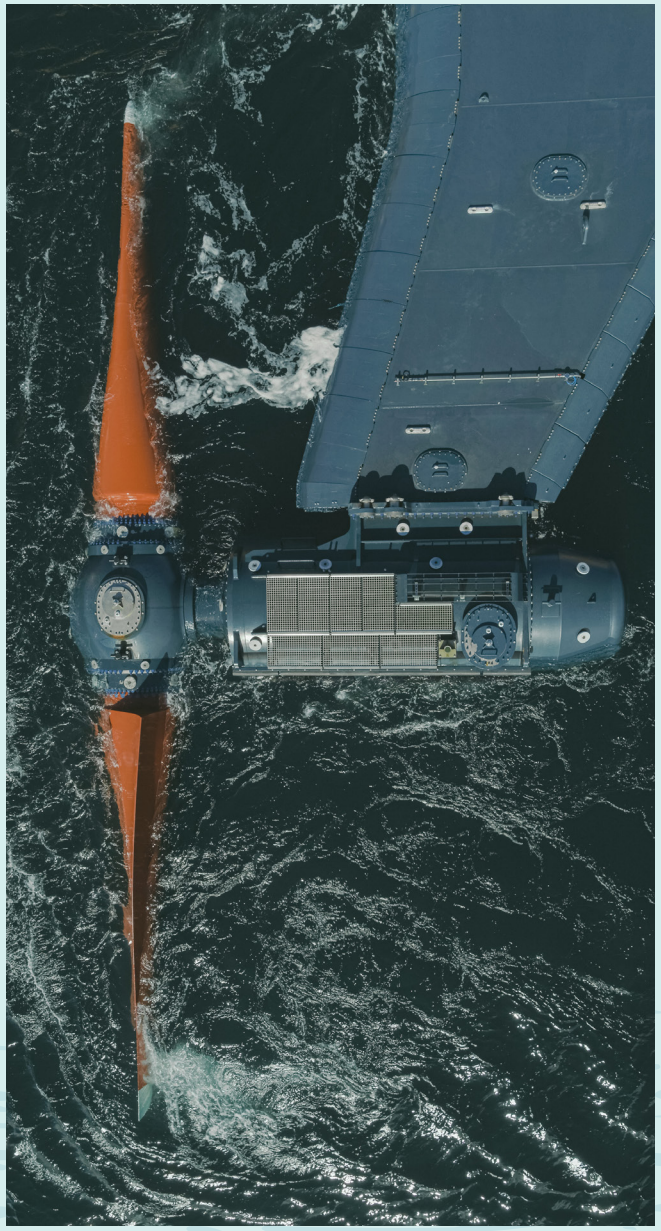

Orbital O2 turbine blade at EMEC (Credit: Orbital Marine Power)


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