# Economic Review of Tidal Stream Energy in Scotland

A report to Scottish Enterprise prepared by
the Policy and Innovation Group
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# Executive summary

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

A commercially successful domestic tidal stream sector has the potential to provide a meaningful contribution to Net Zero, 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 (with these projects set to be delivered 2026–2029). A competitive Scottish supply chain, capable of producing tidal stream devices and key subsystems at volume, is needed now. This supply chain investment, coupled with ongoing and expanded market support for tidal stream, is essential to ensure that Scotland capitalises on its position as a pioneer of this technology.

If Scotland is successful in achieving device commercialisation at an array scale, there could be a potential market for almost 4.3 GW of tidal stream in Scotland by 2050, feeding into potential deployments of 6.2 GW in the UK and 120 GW across the globe in the same timescale. Projects in the UK could generate over £4.5bn in economic benefit to the Scottish economy by 2050, and support over 5,800 high-value jobs in 2050, with significant additional potential from exports.

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 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 sector, this report provides policy recommendations focused on the following areas.

Firstly, targeted recommendations to support both tidal stream device developers and their supply chains, focusing on the need for:

- 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, so Scotland can build upon and maintains its competitive edge in these sectors.
- Delivering a step-change in the capabilities of a modernised and highly competitive supply chain.

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

- Development of soft infrastructures, such as preparing a pipeline of workers with relevant skills and training. This may include those transitioning from the oil and gas sector.
- Opportunities to collaborate with, and share, the supply chain and infrastructures of other established offshore sectors, including offshore wind.
- The build out of hard infrastructure, such as ports, harbours, and national grid capabilities.

Lastly, 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 devices and farms.

## Economic Review of Tidal Stream Energy in Scotland

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Results and recommendations presented here are a from a study conducted by the Policy & Innovation Group at the University of Edinburgh for Scottish Enterprise.

## 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

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# Contents

# 1 Introduction

Scotland is at the global forefront of the development and deployment of tidal stream energy, and there is significant resource around Scotland's coast. The sector is rapidly moving towards building commercial projects and it could form the basis of a significant market in Scotland. Tidal stream is a technology that offers the potential to deliver significant socio-economic benefits to Scotland. It has the future capability to drive the advancement of domestic goals and ambitions relating to Net Zero, the Just Transition, energy security and economic growth. These potential socio-economic benefits come both from developing the technology and from building devices and projects. This includes considerable export potential. As seen in other renewable technologies, there is the potential for rapid growth in deployment with corresponding cost reductions. As a source of predictable renewable energy, tidal stream also offers additional benefits to the electricity system, outlined in section 2.4.

Tidal stream is still an emerging technology; however, it is expected to grow significantly over the coming years. Currently there is just 12.6 MW of operational tidal stream turbines globally [1], with 9.8 MW of that in Scotland. There is now a pipeline of projects supported by Contracts for Difference (CfD) to install 122 MW of tidal stream in the UK by 2029, of which 84 MW is in Scotland. Further projects are being developed, with lease options awarded to several developers by Crown Estate Scotland, plus innovation funding for pilot farms from Horizon Europe.

Previous studies have quantified the economic benefits of offshore renewable energy, including tidal stream, wave energy, and floating offshore wind, at an international, European and UK level. However, there have been no recent studies focused on the benefits of tidal stream in Scotland. As discussed in section 2.4, other studies have also outlined wider power systems benefits from including tidal stream within the installed generation capacity.

These all support the case for pursuing the development of the tidal stream sector. Therefore, this study aims to quantify the potential benefits of tidal stream energy to Scotland, in terms of gross value added (GVA) and jobs supported. It also considers the supply chain competitiveness and volume capability required to realise these benefits.

## 1.1 Scotland leading the development of tidal stream energy

Since 2010, there has been a cumulative total of just over 40 MW of tidal stream devices deployed and tested globally [2], around 20 MW of this has been in Scotland. Much of this has been supported by public sector, including the Scottish Government, Scottish Enterprise and Highlands and Islands Enterprise, or through the European Union's Horizon programmes.

The European Marine Energy Centre (EMEC) was established in Orkney in 2003 to help develop the ocean energy industry. It provides pre-consented test berths for testing wave and tidal stream energy devices, and the first tidal power was provided to the GB grid in 2008 from the EMEC Fall of Warness tidal test site. To date, 24 tidal devices from 12 developers have been tested at EMEC, with some of these companies coming from overseas. This includes Spanish developer Magallanes Renovables, which has tested their floating ATIR turbine at EMEC since 2019 and has been awarded CfD to deploy a further three turbines there, plus others at the Morlais tidal stream energy project in Wales.

Around **half of tidal stream devices deployed and tested globally have been in Scotland**, with 12 companies having tested 24 tidal stream devices at EMEC in Orkney since 2006

Edinburgh-based Nova Innovation installed the first grid connected tidal stream array in the Bluemull Sound, Shetland, with two turbines installed during 2016, and expanded to six turbines by 2023. The initial three turbines have since been decommissioned as part of the ongoing development of the technology. Nova is now developing the 16-turbine SEASTAR array, to be built at EMEC with funding support from Horizon Europe and the UK Government's Contracts for Difference (CfD) scheme.

The MeyGen project in the Pentland Firth near John o' Groats, was developed by Atlantis Resources, now SAE. It is the world's largest tidal stream farm with 6 MW operating since 2017, and the next phases will see a further 59 MW installed by 2029 supported by the CfD. A total capacity of 86 MW is already consented, with a further 312 MW expansion subject to consents.

The third-generation Orbital Marine Power turbine, the O2, was constructed and launched in Dundee in 2021, and has been operating at the EMEC Fall of Warness site since. The floating device with two sets of rotors has a total rated power of 2.0 MW, making it the largest tidal stream device built to date. Orbital has also been awarded CfD for six next-generation O2-X turbines to be deployed at EMEC, including four in the Horizon Europe EURO-TIDES project.

Scotland's universities also continue to be at the forefront of tidal energy research and development. This includes theoretical research, numerical modelling, plus physical testing at FastBlade, the FloWave Ocean Energy Research Facility, Kelvin Hydrodynamics Laboratory, and other facilities.

Globally, several countries are developing and deploying tidal stream technology. There are tidal stream projects operational or under construction in Canada, China, the Faroe Islands, France, Japan, Korea, the Netherlands, and the UK. Other countries developing technology and projects include Australia, Ireland, Italy, New Zealand, Singapore, Spain, Sweden, and the US [1]. There is also significant interest in other countries such as Chile, India, and Indonesia. Timely action and investment are therefore important to maintain the competitive advantage Scotland has as a leading country in the development and demonstration of tidal stream energy.

## 1.2 Motivation and previous work quantifying the benefits of tidal stream

Previous studies have quantified the benefits of offshore renewable energy, either at an international, European or UK level. However, there are not any up-to-date studies that focus specifically on the benefits of tidal stream energy to the Scottish economy. Previous studies mostly quantify economic benefits in terms of gross value added (GVA) to the economy from producing and deploying these technologies, with some also including the number of jobs supported.

The 2023 IEA-OES vision for ocean energy [3] includes high-level estimates of $340bn in GVA and 680,000 jobs by 2050 from deploying 300 GW of wave and tidal stream energy. At a European level, in 2021 the European Technology & Innovation Platform for Ocean Energy (ETIP Ocean) published a study on the potential economic value of wave and tidal in Europe to 2050 [4]. A range of scenarios were presented, which showed the net economic benefit of deploying tidal stream could be up to €78bn.

For the UK, the Offshore Renewable Energy Catapult (OREC) published a study in 2018 quantifying the cost reduction and industrial benefit for tidal stream and wave energy [5]. More recently, in 2021 the Policy and Innovation Group at the University of Edinburgh quantified the value of innovative offshore renewable energy to the UK economy [6]. A 2024 update to this work [7] suggests the GVA to the UK economy by 2050 from tidal stream could be £5.8bn. A parallel study to this report is investigating the economic benefits of wave energy in Scotland [8].

In addition to the potential economic benefits, other recent studies have quantified a range of power systems benefits of incorporating ocean energy (including tidal stream) into a diverse future renewable energy mix [9–11]. These wider benefits arise from the ocean energy resource being available at different times to other renewable energy technologies; tidal stream specifically is predictable and decoupled from other sources.

This report aims to quantify the potential benefits to the Scottish economy of electricity generation from tidal stream. These benefits come from both deploying tidal stream projects in Scotland and the UK as well as from global exports. This is quantified in terms of gross value added (GVA) and full-time equivalent (FTE) jobs. There are also other wider benefits of tidal stream, as a source of predicable renewable energy as discussed in section 2.4. The economic benefit assessment methodology used is set out in section 2.6, followed by the results in section 4. Section 5 then gives an overview of the Scottish tidal supply chain and presents a competitiveness review of key subsystems. The report concludes in section 6 with a summary and recommendations.

# 2 Background on tidal stream, resource, deployment and the supply chain

This study focuses on tidal stream energy, as this sector is rapidly moving towards commercial projects and could form the basis of a significant market in Scotland. As highlighted above, Scotland is at the forefront of tidal stream development globally, with considerable testing and demonstration over the past decade. Several commercial projects have been awarded funding through the Contracts for Difference (CfD) scheme over the past three years, giving increased prominence to the sector. In response to the Scottish Government's Energy Strategy and Just Transition Plan consultation, the tidal stream sector through the UK Marine Energy Council and Scottish Renewables outlined an industry ambition of 700 MW deployed in Scotland by 2035 [12].

The UK Government's recent Clean Power 2030 Action Plan [13] focuses on the short-term goals of almost entirely decarbonising the electricity supply by 2030, as well as ensuring the country can meet the growth in electricity demand in the decades beyond. The report states:

> *"Whilst emerging renewable technologies, like floating offshore wind and tidal stream, are expected to play a limited role in the 2030 energy mix, our ability to deploy them at scale could be important to the UK's achievement of longer-term decarbonisation. ... Emerging technologies could also provide broader system benefits, including ... power generation that is uncorrelated with other energy sources, such as tidal stream. In addition, early investment in the deployment of emerging technologies ... could provide wider economic benefits and export opportunities for the UK."*

So although tidal stream may be limited by 2030, this action plan already highlights that emerging renewable technologies, including tidal stream, play a role in meeting longer-term targets, and have associated power systems benefits.

### Contracts for Difference

Starting in 2014, the CfD scheme is the UK Government's flagship program for supporting low-carbon electricity generation. It is based on top-up payments between a wholesale market reference price and a strike price, offering developers long-term price stability. CfD are awarded via competitive auctions, which has enabled notable cost reductions. Renewable energy projects often have high upfront costs and long lifetimes with low running costs, making them less attractive for traditional investment. The CfD scheme incentivises investment in these by providing project developers protection from volatile wholesale prices over a 15-year period.

To date, there have been six allocation rounds (AR) which have seen a range of renewable energy technologies bid into competitive auctions for contracts. The CfD budget for these auctions is split into different 'pots' for established and less established technologies and covers a range of technologies from biomass and geothermal to onshore wind, wave and tidal.

In AR 4, 5 and 6, tidal stream benefitted from a dedicated minimum budget in the auction, where support is ringfenced for tidal stream in the CfD auction round before the competition opens up to other renewable technologies. This resulted in contracts being awarded to seven developers across 21 different projects, delivering over 120 MW of tidal stream capacity in the UK, expected to be commissioned between 2026 and 2029.

## 2.1 Tidal stream and other forms of offshore renewable energy

There are various methods to harness energy from the seas and oceans, collectively referred to as offshore renewable energy, as summarised in Table 2.1. Although quite different technologies, and at different stages in their commercialisation, tidal stream and wave energy are often grouped together under the term ocean energy or marine energy.

Tides are a predictable movement of water around the oceans, driven by the gravitational force of the moon and to a lesser extent the sun. In most places around the UK, the tides are semi diurnal, with two high and two low tides every 24 hours 50 minutes. There is also a pattern of larger (spring) and smaller (neap) tides every lunar month. The timing of high tide also varies along the coast around the UK. These and other more complex factors lead to a varying but predictable tidal energy resource.

Most tidal stream turbines being developed at present have converged around a similar horizontal-axis design as used in windfarms. Tidal stream turbines may be fully submerged and sit on the seabed with either a gravity or piled foundation. Alternatively they may be attached to a floating platform, which is moored to the seabed. Both are widely being developed, with some designs having multiple rotors and generators mounted on a single device. Alternative concepts have been developed to harness energy from slower currents including tidal kites and Archimedean screws, but these are not as common.

*Table 2.1. Summary of offshore renewable energy technologies*

| Technology | Description |
|---|---|
| Offshore wind | The most developed offshore renewable energy technology, with commercial deployment of multi-GW windfarms. Historically, turbines have been mounted on steel monopile foundations, but with projects moving to deeper water, jacket foundations or floating platforms are being developed and installed. |
| Wave energy | Many concepts have been developed and tested to capture energy from the wind generated waves and swell that propagate across the seas. However, there is no design consensus, and no technology has yet been proven to produce significant amounts of power over multiple years of operation. Further development and demonstration of wave energy is ongoing, including significant research in Scotland. |
| Tidal range | Tidal barrages or lagoons can be used to impound the rise and fall of the tides and used to drive conventional low-head hydro-electric turbines mounted into the structures. While established technology, only a few schemes have been built worldwide, given their significant upfront costs and potential environmental impacts on estuaries. |
| Tidal stream | Tidal stream turbines can capture kinetic energy from tidal currents flowing around the coast, in a similar manner to wind turbines. As water has around 800 times the density of air, smaller diameters are used for tidal stream turbines, but the blades need to be much more robust. As they do not completely block the channel, the impact on the marine environment is not the same as tidal range. |

## 2.2 Tidal stream resource – UK & Scotland

Estimates of the tidal stream resource vary, depending on the scope of the modelling undertaken. Detailed numerical models of individual sites require significant computational resource, so less accurate models as typically run on a regional or global scale. Some resource studies present the theoretical resource, or the total energy contained in the tides. Others limit this to a practical or economic resource, considering other users of the seas and the costs to build these projects.

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 around 11% of the annual electricity demand [14]. Building on an earlier Carbon Trust study [15], this equates to about 11.5 GW of installed capacity, with around 60–70% of this resource located in Scottish waters.

The exploitable tidal stream resource is spatially concentrated around headlands and in channels between islands where the flow is fastest. A significant proportion of the Scottish tidal resource is located within the Pentland Firth and Orkney waters, although estimates for the total exploitable resource vary. An indicative geographical spread of the UK tidal stream resource is also shown in Figure 2.1.

## 2.3 Tidal stream deployment to 2050

At present there is approximately 10 MW of tidal stream turbines installed in UK, all in Scottish waters. There is now a pipeline of 122 MW of tidal stream projects supported by the CfD, to be installed in the UK over the next five years; these are shown in Figure 2.1 and summarised in Table 2.2. A total of 21 contracts were awarded in allocation rounds AR4–AR6, to be constructed by 2028/29. Almost 70% (84 MW) of this capacity is in Scotland. In addition, Scottish developers Orbital Marine Power and Nova Innovation have both been awarded Horizon Europe funding over the next five years to build and operate pilot farms at EMEC. Beyond this there is the potential for significant further growth, helping to meet the ambitious Net Zero targets in Scotland and in the UK. For context, both onshore and offshore wind expanded from 10 MW to 10 GW installed in Europe in under two decades [16].

*Table 2.2. Tidal stream projects awarded a CfD by country and delivery year*

| Delivery year | Scotland (MW) | Wales (MW) | Total (MW) |
|---|---:|---:|---:|
| 2025/26 | — | 5.6 | 5.6 |
| 2026/27 | 35.2 | 4.5 | 39.7 |
| 2027/28 | 30.6 | 27.9 | 58.5 |
| 2028/29 | 18.0 | — | 18.0 |
| Total | 83.8 | 38.0 | 121.9 |

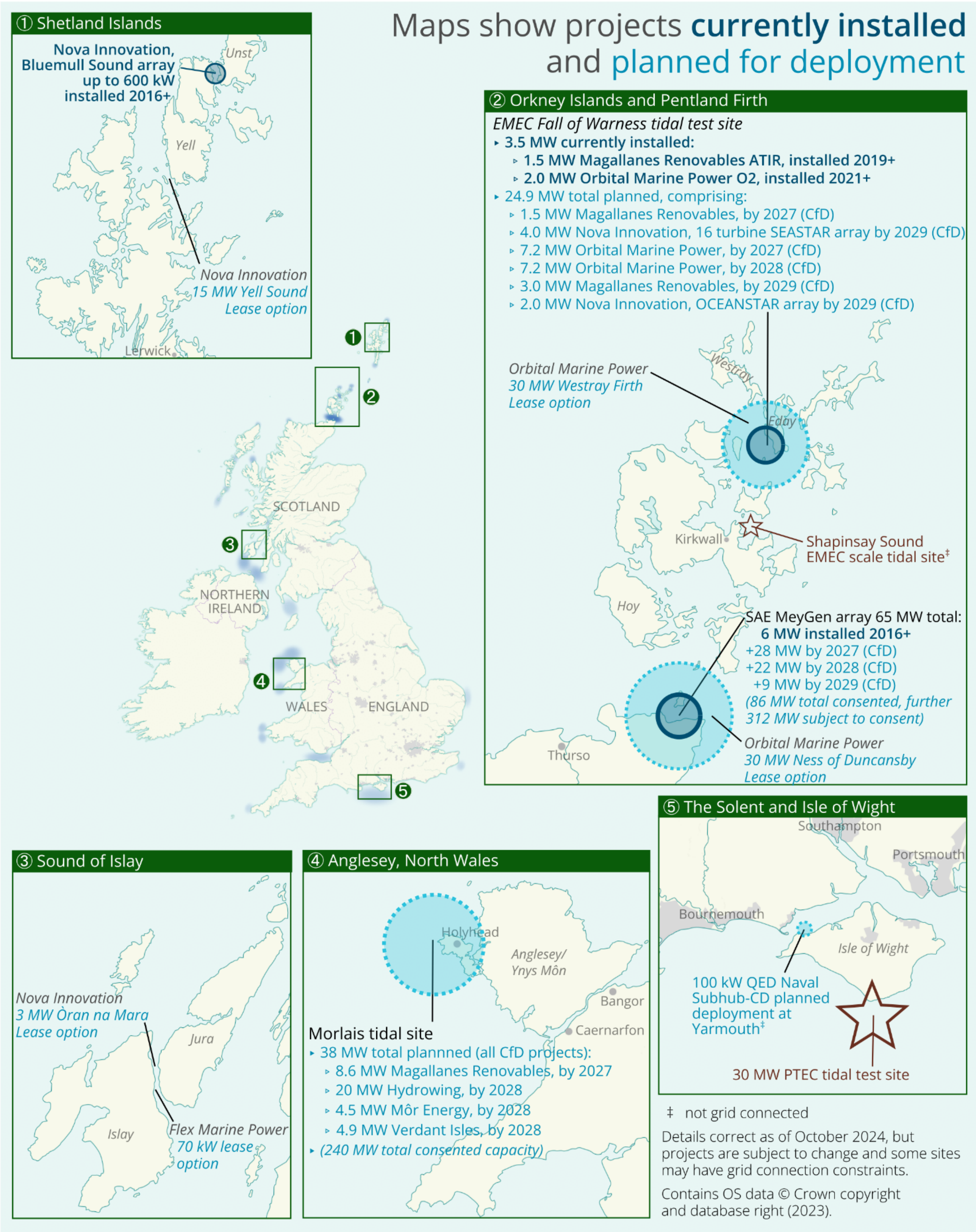



*Figure 2.1. UK tidal stream developments and indicative locations of tidal stream resource*

### 2.3.1 UK deployment

There is the potential in the UK to deploy over 6 GW of tidal stream energy by 2050, based on results of a detailed market allocation analysis of offshore renewable energy by the Energy Systems Catapult (ESC) [17]. That study focused on UK deployment of tidal stream, floating offshore wind, and wave energy. The results from an Energy Systems Modelling Environment (ESME) run by ESC are shown in Figure 2.2.

ESME is a widely used optimisation model of the whole UK energy system, obtaining lowest cost while satisfying constraints such as the provision of energy service demands in buildings, transport, and industry, all subject to $CO_2$ budgets [18]. These 2050 ESME results present a UK energy mix aligned to the Committee on Climate Change 'Further Ambition' position defined in their Net Zero technical report [19]. Within this work, it is assumed that tidal stream meets the cost reduction targets outlined in 2018 by the EU Strategic Energy Technology (SET) Plan, of 100 €/MWh by 2030 [20], with continued cost reduction beyond.

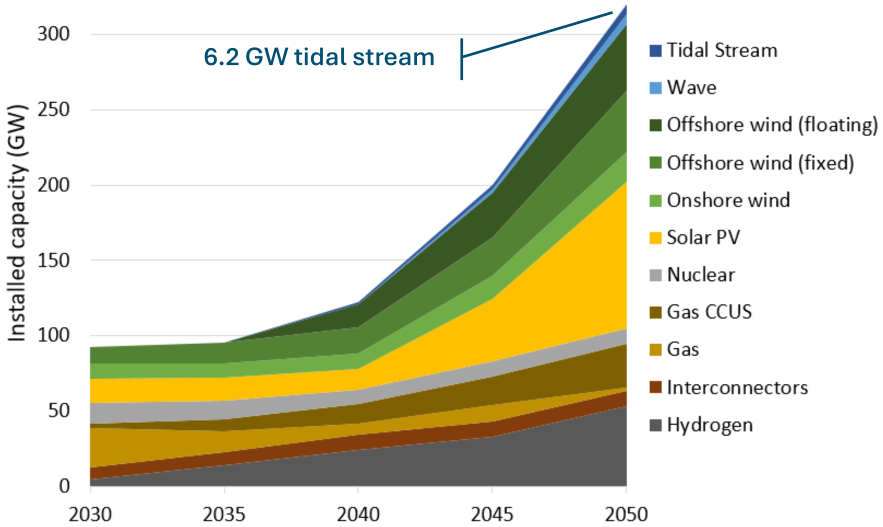



*Figure 2.2. Modelled UK energy mix to 2050 under SET Plan LCOE for wave & tidal stream [17]*

### 2.3.2 Global deployment

The global market for tidal stream energy is much larger than the domestic market, albeit with greater uncertainty and relies on deployment targets to be set by governments across the world. 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 [3]. This total comprises 120 GW of global tidal stream deployment, and 180 GW of wave energy. Modelling or estimating where this deployment will occur is outwith the scope of the present study.

There is the potential for **6.2 GW of tidal stream to be deployed in the UK by 2050**, and the IEA Ocean Energy Systems have a **roadmap to a global deployment 120 GW by 2050**

## 2.4 Wider benefits of tidal stream energy

Several recent studies have quantified a range of wider benefits of using offshore renewable energy including tidal stream within the electricity generation mix for a country or local grid.

Firstly, ocean energy offers an additional source of domestic renewable energy to help meet energy security, decarbonisation and Net Zero targets. It can also contribute to both Scotland and the UK being net exporters of electricity. As outlined above, there is a tidal stream resource of over 7 GW in Scotland, with potential deployment by 2050 of 4.3 GW. This is relatively small, but not insignificant compared to the projected 43 GW of offshore wind or nearly 9 GW of solar expected in Scotland by 2050 in the National Energy System Operator's Holistic Transition scenario in the latest Future Energy Systems report [21, fig. ES.C].

There are also power system benefits, which result from the timing of the resource being offset from both wind and solar [10,11,22–25]. The tides are entirely predictable years in advance, and their cyclic nature with typically four periods of generation per day is well matched with short-term battery storage to provide continuous renewable energy [23].

Power systems modelling within the EVOLVE project considered including 1 GW of tidal stream within the future generation capacity mix for the GB grid in 2030, while keeping the total renewable generation availability constant. This showed that the total renewable energy dispatch increased, while the fossil fuel dispatch reduced with associated $CO_2$ savings of 80,000 tonnes. Incorporating 1 GW of tidal stream generation reduced the average marginal price over the year by 0.8%, leading to potential annual cost savings to the consumer of £100 million [22].

Finally, there are economic benefits, both in terms of value added by the supply chain and the jobs supported. Previous studies quantifying this are covered in section 1.2, and the benefits to Scotland are explored further in this study. Given the geographical distribution of the tidal stream resource, a significant fraction of these will be skilled jobs in coastal communities and around the Highlands and Islands.

## 2.5 Tidal stream supply chain overview

Tidal stream energy remains a young industry, with the majority of technology developers and their devices still in the early stages of commercial deployment. As such, the supply chain that underpins the tidal stream sector requires tailored policy support to ensure it evolves to meet this ambition. The pipeline of UK projects supported by the CfD has increased market confidence and has solidified the future demand for a more comprehensive and more robust tidal stream supply chain. However, in satisfying this demand, great care must be taken to ensure that the associated GVA and socio-economic benefits that will accompany any supply chain development are retained in Scotland. This can be accomplished in a number of ways:

- By sustainably growing the Scottish tidal stream supply chain to accelerate and de-risk the delivery of tidal stream projects.
- Identifying key innovation areas for subsystem development through which the competitive performance of Scotland's supply chain can be increased.
- Growing the domestic market, with a focus on pipeline projects in the short-to-medium term.

- Identifying potential international export opportunities, both technologically and skills based.
- Identifying synergistic overlaps with the development and deployment of complementary technologies such as the wind and wave energy sectors.

Achieving these aims is essential to ensuring that the GVA and socio-economic benefits outlined in the later sections of this report are unlocked and their value re-invested into Scottish companies, organisations and communities. Currently, the Scottish tidal stream supply chain has been used to fulfilling the order requirements of a small number of devices from a limited pool of developers. Given the expected increase in demand for tidal stream energy in the coming years, it is vital that Scotland not only increases its ability to competitively manufacture the various subsystems required, but also begins preparations for the sector to scale production to meet the volumes and capacity expected. This foresight will help to ensure that Scottish developers not only continue to win funding, CfD awards and fulfil international contracts, but that these successful developers maintain a high level of Scottish content within their individual supply chains.

The challenges faced by the Scottish supply chain, such as access to funding, availability of skilled workers, innovation of materials and components, and build-out of supporting infrastructure, impact both technology developers and commercial manufacturers alike. However, the policy mechanisms that are required to respond to these challenges and increase competitiveness across the entirety of the supply chain are very different. For example, the policy support required for a technology developer investigating the use of novel composite materials for turbine blades will not be the same as that that is required for composite manufacturers to incorporate their findings into their manufacturing process, even though they are both contributing to increasing the competitive performance of the sustainable energy technology sector. Therefore, gaining a better understanding of the current state-of-the-art within the Scottish supply chain, and how this compares to its industrial competitors, is a vital step towards improving competitiveness and scalability of production across the entirety of the supply chain.

## 2.6 Infrastructure to support tidal stream energy

In addition to a strong supply chain, suitable infrastructure will be needed to support the deployment of tidal stream energy in Scotland. Key requirements will be ports and harbours to support both the deployment and operation, plus the electricity transmission grid to deliver the power to where it is needed. There is a significant overlap with the significant planned deployment of offshore wind, including floating turbines, around Scotland. There is also the potential, although less certain, for significant wave energy deployment off the northern and western coasts of Scotland. Although the requirements for tidal stream and wave energy projects will differ from those of offshore wind, and the scale for tidal will be significantly smaller, all these technologies need to be considered in aggregate when planning these large-scale infrastructure projects.

Incorporating future tidal stream energy into infrastructure planning requires visibility of the likely locations for the construction of tidal farms. As noted in section 2.2, the location of tidal resource is well understood, with much of the Scottish resource in the Pentland Firth and Orkney waters. Tidal stream is already considered within Scotland's National Marine Plan [26].

### 2.6.1 Ports & harbours

The UK and Scottish Governments announced in January 2023 that two sites in Scotland were to be given Green Freeport status:

- Inverness and Cromarty Firth Green Freeport: the ports of Inverness, Invergordon and Nigg.
- Forth Green Freeport: Leith, Rosyth, and Grangemouth docks plus Edinburgh Airport.

These special economic zones enable tax incentives and lower tariffs within the defined boundary, for example importing, manufacturing, and exporting goods without being subject to the usual paperwork and import taxes. They are designed to create more high-quality jobs and boost economic output of these regions, as well as attracting other investment including unlocking private funding. The freeports in Scotland are termed green freeports, as they should promote decarbonisation, contribute to the energy transition and Scotland's 2045 Net Zero target. They also aim to become hubs for global trade, and foster innovation.

In addition to the green freeports, investment will be needed at a range of ports and harbours around Scotland to build and operate tidal stream farms. A recent study into the infrastructural and industrial production requirements for ocean energy in Europe showed that, if tidal stream and wave energy follow a similar deployment trajectory to wind, there will be significant infrastructure requirements over the coming decades, and that planning for this would need to start now [27].

That study estimated ocean energy may only need around 1% of the port space needed for offshore wind projects in the early 2030s; however, by the end of the decade this could grow to around 13% [27]. Given that port infrastructure projects can take a decade or more to develop, it is important to start considering the potential requirements for tidal stream and wave energy projects alongside those for offshore wind.

Tidal stream turbines are significantly smaller than offshore wind turbines. They also do not need the unlimited air clearance requirements required for floating wind turbines. Similarly, individual projects are likely to be smaller in scale for tidal, tens to hundreds of MW versus around the GW scale for offshore wind. These two factors combined means that smaller or more constrained ports may be suitable for tidal stream projects, even if they are not suitable for the continued expansion of offshore wind.

A port used to build out tidal stream projects of 10–50 MW annually may only require 0.7–6 ha of quayside laydown space, 50–200 m quayside length, water depth of 3–10 m, and clearance of 10–50 m, although this will be dependent on the type of technology used and vessels used to deploy [27].

### 2.6.2 Electricity grid

The National Energy System Operator (NESO) is responsible for the National Grid in Great Britain [i]. This covers both planning future upgrades at a country-wide level and operating the grid, balancing supply to demand at all times. The high-voltage transmission in Scotland is owned and operated by Scottish and Southern Electricity Networks (SSEN) in the north, and by ScottishPower Transmission in the south. A series of Distribution Network Operators manage the lower voltage supply.

[i] There is a separate grid for covering the whole island of Ireland, which is interconnected to the GB grid.

Currently, Scotland is a net exporter of electricity, and this is projected to increase with the continued expansion of all forms of renewable generation. This leads to major grid constraints relating to power flow from north to south. The current peak electricity demand in Scotland is about 4 GW and this is projected to increase to about 6 GW by 2030, and the corresponding generation capacity is presently 17.8 GW rising to approximately 43 GW [28], much of this from offshore wind.

The latest Electricity Ten Year Statement (ETYS2023) [28] highlights that network reinforcement will be required on most of the boundaries used to define critical parts of the transmission system, and plans are in place for some of these. SSEN are planning a transmission network reinforcement to connect Orkney via a new HVAC link, capable of connecting 220 MW, due to be commissioned in 2028. They have also started consultation on a second HVDC link to Shetland with a planned capacity of 1.8 GW, three times that of the first link completed in August 2024.

Further grid upgrades will be required to support the development of increased renewable generation in Scotland, particularly offshore wind including the ScotWind projects. NESO undertook a Holistic Network Design of the grid infrastructure to connect 23 GW of offshore wind in the UK and facilitate the Government's ambition for 50 GW of offshore wind by 2030 [29].

The increased potential from ocean energy, particularly tidal stream, should also be factored into these plans. Indeed, the ETYS2023 already notes "*the prospect of new marine generation resource in the Pentland Firth and Orkney waters in the longer term*", in the assessment of boundary B0 north of Beauly [28]. NESO's Beyond 2030 analysis recommends new high-capacity 400 kV circuits will be required, many of these subsea off the east coast of the UK, as well as upgrades to the onshore transmission network. The Eastern Green Link 2 is currently being constructed, a 2 GW offshore link between Peterhead, Aberdeenshire and Drax, North Yorkshire, due to be commissioned in 2029. In November 2024, Ofgem approved an additional five subsea projects, linking the UK with the rest of Europe, including another interconnector between Scotland and Northern Ireland.

As with development of ports and harbour infrastructure, consideration of all forms of renewables in forward planning for grid upgrades will be required to enable the significant future economic potential of tidal stream energy.

# 3 Economic benefit methodology and input assumptions

The main output from this work is an assessment of the future potential economic benefit of tidal stream energy to Scotland. This is quantified in terms of Gross Value Added (GVA) and Full-Time-Equivalent (FTE) jobs, considering the direct and indirect benefits, and where appropriate, also induced effects.

How the market for tidal stream energy will develop over the next decades is not clear, and therefore a series of practical assumptions have been made within the modelling. The reality will be more complex, diverse, and correspondingly more uncertain.

As shown at a high-level in Figure 3.1, the economic benefit is calculated using a set of credible input assumptions on the deployment in key markets, local content retention rates, and the technology and the breakdown of a typical project. A series of scenarios are used to explore the range of potential benefits resulting from the deployment of tidal stream energy, in terms of both GVA and FTE jobs. These are calculated using effects and multipliers from the Industry-by-Industry Input-Output (IO) tables by the Scottish Government, that represent how the different sectors of the national economy interact.

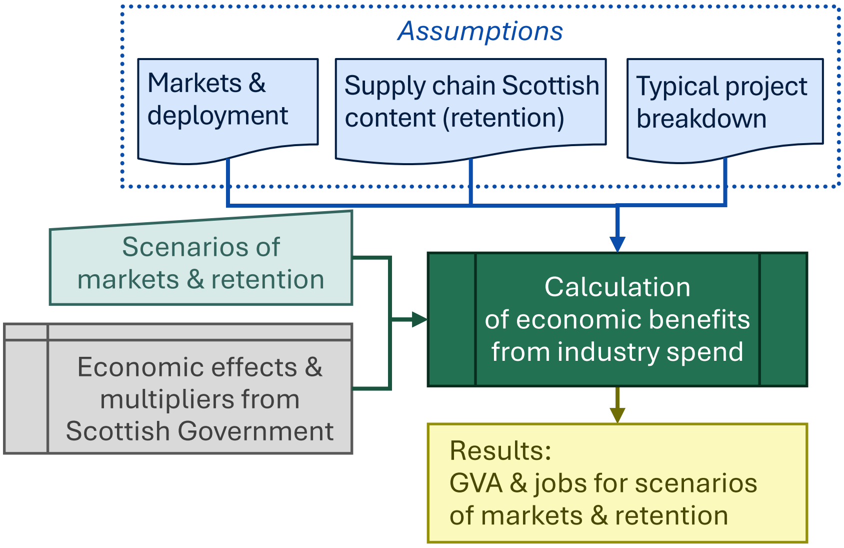



*Figure 3.1 . High-level representation of the modelling methodology*

The first step is to consider the size and deployment pathway for each of the market geographies considered. The total cost associated with the projects in aggregate is allocated to project stages and supply chain industries, with the contract value that could be won by Scottish content estimated using scenarios with differing retention rates. Finally, the associated benefit to the Scottish economy in terms of GVA and jobs is calculated.

This is discussed in more detail in the following sections:

3.1. Markets and deployment pathways to 2050.
3.2. Scenarios to illustrate the potential economic benefit.
3.3. Scottish/local content retention rates used in the analysis.
3.4. Typical project cost and industry breakdowns.
3.5. Methodology for the calculation of resulting GVA and jobs.

## 3.1 Markets and deployment pathway

Three markets are considered within this work, shown in Figure 3.2:

1. projects in Scottish waters,
2. projects in the rest of the UK, *and*,
3. the global or export market.

As covered in section 2.3.1, a deployment pathway for tidal stream technology in the whole of the UK has been modelled in line with previous work [16,17,30,31]. This reaches 1 GW around 2035 and 6.2 GW by 2050. Of this UK deployment, 70% (4.3 GW) is assumed to be in Scottish waters, based on:

- the approximate split of the UK resource in Scotland,
- the size of projects that were awarded Contracts for Difference in Allocation Rounds 4 to 6, *and*,
- the Marine Energy Council ask for a target of 1 GW of tidal stream by 2035, of which 700 MW is in Scottish waters.

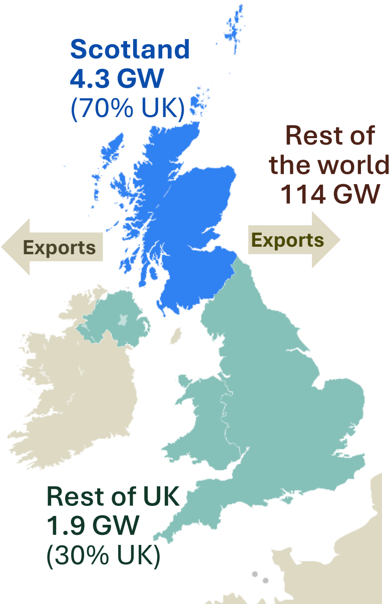


*Figure 3.2. Schematic of tidal deployment by market*

For global deployment, a pathway to 120 GW of tidal stream by 2050 has been used, consistent with the IEA-OES vision for ocean energy. 114 GW of this is in the rest of the world, outwith the UK.

In both UK and global trajectories, tidal stream deployments are expected to grow year-on-year from 2025 to 2050, although the rate of growth slows over time, as has been observed with other renewable technologies in various regions. The deployment trajectory is smoothed over time, with the implicit assumption that any supply chain and infrastructure barriers are overcome in a timely manner. The deployment of tidal stream is expected to continue beyond 2050; however, this is not included in the modelling.

While tidal stream is an emerging technology with higher levelised costs than other energy sources at present, cost reductions with increasing global deployment are expected, as have been observed for other renewable energy technologies. A central cost reduction pathway with an ambitious but achievable 15% learning rate has been used. This is consistent with previous work including the SET-Plan and what has been observed in other comparable technologies in recent decades [30]. The cost reduction trajectory is also assumed to be consistent between markets, resulting from collaboration and global supply chains.

## 3.2 Scenarios used to illustrate potential benefits

For each of the three markets in section 3.1, varying levels of Scottish developer and supply chain ambition has been considered, ranging from moderate ambition up to leaders in the field. Within this, two factors have been used to model the amount of Scottish content within tidal stream projects:

1. The percentage share of the market where Scottish companies are involved in projects.
2. Within this subset of the markets, the amount of Scottish content has been modelled using retention rates, as detailed in section 3.3.

These two factors are shown separately for transparency, but could equally be modelled using a single, lower, retention rate.

A set of eight scenarios have been used to illustrate this for the three markets, as summarised below and detailed in Table 3.1. The first four relate to the domestic (UK) market, the latter four are the export market.

- For **Scottish projects**, it is assumed there is some level of Scottish content in all projects, and thus the economic benefit is only limited by the retention rates. The proportion of local content (modelled as a retention rate) is assumed to increase over time as the supply chain develops, as discussed in section 3.3.
- For projects in the **rest of the UK**, it is assumed there are some projects which will have no Scottish content; they will be developed by a non-Scottish company, with the supply chain entirely from the rest of the UK or the rest of the world. We present scenarios where either half or one quarter of projects have no Scottish content, i.e. Scottish companies and their supply chains are active within 50% or 75% of projects in the rest of the UK. For these, similar supply chain retention rates to projects in Scotland are used.
- For the **global export market**, Scottish involvement in a market share of either 5% or 20% is assumed, with constant low or medium market retention rates.

*Table 3.1. Scenarios of market share and supply chain retention by market and ambition level*

| Market & Size | | Ambition | Projects share with some Scottish content | Scottish content within those projects (retention rate) |
|---|---|---|---|---|
| Domestic | **Scottish** (4.3 GW) | Moderate | 100% | Medium* |
| | | Leaders | 100% | High* |
| | **Rest of UK** (1.9 GW) | Moderate | 50% | Medium* |
| | | Leaders | 75% | High* |
| **Global export** (114 GW) | | Moderate | 5% | Low |
| | | | 5% | Medium |
| | | | 20% | Low |
| | | Leaders | 20% | Medium |

*retention rate reaches this over time

## 3.3 Scottish supply chain content (retention rates)

The amount of local or Scottish content in the supply chain has been modelled using retention rates[ii]. Scenarios consistent with previous sector analyses [5,6,32–35] and with the local content commitments and ambitions set out for the ScotWind leasing round in the Supply Chain Development Statement Outlook documents [36]. A set of low, medium and high retention rates have been developed for five key project cost-centres, as shown in Table 3.2. Retention rates for decommissioning vary by activity, but correspond to those used for installation, O&M and project management. The retention rates represent an average for all projects in each market, although it is acknowledged that there will be significant differences between projects in reality.

A very high level of local content has been reported for recent tidal turbine builds, over 80% in some cases [31]. 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 policy interventions in place the supply chain should develop, and retention rate may increase again over

[ii] These are sometimes referred to as a 'leakage rates', where: retention = 1 − leakage.

time for domestic projects. The modelled retention rates start at the lower rate and are assumed to increase linearly to the higher rate by 2050. For the global (export) market, a constant rate has been assumed throughout, since other countries' will also develop their own supply chains. The retention levels (low/medium/high) used for the scenarios of Scottish ambition for domestic and export markets are shown in Table 3.3.

*Table 3.2. Supply chain retention rates by cost centre for low, medium & high levels*

| Stage | Low | Medium | High |
|---|---|---|---|
| Development & Project Management (PM) | 22% | 55% | 85% |
| Device manufacture | 17% | 50% | 80% |
| Balance of Plant | 9% | 42% | 70% |
| Installation | 10% | 43% | 85% |
| Operations & Maintenance (O&M) | 17% | 50% | 85% |

*Table 3.3. Scenarios of supply chain retention levels for domestic and global markets over time*

| Market \ Scottish Ambition: | Moderate | Leaders |
|---|---|---|
| Domestic (Scotland) | Medium (increasing from Low) | High (increasing from Medium) |
| Domestic (Rest of UK) | Medium (increasing from Low) | High (increasing from Medium) |
| Global (export) | Low (constant) | Medium (constant) |

## 3.4 Typical project cost breakdown and allocation to industries

The final set of assumptions relate to the technology, including costs and allocation to supply chain industry sectors. This needs to represent a 'typical' tidal stream device and project over time, which is an unavoidable simplification. In reality, a range of projects will be developed to suit particular local constraints with various tidal stream turbines. The cost breakdown is also likely over time to change as the sector and technology develop. It is possible different elements may be more easily automated or mass produced, leading to different cost reduction trajectories.

A cost breakdown of components for a typical tidal stream project was obtained from a study by BVG Associates [37]. This has been refined using published data from the MeyGen project [38] and from Magallanes Renovables [39] as well as internal assumptions, splitting these into development, capital, operational and decommissioning expenditures (DEVEX, CAPEX, OPEX, DECEX).

Projects costs have been allocated to supply chain sectors using standard industry classification (SIC) codes, which align with those used in the IO tables. The latest UK and Scottish IO tables are split into around 100 industries, of which 18 are considered most relevant to tidal stream projects. This does not capture all aspects of the device build and project life cycle, but it aims to capture the spread of key activities. A more granular breakdown of sectors has been assumed than in previous work, with project costs split into six main cost centres using the 18 SIC codes, as shown in Table 3.4.

The project operational lifetime is assumed to be 25-years, in line with industry expectations. Installation and commissioning occur prior to this, i.e. year 0, with decommissioning in year 26. There is therefore very limited decommissioning by 2050. Construction of the device and balance of plant is assumed to take two years, with the bulk of development and project management costs occurring over five years prior to installation.

*Table 3.4. Project stages with Standard Industry Classification codes and timeline used for each*

| Stage | Share of cost | SIC codes used | Timeline years |
|---|---|---|---|
| Development & project management | 8.0% | M691, M692, M70, M71, M72, M73, M74, K65 | -4 to 0 |
| Generating device supply | 54.0% | C25, C27, C28 | -1 and 0 |
| Balance of plant supply | 19.5% | C25, C27, C28, C33, F41–43 | -1 and 0 |
| Installation | 12.0% | H49, H50, H52, C33 | 0 |
| Operations & maintenance† | 3.0%† | C27, C33, H50, K65, L68, M70 | 1 to 25 |
| Decommissioning | 6.5% | E38, H50, M70 | 26 |

*† annual O&M as a percentage of fixed costs (DEVEX + CAPEX + DECEX)*

## 3.5 Calculation of GVA and jobs

This assessment builds on existing University of Edinburgh in-house GVA models developed for analysis of technologies in Europe, the UK and Scotland [4,6,40]. The model calculates the yearly benefits, per industry and supply chain cost-centre, to Scotland and to the UK, for deployments in Scotland, rest of the UK, and global exports. As described in the previous sections, the model builds on a range of credible assumptions to represent future tidal energy projects and technologies.

An annual spend profile was developed based on the deployment and cost reduction trajectories, plus the project timeline assumptions in the previous section. This spend profile includes historical projects and extends beyond 2050 to fully capture all project expenditure. However, only costs occurring in 2024 to 2050 (inclusive) are counted in the analysis.

The GVA and FTE jobs are calculated using effects and multipliers determined from the Leontief inverse of the Industry by Industry (IxI) Input-Output (IO) tables, produced for Scotland by the Scottish Government [41]. These express the GVA and jobs which result from a given spend in each industry within Scotland. The GVA includes direct, indirect, and induced effects, while only direct and indirect jobs have been counted in this work. Direct refers to those immediately linked to the life cycle of the tidal stream projects, including Tier 1 suppliers for device manufacture and installation. Indirect then refers to the additional effects resulting from this work by companies supporting Tier 1 suppliers, while induced effects correspond to the knock-on spend within the wider economy. The jobs are quantified as FTE since many of the roles, particularly in the supply chain, will spend only part of their time on tidal energy related tasks.

As with all modelling, simplifications and assumptions are required. It is also important to consider that the IO tables are developed using many sources of data, and are a historical view of the economy, which is being used to show potential future benefit. Continuing impacts to the global economy from the COVID19 pandemic and resulting changes in working patterns are not fully captured within these.

The figures calculated only capture the benefits from the lifecycle of developing, building, operating, and eventually decommissioning tidal stream energy projects; they do not capture any additional value resulting from underpinning innovation and research nor the possible exploitation of technical know-how in wider energy markets. It is likely that companies within the wider supply chain developing technology or services for the tidal stream energy sector may also find opportunities in other sectors. It is also assumed that the supporting infrastructure to build and connect tidal stream projects is in place, as discussed in section 2.6.

# 4 Economic benefit results (GVA & jobs)

For the three markets considered: Scotland, rest of the UK, and global exports, the results are illustrated with a set of scenarios with varying levels of Scottish ambition: Moderate and Leaders, as shown in Table 4.1, and more fully described in section 3.2. Combinations of these scenarios are also presented in the results.

- In the '**Moderate**' ambition scenarios, Scottish developers and their supply chain are involved in a smaller share of export markets and have lower retention rates within those projects, as more of the supply chain is outwith Scotland.
- The '**Leaders**' scenarios have both a larger share of the markets and higher retention rates of Scottish content within projects.

While two levels of ambition are presented, the true figure could fall between or below 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 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 energy, both in the UK and the rest of the world, is predicted to grow year-on-year from 2025 to 2050.

*Table 4.1. Scenarios of market share and supply chain retention by market and ambition level*

| Market & Size | | Ambition | Projects share with some Scottish content | Scottish content within those projects (retention rate) |
|---|---|---|---|---|
| Domestic | **Scottish** (4.3 GW) | Moderate | 100% | Medium* |
| | | Leaders | 100% | High* |
| | **Rest of UK** (1.9 GW) | Moderate | 50% | Medium* |
| | | Leaders | 75% | High* |
| **Global export** (114 GW) | | Moderate | 5% | Low |
| | | | 5% | Medium |
| | | | 20% | Low |
| | | Leaders | 20% | Medium |

This is a repeat of Table 3.1 for convenience. *retention reaches this rate over time

To achieve even the moderate ambition scenarios will **require significant effort and investment across the sector**, including focused and policy interventions

## 4.1 Economic benefit in terms of GVA

Results are first presented in terms of economic benefit quantified using gross value added (GVA), including direct, indirect, and induced effects. The total GVA is calculated between now (2024) and 2050, discounted using the UK Treasury Social Time Preference Rate of 3.5%, consistent with previous studies.

### 4.1.1 Domestic scenarios: GVA from projects in Scotland and the Rest of the UK

The GVA from domestic tidal stream projects, i.e. those in Scottish waters and around the rest of the UK, is shown in Figure 4.1. In these, around 4.3 GW of tidal stream capacity is projected to be installed in Scotland by 2050, with a further 1.9 GW in the rest of the UK.

For the Moderate Scottish ambition scenario, around £1.7bn in GVA results from projects in Scotland, with a further £370m from projects in the rest of the UK, giving a total of £2.1bn.

For the Leaders scenario, this increases to almost £3.4bn from projects in Scotland plus over £1bn from projects in the rest of the UK. The higher ambition Leaders scenario has almost £4.5bn in GVA to the Scottish economy resulting from projects in Scotland and the UK. Realising this additional benefit will require significant policy interventions plus public and private investment to foster Scottish companies and their supply chains.

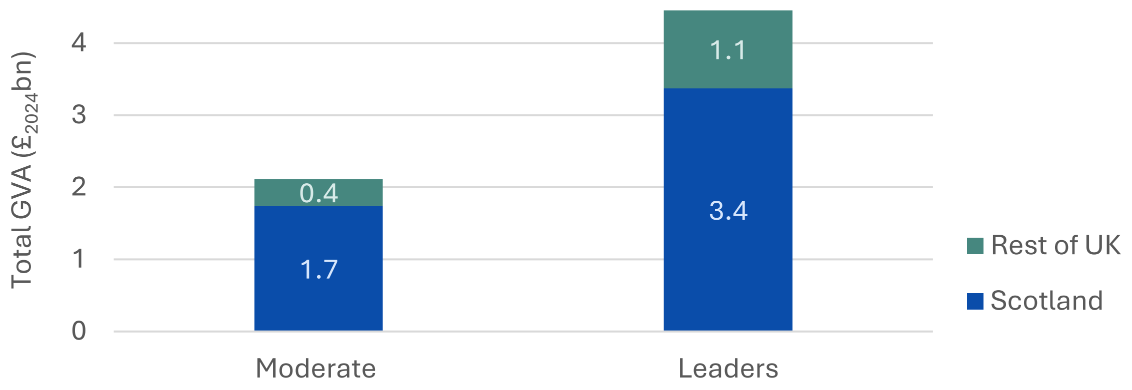



*Figure 4.1. Total discounted GVA from 2024 to 2050 by scenario for UK projects*

Tidal stream deployments in Scotland and the rest of the UK have the potential to generate **almost £4.5bn in GVA** to Scotland by 2050

### 4.1.2 Global export scenarios: GVA from overseas projects

Scenarios of Scottish market share and supply chain retention for global exports are shown in Figure 4.2, broken down by share of the 114 GW global tidal stream market that Scottish companies are involved with and by the retention rates achieved within those projects. This shows the economic benefit could range from just over £700m for the Moderate scenario of 5% of the global market with low retention rates, to almost £11.8bn for the Leaders scenario with Scottish involvement in a fifth of the global tidal stream market and medium retention rates.

It is noted that Scottish involvement in 20% of global tidal stream projects is an ambitious scenario but shows the potential scale of the market and benefits available to Scotland with the right policy intervention and support mechanisms implemented in the next few years. In 2018 Vestas had a 22% market share of wind turbines globally [42], albeit this was from manufacturing centres in multiple countries. In both cases, the supply chains would be from a range of different countries.

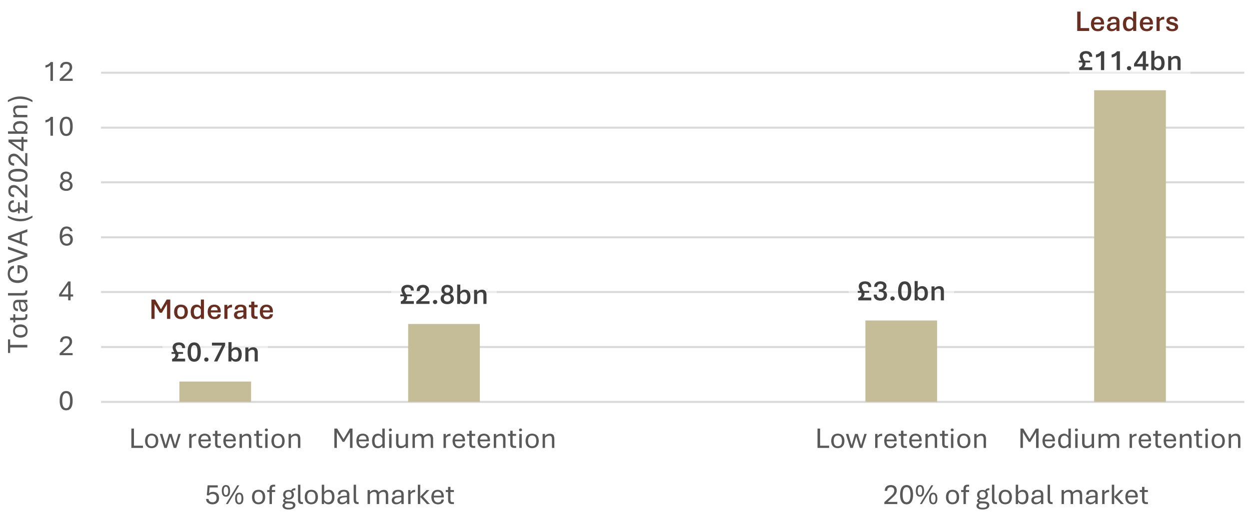



*Figure 4.2. Total discounted GVA from 2024 to 2050 for global exports by scenario of Scottish market share and supply chain retention*

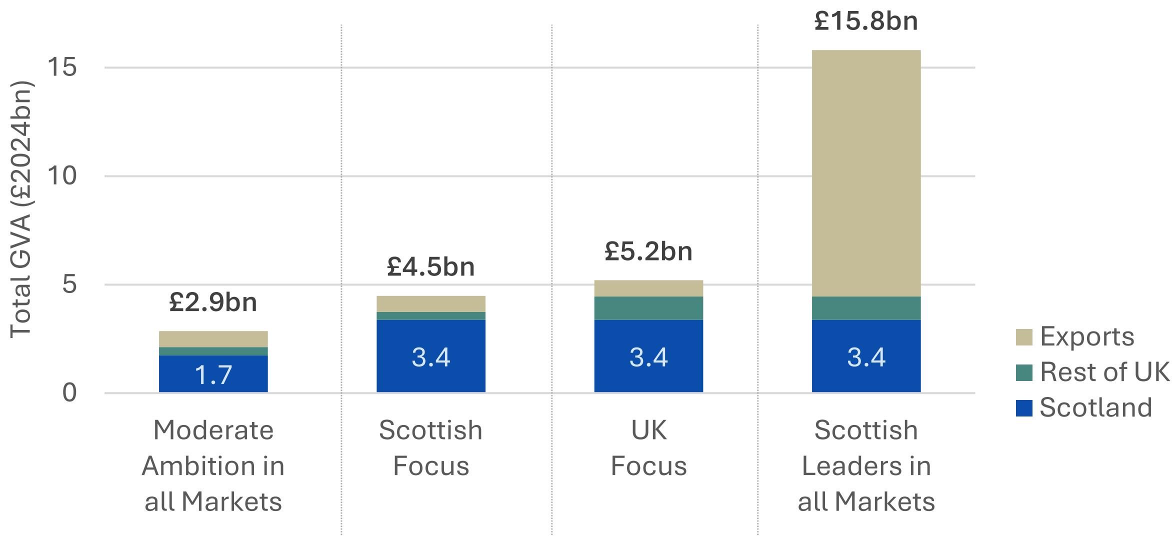
Exports of tidal stream technology could have the potential to generate **up to £11.4bn in GVA** to Scotland

### 4.1.3 Combination of domestic and global scenarios: total GVA from all markets

The total GVA from all markets is then explored using four combinations of these scenarios as follows, with results shown in Figure 4.3:

- **Moderate Ambition in all Markets** — the combined total of the Moderate scenario in the three markets, with lower retention rates and a smaller share of non-Scottish markets. This has a total GVA to Scotland of just under £2.9bn.
- **Scottish Focus** — has higher retention rates in Scottish projects, as Scottish companies are Leaders in this market, but Moderate in other markets. This has a total GVA of nearly £4.5bn.
- **UK Focus** — has higher retention rates and market share in all the UK with Scottish companies Leaders in this whole market, but still with limited global export market share and low retentions. This has a moderately higher GVA than the Scottish focus, at nearly £5.2bn.
- **Scottish Leaders in all Markets** — is the optimal scenario, with Scottish companies involved in a larger share of all markets and with higher retention rates. This could see almost £16bn in GVA generated in total.

The biggest difference within these is the global export market, and as shown previously, both market share and retention rates play a significant role in how successful Scottish companies are. The next biggest difference, is Scottish companies becoming Leaders in Scotland, adding over £1.6bn compared to the Moderate ambition in all markets. It should be noted that all these markets are significant prospects for Scottish developers and their supply chains.




| | Moderate Ambition in all Markets | Scottish Focus | UK Focus | Scottish Leaders in all Markets |
|---|---|---|---|---|
| Exports | Moderate | | | Leaders |
| Rest of UK | Moderate | | Leaders | |
| Scotland | Moderate | Leaders | | |

*Figure 4.3. Combinations of total discounted GVA from 2024 to 2050 for all three markets*

### 4.1.4 Split of GVA by project cost centre

The split of GVA by the main project cost centres is shown in Figure 4.4, for the UK focus scenario. The modelling assumptions used mean this split does not vary significantly between scenarios. 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. As the project lifetime is modelled as 25 years, and there are few deployments at present, the GVA from decommissioning is not presented but would be a growing sector post 2050.

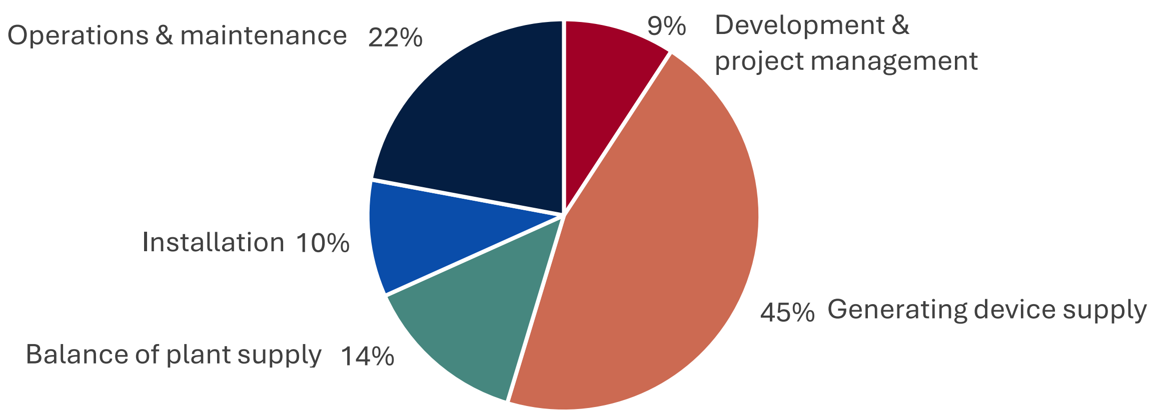



*Figure 4.4. Split of total discounted GVA from 2024 to 2050 by main cost centre*

Almost **half the gross value added** comes from **manufacturing the tidal stream device** with **operations and maintenance** accounting for **nearly a quarter**.

## 4.2 Economic benefit in terms of jobs

The results can also be quantified in terms of the number of full-time-equivalent (FTE) jobs in Scottish companies, resulting from projects in Scotland, in the rest of the UK, and from global exports. Some jobs, especially those relating to O&M, may require workers to be based near the project site rather than in Scotland, but they could still be employed by a Scottish company. Conversely, Scottish companies may be able to undertake some aspects remotely, or Scottish experts may travel overseas to the project site.

The results presented include both direct and indirect jobs, rounded to the nearest 50. They are shown for the medium term by the total number of jobs supported in 2035, and for the longer term by the total number of jobs supported in 2050. They are first shown by market and scenario and are then broken down by cost centre and industry.

### 4.2.1 Total FTE jobs in 2050

The total FTE jobs supported by the tidal stream sector in 2050 are shown in Figure 4.5, broken down by market for the four combined scenarios presented earlier.

- The **Moderate Ambition in all Markets** scenario has over 4,600 jobs; over 2,700 of these from projects in Scotland, 550 from projects in the rest of the UK, and nearly 1,350 from the global export markets.
- The **Scottish Focus** scenario has nearly 4,450 jobs from Scottish projects, bringing the total to over 6,300.
- In the **UK Focus** scenario, projects in the rest of the UK make up over 1,400 jobs, with over 7,000 FTE jobs in total for this scenario.
- Finally, the most ambitious **Scottish Leaders in all Markets** scenario could see over 16,600 jobs from the export markets. Combined with the 5,850 jobs from domestic projects, this brings the total to over 22,500 FTE jobs.

These are FTE jobs in Scottish companies, resulting from developing, building and operating tidal stream devices and 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.

Exports in the 'Scottish Leaders in all Markets' scenario represents a very significant opportunity for Scotland, with over 16,000 jobs by 2050, however this is an ambitious scenario where Scottish companies have significant input to a fifth of all tidal stream projects globally. It should also be highlighted that some of these jobs, particularly linked to the project development, installation, and O&M may be located outwith Scotland, closer to the project site.

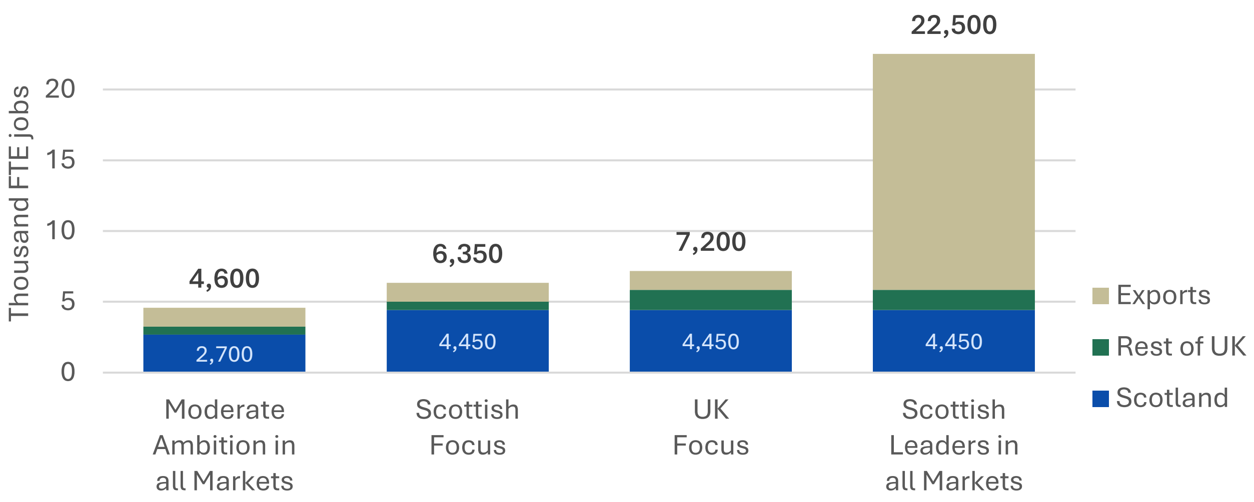



*Figure 4.5. Total FTE jobs in 2050, by market and scenario (results rounded)*

### 4.2.2 Jobs by main cost centres

The total number of jobs supported in five main cost centres are broken down in Figure 4.6, shown for the UK focus scenario in 2035 and 2050. There is a projected threefold increase in the number of FTE jobs in the tidal stream sector between 2035 and 2050, driven by the ambitious deployment trajectory to 4.3 GW in Scotland and 120 GW in the world.

The largest growth in absolute terms is the number of jobs supported by the build and supply of the generating devices, increasing from 1,200 to over 3,000. In terms of share however, it is the jobs associated with O&M, which increase from around 10% in 2035 to almost 28% in 2050, resulting from the increased number of projects in the operation phase. The relative shares between the other cost centres stays fairly constant between 2035 and 2050, as the project cost breakdown used in the analysis remains constant. Again, decommissioning jobs are not presented, however decommissioning would be a growing sector post 2050.

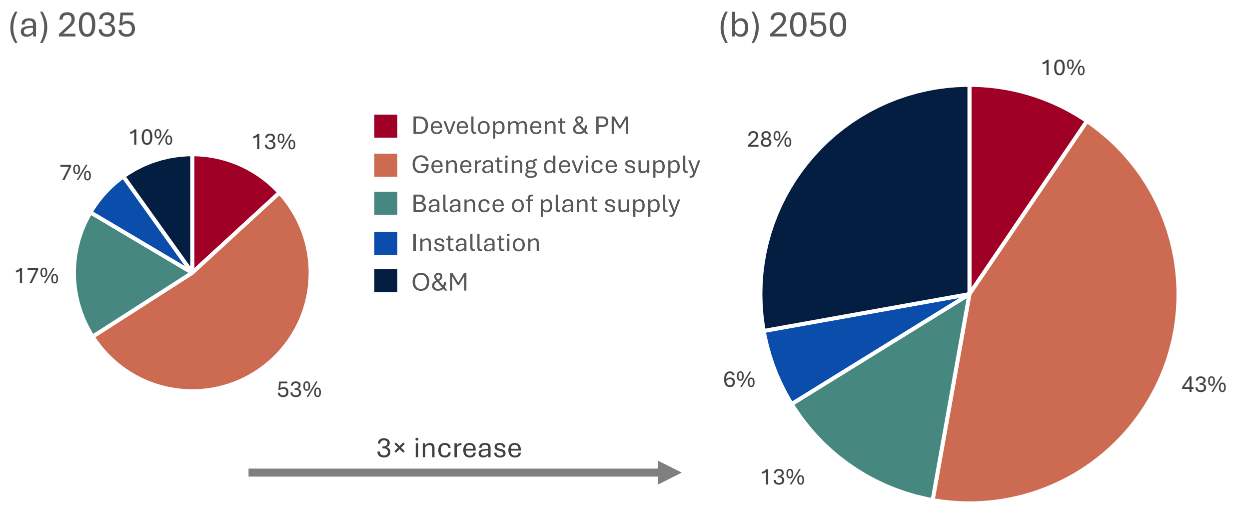



*Figure 4.6. Total FTE jobs for UK Focus in (a) 2035 and (b) 2050, split by cost centre*

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

### 4.2.3 Jobs by industry

The breakdown of direct jobs by standard industry classification (SIC) codes is shown in Figure 4.7, for the UK focus scenario. It should be noted that these are closely linked to the input assumptions in terms of the cost breakdown and allocation to SIC codes used.

Within our analysis, SIC section C (manufacturing) accounts for almost two-thirds of all direct jobs within the tidal stream sector. Unsurprisingly, half of this is the manufacture of electrical equipment, with a considerable share also allocated to the fabrication of metal products, i.e. the device hull or support structure. Most of the transportation and storage is assumed to be water transport for the installation, operation and maintenance.

It is clear there is a significant overlap with other sections of the Scottish economy, particularly the oil and gas industry. Therefore, there is the opportunity for jobs in the tidal stream sector to contribute meaningfully to the Just Transition as the sector develops.

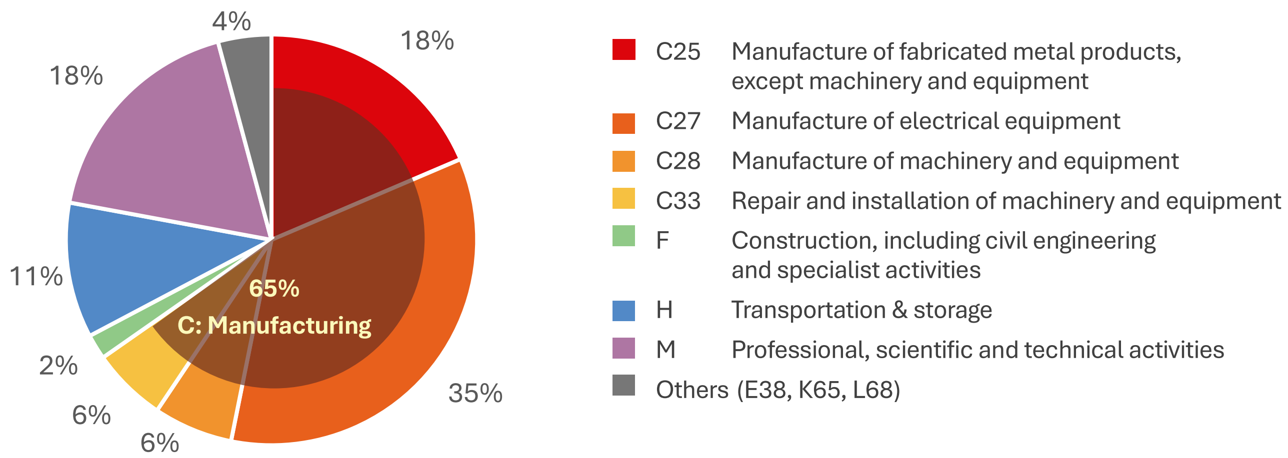



*Figure 4.7. Total direct FTE jobs in 2050 for UK focus scenario, split by industry (SIC)*

Over **two-thirds of direct jobs** are in the **manufacturing sector**, predominantly for electrical equipment and fabricated metal products.

A strong supply chain is required in Scotland to support the development, building and operation of tidal stream devices and farms, in Scotland, the rest of the UK, and for global exports. This is discussed further in section 5.

# 5 Scottish tidal stream sector supply chain overview and competitiveness review

The continued development of Scotland's supply chain is of vital importance to the realisation of the GVA and job benefits outlined in the preceding sections of this report. The year-on-year increase in the pipeline of tidal stream projects has underlined the need for rapid expansion in both the UK and Scotland's domestic supply chain capabilities. This is fundamental to ensure that as the sector continues to move beyond the deployment of single devices to the array-scale deployments associated with the fulfilment of the recently awarded CfD, there is a high level of both UK and Scottish supply chain content contributing to these successful projects. For Scottish tidal stream developers, supply chain manufacturers, and national governments, there is increasing importance to having a comprehensive and long-term strategy that ensures both continued innovation with regards to tidal stream devices, and their underpinning supply chains.

To investigate the Scottish supply opportunity and future requirements, this chapter of the report aims to analyse the supply chain actions required to support the manufacture of core tidal stream device subsystems and the provision of necessary areas of expertise. As shown in Figure 5.1, this starts with an overview of various tidal stream supply chain categories, identifying a number of common device subsystems and areas of expertise that support the tidal stream sector. Sections 5.2 and 5.3 will then introduce two separate evaluation frameworks:

1. Tidal stream supply chain classification framework
2. Tidal stream supply chain competitiveness framework

Following an overview of publicly available information on the current market leaders and state-of-the-art for each supply chain category in section 5.4, these evaluation frameworks will be used to help shape recommendations for the future development of each category.

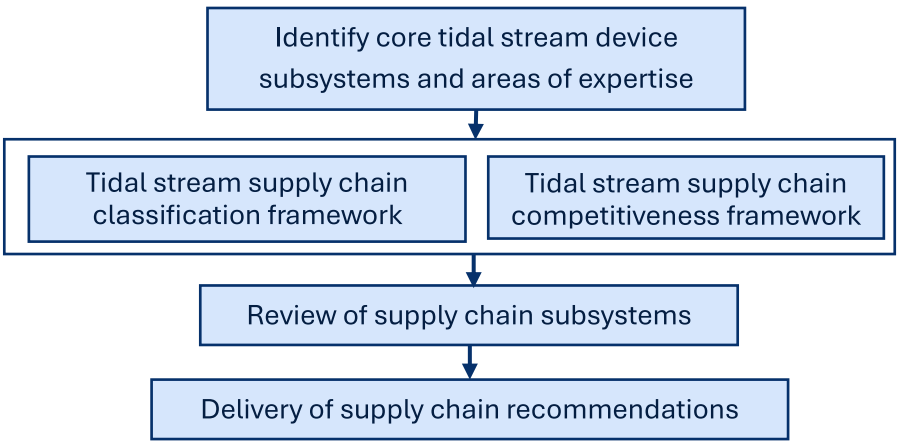



*Figure 5.1. Overview of section 5 methodology*

## 5.1 Supply chain categories for device subsystems and areas of expertise

Developing the Scottish supply chain to a level that ensures that successful tidal stream projects deployed within the UK and international markets contain a high level of Scottish content, is a non-trivial objective. Scotland enjoys a unique position as a pioneering nation in the development and deployment of much of the world's current tidal stream technology. This expertise, built up over the last two decades, has made Scotland's research and deployment facilities synonymous with the advancement of the sector.

Scotland is not the only nation actively developing a tidal stream sector. Other competing nations have also identified the benefits of tidal stream energy, both socio-economic and from an energy systems perspective. Given that there is a strong technological overlap between the tidal stream sector and other prominent sectors, such as wind turbine manufacturing, ship building, aeronautics and oil & gas industries, our competitive advantage could be eroded as the tidal stream sector moves forward into an era of global commercialisation and volume deployment. Many of these other nations also benefit from comprehensive policy programmes, well maintained innovation ecosystems, access to private capital and the materials and processes required to underpin robust supply chains. However, the Scottish tidal stream energy sector will be able to benefit from actions in response to the UK's Clean Power 2030 Action Plan [13]. This plan outlines a "*secure, sustainable, competitive and reliable supply chain"* that is delivered *"by both powering up our domestic manufacturing and ensuring access and competitiveness in international markets"* is essential to achieving this ambitious goal. This ambition stretches beyond 2030, with a sustained increase in the need for supply chain competitiveness due to continue out towards 2050.

Therefore, to ensure that Scotland achieves its aims of remaining amongst the leading nations developing tidal stream technologies and continues to deliver devices with a high-level of Scottish content, it is important to assess Scottish capabilities with regards to the development of various supply chain categories, including key device subsystems and areas of expertise. The manufacture, configuration, assembly, and deployment of tidal stream energy devices is a complex systems integration process and one that varies depending on the design of the device in question. However, in the tidal stream supply chain, there are several device subsystems and areas of expertise that are common across different tidal stream device concepts and required for overall device deployment:

**Device subsystems**

1. Device hull and sub-structure
2. Blades
3. Power take-off (generators, gearboxes and pitch systems) and power conditioning systems
4. Subsea electric cables
5. Device moorings (and foundations)

**Areas of expertise**

- Development and testing of devices
- Overall device manufacture/assembly and subsystem integration
- Project development
- Installation, operation and maintenance

These are shown in Figure 5.2 for two Scottish tidal stream devices (a) the Nova Innovation M-100D and (b) the Orbital Marine Power O2, illustrating how these different subsystems are utilised across tidal turbines with fundamentally different designs. It is important to note that while these device subsystems and areas of expertise have been identified at a high level to fit with the scope of this report, there is the potential for a large amount of variance in the technologies that underpins each of these categories. Regardless, it is essential for the Scottish tidal stream supply chain to develop the ability to competitively manufacture and supply in volume the subsystems described in the following sections.

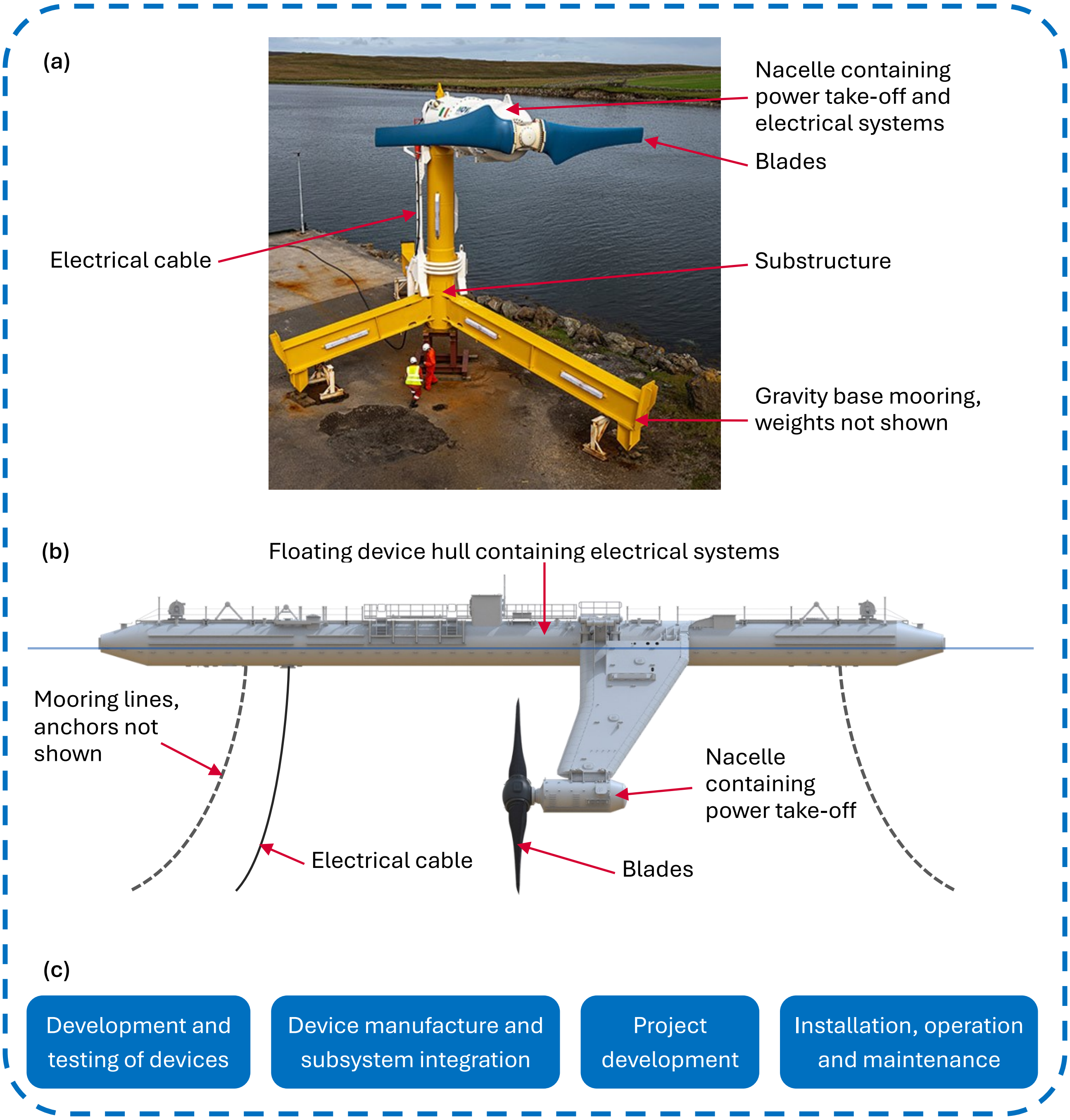



*Figure 5.2. Typical device subsystems for (a) fixed and (b) floating devices and (c) areas of expertise*

## 5.2 Supply chain classification framework

As the tidal stream sector begins to scale to meet the deployment trajectory associated with the current CfD scheme project pipeline and beyond, it will be necessary for the Scottish supply chain to evolve alongside it. However, given the range of subsystems identified in the previous section, careful thought must be given to the level of policy support offered versus the potential socio-economic impact and benefit that it will bring to the Scottish supply chain.

To help identify which of the underpinning supply chain device subsystems and areas of expertise should be prioritised as an area of focus for policy support, this section provides an overview of current state-of-the-art of the various supply chain categories in question. This will enable the opportunity provided by each supply chain category to be assessed, as defined by the four ranking classifications in Table 5.1.

Several of the supply chain categories have been identified as having the potential to move from one classification to another, depending on the level of policy and financial support provided. This has been represented by an arrow indicating the transition from one classification to another. However, even for those categories that were given a single classification, sustained support will be required to ensure that this position does not drop to a lower classification. The tidal stream sector may also stand to benefit from infrastructure and supply chain investments and clustering activities, similar to those that have previously been made into other offshore renewable energy sectors.

*Table 5.1. Outline of supply chain classification framework*

| Classification | Description |
|---|---|
| **Leading the Sector** | The Scottish supply chain already holds a high level of expertise, both in competitive manufacturing and the potential for volume production. Policy recommendations should aim to maintain and expand this position, while maximising international export opportunities. |
| **Matching the Sector** | The Scottish supply chain holds a moderate level of expertise in the manufacture of this subsystem and/or in developing this area of expertise, however other nations are at a similar level with regards to their ability to manufacture competitively and at volume. Policy recommendations should focus on providing support so that this supply chain category continues to grow at a rate consistent with the opportunity that it represents. |
| **Following the Sector** | The Scottish supply chain already faces strong international competition with regards to the competitive manufacture and volume production of this specific subsystem and/or areas of expertise. Policymakers should carefully consider the credibility of developing the supply chain for this category. |
| **All to Play For** | Currently no one country holds a world-leading position with regards to the competitive manufacture and volume production of this subsystem/area of expertise. Policy recommendations should aim to accelerate the growth of this sector in Scotland, positioning the Scottish supply chain to emerge as a world-leader. |

These four classifications are illustrated in Figure 5.3, where the vertical axis represents the current strength of Scotland's supply chain, and the horizontal axis shows both the strength of other counties (increasing towards the left) and conversely the potential opportunity for Scotland (increasing towards the right).

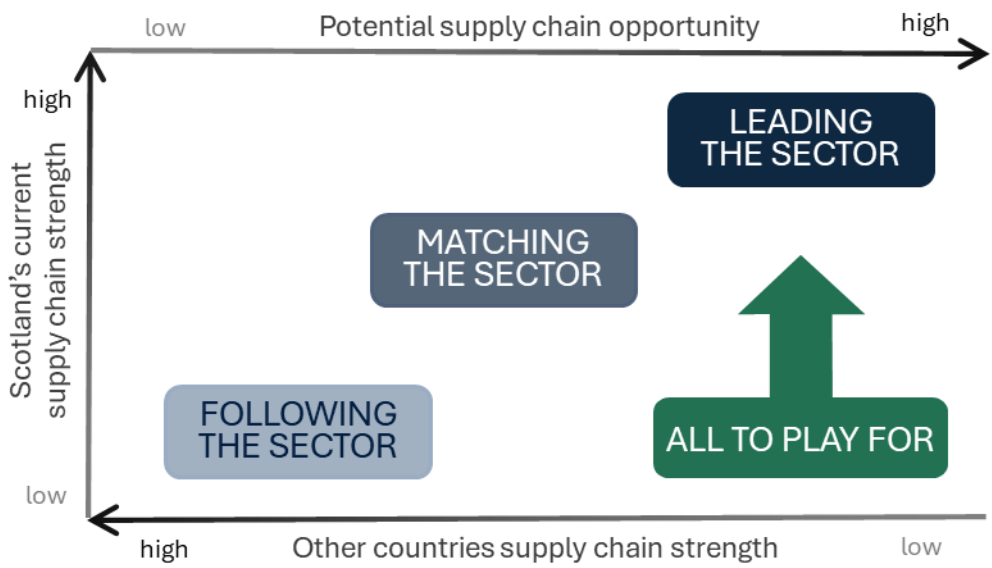



*Figure 5.3. Tidal stream supply chain opportunity ranking*

## 5.3 Supply chain competitiveness framework

Assessing the supply chain opportunity through an overview of the current state-of-the-art for each supply chain category is only the first step in developing a comprehensive understanding of the Scottish tidal stream supply chain capabilities. The development of the device subsystems and/or areas of expertise representing the greatest opportunity to the Scottish economy and renewables industry will require the development of comprehensive and informed recommendations. These recommendations should aim to ensure that the underlying factors which may determine Scotland's ability to produce device subsystems and areas of expertise competitively and at volume are addressed.

To ensure that the various underlying factors that contribute to a supply chain's competitive performance are adequately addressed, this chapter makes use of a novel competitiveness framework, as shown in Figure 5.4. This has been designed with the intention of outlining several key factors by which the competitiveness of the tidal stream sector can be assessed and measured, detailed in Table 5.2. Taking inspiration from the World Economic Forum's Global Competitiveness Index framework [43], a widely utilised global competitiveness framework, this report has identified the following factors, each designed to target a specific aspect of competitiveness policy relating to the tidal stream sector.

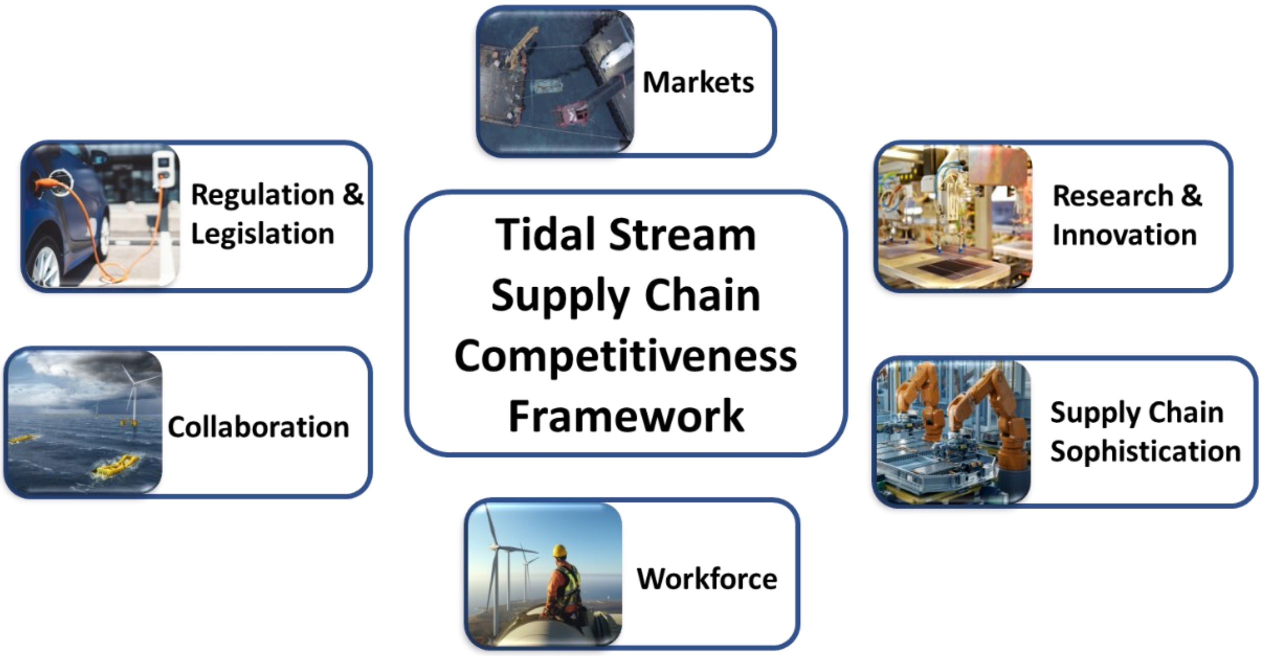



*Figure 5.4. Tidal stream supply chain competitiveness framework*

*Table 5.2. Summary of tidal stream supply chain competitiveness framework*

| Factor | Description |
|---|---|
| **Markets** | Providing a highly visible and supported route-to-market for underpinning innovations, from technical equipment to manufacturing processes, is essential to increase sector and investor confidence |
| **Research & Innovation** | Research and innovation efforts are pivotal for the future progression of tidal stream helping to provide sustainable solutions to societal, economic and environmental challenges |
| **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 device subsystems |
| **Workforce** | Assessing the ongoing availability of a skilled workforce across all education levels, bolstered by the availability of focused training to maximize workforce potential and ease the transition from other sectors and countries |
| **Collaboration** | The ability to facilitate knowledge exchange and collaborative working between different sectors and stakeholders, combined with the development of innovation clusters |
| **Regulation & Legislation** | Designing a fit-for-purpose regulatory and legislative framework that helps rather than hinders the accelerated development and deployment of new tidal stream energy technologies and employs appropriate financial tools to support and protect the sector. |

## 5.4 Review of supply chain categories

The following section will provide an overview of the supply chain categories considered as part of this report. In doing so it will detail a non-exhaustive list of companies and organisations operating both in Scotland and in other nations around the world. Many of these organisations can be considered multi-national in scope, with their main offices often in different locations from their manufacturing hubs. In the instances where there is limited development of a supply chain for the tidal stream sector, companies and organisations with experience in manufacturing subsystems for complimentary industries, such as the floating offshore wind sector, have been selected. It is worth noting that some of the companies listed below, especially those producing bespoke device subsystems, are still in the early stage of development. As such, expectations around their ability to produce device subsystems at high volumes should be tempered in the immediate short-term. These companies do, however, remain an exciting prospect and, potentially, an integral part of Scotland's future supply chain.

## Device subsystems

### 5.4.1 Device hull and sub-structure

Device hulls and sub-structures represent the largest fabricated subsystem of tidal stream devices, regardless of the specific design or configuration of the device in question. These subsystems are primarily fabricated using steel. The fabrication of floating and submersible steel platforms is a complex task, requiring high-skilled fabrication techniques and significant space for construction and assembly. However, as the fabrication and manufacture of tidal turbine sub-structures is limited to a small number of projects, it is indicative to look to the capabilities of wind turbine tower fabricators for an indication of how this sector may develop. Table 5.3 highlights a selection of large-scale organisations with fabrication expertise.

*Table 5.3. Examples of potential non-Scottish tidal turbine sub-structure fabricators*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| CS Wind | South Korea | CS Wind recently announcement of the expansion of its North American factory, which is set to become the world's largest wind turbine tower manufacturing plant. This expansion will see it increase its production capacity to 10,000 wind turbine towers annually. |
| Siemens Gamesa | Spain | Siemens Gamesa has commissioned German steel manufacturing company Salzgitter AG to begin fabrication of its new GreenerTower, a wind turbine made of more sustainable steel and showcasing a marked reduction in associated $CO_2$ output |
| GRI Renewable Industries | Spain | GRI Renewable Industries has worked with Poland's state Industrial Development Agency (GK ARP) to develop an offshore wind tower factory in the Baltic coast city of Gdańsk. |
| Titan Wind | China | Titan Wind has a European manufacturing presence in both Germany and Denmark, with the Danish facility producing wind turbine towers |
| Mainstay Marine Solutions | Wales | This location has comprehensive new-build and maintenance facilities that benefit from an ideal location in the deep-water port at Pembroke Dock on the Milford Haven Water way. |

Despite the relatively small number of tidal stream devices manufactured to date, there is still a number of Scottish companies, shown in Table 5.4, who have played a primary role in the fabrication of the existing fleet of tidal turbine sub-structures.

*Table 5.4. Examples of potential Scottish tidal turbine sub-structure fabricators*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| Gray Fabrication | Fife | Extensive experience in the rolling, bending and pressing of heavy plate and has in the past supplied sub-structure components to leading tidal device developers within Scotland |
| Texo | Dundee | Successfully led the fabrication of the existing Orbital O2 tidal turbine at their Port of Dundee quayside facility. This was a highly novel undertaking, involving a complex combination of fabrication, assembly and launch projects components, that has led to an increased capacity in the ability of Scottish steel fabricators to develop highly bespoke sub-structures to the tidal stream sector |
| Harland & Wolff, Arnish | Isle of Lewis | Arnish point is a 38-hectare development site with a purpose-built fabrication and assembly halls, including fully equipped client, project and administration office facilities. |
| Harland & Wolff, Methil | Methil | The site features two load out quays with 20,000 tonnes capacity each across an open construction area of 6.9 ha and 1.7 ha. The Methil yard covers an area of 54 ha, with 28 ha of covered and open assembly areas, 7,500 $m^2$ of covered fabrication area and 6,800 $m^2$ of covered storage area. |
| Global Energy Group (GEG) | Inverness | GEG owns the Port of Nigg, Scotland's leading renewable energy hub. GEG has extensive experience in providing pre-assembly support for some of the largest offshore wind projects in the UK and its fabrication division has also supplied critical subsystems to these projects. It was recently announced that Global Energy Group were the preferred supplier to lead the manufacture and assembly of several O2 tidal turbine devices as part of their recent CfD award. |

### *Summary*

Scotland possesses a strong base of fabrication expertise and benefits from its position as an industry pioneer in overcoming the initial challenges and barriers associated with tidal stream device fabrication. However, without significant expansion of fabrication facilities and expertise, future large-scale projects could either be curtailed or led from outside Scotland. Avoiding this scenario will require investment in specialist equipment, automation capabilities, the future workforce and the fostering of attractive industrial settings to ensure that Scotland can compete on both price and quality.

Scottish developers have so far only commissioned a small number of devices, and the fabrication of tidal stream device hulls and substructures is a relatively niche industry. The upside of this is that it has enabled high levels of local content as device developers have largely engaged with regional fabricators within Scotland. This has also helped to nurture bespoke knowledge and grow fabricating expertise in response to the unique challenges posed by the tidal sector. The development of the Nigg Offshore Wind facility provides a strong indicator that Scotland will continue to expand its fabrication capabilities, with the on-site tubular steel rolling facility enhancing Scottish manufacturing capacity.

However, Scotland's position of strength with regards to the fabrication of tidal stream sub-structures could be eroded if it is taken for granted. Competing nations, with developed manufacturing capabilities in complimentary industries, such as wind turbine manufacturing, shipbuilding, oil & gas and the aeronautics industry, could begin to focus their own domestic supply chains on this opportunity. While the evidence above underlines Scotland's commitment to expanding its own steel fabrication capabilities, there are a number of international competitors who are both employing innovative manufacturing processes and targeting ambitious manufacturing capacities.

**Device hulls/structures**
**Current supply chain classification**

**MATCHING THE SECTOR**

*Recommendations to improve supply chain capabilities*

- Focused efforts are required to bring an increased number of large-scale manufacturing and fabrication facilities to Scotland. This will require significant financial support to ensure that potential facilities are well provisioned and have sufficient space. Scotland should proactively engage with potential OEMs, who would stand to benefit from these upgraded facilities, as a source of potential investment. For example, the Port of Nigg is likely to be a long-term location where the potential clustering of different offshore developers will lead to localised areas of fabrication expertise.
- By co-locating tidal stream fabrication facilities alongside those of the more mature wind sector, multiple developers can work together, utilising fabrication facilities at a capacity and capability required by shared industry, but not usually available in a single location. The provision of space suitable for assembly may also attract fabricators and manufacturers, helping to foster 'clustering benefits' for workforce and supply chain, as well greater efficiencies from sharing high-cost infrastructure. Tidal stream developers have the added benefit of being able to deliver pre-fabricated subsystems to ports for assembly with relative ease, compared to the wind sector, due to their overall smaller size.
- Significant investment will be required in the upskilling of the existing workforce to ensure that Scottish workers are able to compete with established fabricators, both in the rest of the UK and Europe. This should include efforts to ensure that a steady pipeline of new workers emerges to support the evolving sector, drawing both from the oil and gas sector to help facilitate a Just Transition and young people entering the workforce.
- The implementation of policy frameworks, similar in design to that used in the recently announced CfD AR7 Clean Industries Bonus [44], could be considered to help promote a minimum level of Scottish content in tidal stream energy projects deployed within Scottish waters. This could help to secure a long-term and predictable market for fabricators of both substructures and subcomponents.
- The extension of the CfD scheme, and sector-specific ringfenced funds, could help to bring about a transparent tidal stream deployment pipeline. This will help in outlining substructure and component needs beyond 2030, enabling producers to understand the long-term needs of the sector, bolstering capacity planning in a range on ancillary sectors.

### 5.4.2 Blades

Tidal turbine blades are typically made from a combination of glass fibre-reinforced and carbon fibre-reinforced composites, with the use of steel inserts to connect the blade root to the rotor house. While similar in concept to wind turbine blades, the structural design of tidal turbine blades differs in response to the harsh environment in which they are deployed. The forces exerted by the rushing tides, combined with the corrosive potential of ocean water, leads to a composite blade with a much thicker, yet shorter, design. For example, the rotor diameter of a 3 MW GE Wind turbine is approximately 130 m, with the potential for larger, higher-rated turbines to reach diameters of over 260 m. In contrast, Proteus' AR3000 tidal turbine is expected to achieve a power rating of 3 MW with a 24 m rotor. The overall smaller size also makes tidal turbine blades more readily exportable. Finally, there is also a growing desire to ensure that the manufacturing process proceeds sustainably, adhering to circular principles where possible.

The tidal turbine manufacturing sector is relatively small, catering to a limited number of developers and manufacturing blades to order, a number of which are fabricated as part of European research projects. In stark contrast, the blade manufacturing sector that supports the offshore wind sector is extremely mature and possesses an established supply chain capable of supporting a rapidly growing sector. A selection of the international manufacturers with specific experience of producing tidal turbine blades are listed below, Table 5.5, with large-scale established wind turbine blade manufacturers omitted for clarity. There is a more limited number of Scottish manufacturers in this sector, however those listed in Table 5.6 are already working closely with Scottish tidal turbine developers to meet the needs of projects associated with European projects and the first CfD deployments.

Additionally, within the UK, there are currently two large-scale facilities producing wind turbine blades: Vestas on the Isle of Wight and Siemens Gamesa in Hull. Both facilities are currently producing wind turbine blades for Scottish wind farm projects. Currently, there are also tentative plans for Vestas to locate a turbine blade factory at Leith docks in Edinburgh.

*Table 5.5. Examples of Non-Scottish tidal blade manufacturers*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| INPRE Composites | Navarra, Spain | INPRE Composites is actively expanding the application of GFPR to the development of tidal turbine blades. They are the lead manufacturers for the EU Horizon 2020 NEMMO project, delivering 4 novel-design blades in late 2023, for testing and deployment with Magallanes Renovables in Scottish waters |
| Designcraft | Southampton, England | Desingcraft has worked on novel blade design and blade attachment mechanisms for tidal turbine blades |
| Torcado | Netherlands | Tocardo has established itself as one of the leading manufacturers of tidal turbine systems, including tidal turbine blades |

*Table 5.6. Examples of Scottish tidal blade manufactures*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| FastBlade | Edinburgh | The University of Edinburgh's FastBlade facility, based in Rosyth, Scotland, has begun the testing and manufacture of highly-novel blade designs, partnering with turbine blade manufacturers and device developers. |
| Shetland Composites | Shetland | A leading manufacturer of tidal turbine blades, supplying blades to one of the world's leading tidal turbine companies |

*Summary*

Tidal turbine blade manufacture still remains a nascent industry, with the majority of blades in production being produced on a one-off basis for a limited number of developers. At the point of writing, there is no single nation that currently holds a definitive lead in the development and manufacture of tidal turbine blades. However, as one of the pioneering nations in the tidal stream sector, Scotland possesses much of the necessary expertise in composites research, manufacturing, testing and deployment to position itself as a leading nation. Additionally, Scotland's growing expertise in the development and manufacture of wind turbine blades, underlined by the presence of existing production facilities from two of Europe's leading blade OEMs, provides hope that there can be synergistic development overlaps. Scotland also possesses both the facilities and academic institutions to drive sustained research into future materials, manufacturing processes and end-of-life scenarios, solidifying our position at the sectors forefront

**Tidal turbine blades**
**Current supply chain classification**

**ALL TO PLAY FOR**

*Recommendations to improve supply chain capabilities*

- The formation of a world-class collaborative advanced tidal turbine blade technology institute, utilising Scotland's existing academic expertise in composites and turbine blade testing. This should include a mechanism for ensuring that advances in blade design are supported to move beyond early-stage research and innovation and towards commercial implementation and deployment. This can be enabled via increased funding and robust support to ensure that there is adequate pull through from industry.
- Regulation mandating the gradual move to increased levels of circularity, both for blade materials and design process, can continue to spur innovation and help to future-proof the Scottish market by anticipating a global shift towards a need for more recyclable turbine blades. This may also provide an opportunity to provide expertise to the wind sector who will also be tackling this issue.
- Increase the Scottish manufacturing capacity of tidal turbine blades in line with the deployment trajectories expected as a result of planned deployments, both domestically and in line with other nations prospective deployment timeline.
- Provide incentives to ensure that ongoing innovations in the design and manufacturing process of composite materials for tidal turbine blades, occurring as a result of the work carried out by Scottish research institutes, are able to enter commercial deployment.

- The implementation of automated blade manufacturing processes will enable a step change in the production process. There is an opportunity for collaborative learning from the wind sector, as Siemens Gamesa and Denmark's Tekniske University are pioneering the use of an automated preforming robot system (APRS) for the layup of composite materials. This new process, replacing the current manual hand lay-up process, will decrease the time that expensive turbine moulds are used, improve blade quality and reduce material waste.

### 5.4.3 Power take-off and power conditioning systems

The term power take-off (PTO) can be considered a general term that encompasses a number of subcomponents responsible for enabling tidal stream devices to convert the energy extracted from the tides into usable electricity. The following subcomponents will be considered, with each of them receiving an individual supply chain classification:

- Power take-off, which considers:
  - Generators
  - Gearboxes
  - Pitch systems
- Power conditioning systems

Recommendations for these subcomponents will be presented collectively at the end of section 5.4.3

#### 5.4.3.1 Generators

The generator of a tidal turbine converts the mechanical energy into electrical energy by using the properties of electromagnetic induction. The most commonly used generators in wind and tidal energy applications are induction, doubly fed induction, and permanent magnet synchronous generators.

Table 5.7 lists a number of the leading European suppliers of generators to both the wind and tidal stream sectors. However, it should be noted that the global market for wind turbine generators is currently dominated by China, who manufacture 73% of the world's supply [45].

*Table 5.7. Examples of non-Scottish generator manufacturers*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| Winergy | Germany | A primary supplier of both gearboxes and generators to the wind sector, with over 125GW of gearbox capacity supplied to date, Winergy operates production facilities in Europe, USA, China and India. |
| ABB Motion | Sweden/ Switzerland | A major manufacturer of generators for both wind and tidal stream sector, offering bespoke generating options for both technologies. ABB Motion has manufacturing facilities in Sweden, , Finland and India. |
| Ingeteam | Spain | Specialising in electrical engineering and the production of generators for the energy sector, Ingeteam has installed over 80GW of wind turbine power worldwide, representing an 8% share of the global market. Ingeteam are also investing heavily in power and control electronics, with the opening of a new facility in Northern Spain. |
| Elin Motors | Austria | A major manufacturer of generators and motors, Elin Motors possesses one of Europe's most modern motor and generator factories in Austria. |

Scotland does retain a level of domestic expertise in the manufacture of generators, driven in part by the long association with the oil and gas sectors. However, there are few manufacturers producing generators at the scale and ratings required by the offshore renewable energy sector. While this doesn't mean that companies couldn't be developed to meet these standards, it will require time and the implementation of bespoke policy programmes and financing to ensure that Scottish manufacturing expertise in this area is supported. There is much more limited evidence of Scottish capability in the production of generators at the scale required to meet the potential demand of the tidal stream sector, as shown in Table 5.8.

*Table 5.8. Example of Scottish Generator Manufacturers*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| TDC Parson Peebles | Rosyth, Scotland | An established high-value manufacturer, Parson Peebles has extensive experience supplying and supporting power generation solutions to the oil and gas sectors. They are also engaged in national hydropower pumped storage, wave and wind farm projects. |

*Summary*

This is an established sector, and one that is pivotal to the ongoing global Net Zero transition. As a result, there is extensive international competition, much of which is underpinned by historic and long-term development of manufacturing capabilities and capacities. In nations where expertise in the manufacture of generators has emerged in recent years or decades, this has often been paired with the establishment of significant wind turbine manufacturing capabilities. These conditions are difficult, and sometimes economically unviable, to reproduce. Therefore, advancement of this subsystem should focus on developing Scotland's existing capacity to service more bespoke sectors, such as tidal stream.

**Generators**
**Current supply chain classification**
**FOLLOWING THE SECTOR** → **MATCHING THE SECTOR**

### 5.4.3.2 Gearboxes

Following design conventions from the wind sector, a number of tidal device developers have included a gearbox in their PTO subsystems, allowing the rotational motion of the turbine rotor to be increased before it is used by the generator. Developers such as Orbital Marine Power, Minesto, Proteus and Andritz Hydro all utilise a gearbox-based PTO subsystem. However, not all tidal stream devices require the use of gearboxes. Developers such as Hydroquest, Sabella and Nova Innovation utilise a direct drive system, where the rotor is connected directly to the generator, where the generator speed is equal to the rotor speed.

The global market for wind turbine gearboxes is currently dominated by a number of Chinese companies, who manufacture 80% of the world's supply [45]. In addition to this, there are a number of smaller European companies contributing to wind projects across Europe and the UK, detailed in Table 5.9.

*Table 5.9. Examples of Non-Scottish Gearbox Manufacturers*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| Wikov Group | Austria | Wikov Group, based in Prague, has worked experience of delivering gearboxes to both the wind and tidal stream sector |
| Winergy | Germany | A primary supplier of both gearboxes and generators to the wind sector, with over 125GW of gearbox capacity supplied to date, Winergy operates production facilities in Europe, USA, China and India. |
| ZF Wind Power | Belgium | ZF is one of the leading providers of wind power gearboxes with a global market share of approx. 25%. ZF also operates six manufacturing plants across Belgium, India, Germany, USA and China. |

*Summary*

By 2026, Europe is expected to encounter a supply chain bottleneck with regards to the supply of generators and gearboxes, as the roll-out of wind turbines outstrips supply [45]. As a result of historical tendencies to outsource the production of these components to nations such as China, Scotland is not well-situated to challenge this current shortfall, nor does it have facilities or expertise in large enough quantities to do so. The established presence of existing expertise and well-equipped manufacturing facilities in Europe, alongside the expansive policy support programmes being offered in the USA, indicates that even if Scotland were to attempt to anticipate a response to this potential shortfall, there is limited advantage to building out domestic capacity.

**Gearboxes**
**Current supply chain classification**

**FOLLOWING THE SECTOR**

### 5.4.3.3 Pitch Systems

Pitch systems enable the blade pitch angle to be controlled and adjusted relative to the tidal flow that it sits within, increasing power efficiency and enabling the rated capacity of the turbine to increase. The pitch system also plays an important role in regulating the rotational speed of the rotor. Pitch systems include a series of subcomponents including a control subsystem, sensors, pitch actuators and bearings to facilitate smooth movement of the blades. Pitch systems are considered an industry standard within the wind sector, and as such, most leading European wind turbine OEMs have significant capabilities with regards to production. Examples of these are listed in Table 5.10.

*Table 5.10. Non- Scottish Pitch System Manufacturers*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| Vestas | Denmark | Vestas is the largest wind turbine company in the world, installing over 177GW of wind turbines worldwide and has extensive experience in installation and servicing, developing a strong capacity with regards to the in-house development of pitch systems |
| Siemens Gamesa | Spain/ Germany | Siemens Gamesa, a Spanish-German wind engineering company, is the world's second largest wind turbine manufacturer, with manufacturing and research facilities spread across Europe |
| SKF | Sweden | SKF is the world's largest bearing manufacturer and has a global manufacturing presence and extensive experience in the delivery of pitch systems for the wind and tidal stream sectors. |

*Summary*

The technological lead enjoyed by many of the world's leading wind turbine OEMs, who are actively driving innovation in pitch systems to increase the performance and economic returns of their turbines, indicates that this is a subsystem where Scotland will struggle to establish a position. While the unique challenges posed by deploying pitch systems in a marine environment may help to bring about innovations led by Scottish developers, there is a high chance that they will exploit existing global supply chains to fulfil these needs.

**Pitch Systems**
**Current supply chain classification**

**FOLLOWING THE SECTOR**

#### 5.4.3.4 Power Conditioning System

The power conditioning system (PCS) is the general term for devices that use power electronic technologies, such as inverters, rectifiers and drive controllers, to convert electric power from one from to another or to limit current and voltage to maximise power output. A growing fraction of the power generation on the national grid today is PCS based, underlining its importance to the Net Zero transition. Additionally, the rate of penetration levels of PCS-based generation and storage is increasing rapidly due to the increased addition of offshore energy sources that produce variable AC, such as wind turbines. There is much more limited evidence of Scottish capability in the production of power conditioning systems at the scale required to meet the potential demand of the tidal stream sector. Example companies are listed in Table 5.11 and Table 5.12.

*Table 5.11. Non-Scottish power conditioning system manufacturers*

| Company | Nationality | Evidence of Supply Chain Capabilities |
|---|---|---|
| GE Power Conversion | Paris | GE power conversion designs and delivers advanced motor, drive and control technologies that help improve the efficiency and decarbonization of energy-intense processes and systems, helping to accelerate the energy transition across marine, energy and industrial applications |
| Siemens | Germany | Siemens is the largest industrial manufacturing company in Europe, with extensive experience in power conditioning in a range of sectors including energy, rail transport and industrial automation |

*Table 5.12. Scottish power conditioning system manufacturers*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| Supply Design | Rosyth, Scotland | Supply Design, based in Rosyth, specialises in the design and development of high-performance power converters for leading OEMs and has direct experience of working with the offshore energy sector. |

*Summary*

There are established European supply chains for the majority of OEMs and companies who are utilising PCS' have either direct experience of delivery for renewables projects or complimentary sectors. However, given that there is a level of existing expertise in Scotland, this sector should be carefully monitored to assess the opportunity for these companies to provide bespoke PCS solutions to the tidal stream sector.

**Power Conditioning Systems**
**Current supply chain classification**

**FOLLOWING THE SECTOR** → **MATCHING THE SECTOR**

#### 5.4.3.5 Overall Summary

Scottish expertise in the manufacture of the subcomponents underpinning PTO and PCS is varied. International competitors from the USA and China enjoy a large technological lead, underpinned by robust supply chains. While Scottish expertise in complimentary industries, such as oil & gas and the wind sector, has meant that a limited number of companies are now well positioned to contribute to the tidal stream supply chain, this may not translate into large-scale sector progression. Funding and investment should be provided to the companies who have an established presence, raising awareness and alerting them to the possible opportunities of serving a smaller, more bespoke tidal stream market. However, long-term alteration of current market structures is unlikely given that major competitors have spent decades honing their skillset, technological designs and development capabilities.

*Recommendations*

- Given the large lead enjoyed by major competitors in the development of both gearboxes and pitch systems, Scottish government and policymakers should carefully assess the impact of prioritising these areas over other subsystems with fewer barriers to entry. However, the implementation of a targeted innovation call to support the next generation of power train technologies, where the progression of the technology in question builds upon or advances existing Scottish expertise, should be considered.
- Any Scottish industrial strategy should focus on developing workforce capabilities with regards to the assembly of pre-manufactured subcomponents. This will enable a proportion of the associated value chain to be retained by Scottish developers and help to establish and grow Scottish reputation as a world leading systems integrator. This ambition should be supported by the requisite investment in state-of-the-art assembly facilities.
- Investment into Scottish capabilities to maintain and repair powertrain systems could further siphon off a proportion of the value associated with this subsystem, ensuring economic returns to Scotland even without a solid manufacturing base.
- The extension of the CfD scheme, and sector-specific ringfenced funds, could help to bring about a transparent tidal stream deployment pipeline. This will help in outlining substructure and component needs beyond 2030, enabling producers to understand the long-term needs of the sector, bolstering capacity planning in a range of ancillary sectors.
- The publication of a transparent tidal stream deployment pipeline, outlining PTO and power conditioning system requirements beyond 2030 will help producers to understand the long-term needs of the sector, bolstering capacity planning in a range on ancillary sectors.

### 5.4.4 Subsea electric cables

Offshore energy devices have the additional challenge of ensuring that the power they generate can be exported consistently and reliably back to shore. These will link devices, potentially via offshore hubs and substations, to export cables that deliver the power to shore and the grid. These cables come in a range of power ratings, with higher capacity cables typically used for export. Most of these cables are static and will be on or in the seabed, however a portion of the cable at the device, and hub/substation if used, will be exposed to environmental loads such as wave action and tidal currents. Floating devices will require dynamic cables capable of also withstanding the, potentially considerable, motion of the device. Given the lack of established array configurations for tidal stream devices, there is no standardised layout, and cable ratings are typically configured to the output of the device. While there is significant commonality with the subsea cables used for offshore wind projects, those for tidal stream arrays will likely be smaller and lower voltage.

The manufacturing process for subsea cables typically involves a conductive core, made from either copper or aluminium, insulated with a synthetic material. Various specialised equipment is also required for manufacture, including plastic extruders, vertical layup machines, horizontal armouring machines, and cable spooling equipment. There is also a need for appropriate storage, transportation and deployment tools and vessels.

A number of high-profile European cable manufacturers are listed in Table 5.13. There have been two recent high-profile examples of investment into Scottish subsea cable manufacturing capabilities, listed in Table 5.14.

*Table 5.13. Non-Scottish subsea electric cable manufacturers*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| NKT | Denmark | NKT has production facilities in 10 European countries, including a high voltage cable office in Teesside, England, to serve ongoing and future projects along the UK east coast |
| Nexans | French | Nexans is the second largest manufacturer of cables in the world and has recently finalised the expansion of its Norwegian subsea cable facility to address regional and global demand |
| Prysmian | Italy | Prysmian is the world leader in the production of cables for the offshore sector and has extensive global production facilities, catering to a range of markets. This includes a headquarters in Southampton and three further manufacturing facilities in the UK |
| Hellenic Cables | Greece | Hellenic cables, a Greek company, has production plants and logistic centres in Greece, Romania and Bulgaria |
| JDR Cables | UK | JDR cables, a British company, has expanded manufacturing facilities at its Hartlepool factory in recent years, in response to the increased demand for subsea cables from the UK's oil and gas and wind industries. This has also resulted in the planned opening of a new factory in Blyth, with construction currently underway |

*Table 5.14. Examples of planned Scottish subsea electric cable manufacturers*

| Company | Location | Evidence of Supply Chain Capabilities |
|---|---|---|
| Sumitomo Electric UK Power Cables Ltd. (SEUK) | Scottish Highlands | SEUK is developing a facility in the Scottish Highlands capable of producing high-voltage transmission cables. This collaborative project, involving funding from Scottish Government, Highlands and Islands Enterprise and Scottish Enterprise, intends to satisfy the growing demand for subsea cables in the North Sea region, reducing lead times and bolstering Scotland's own domestic production capabilities. |
| XLCC | Hunterston | The UK Infrastructure Bank has recently announced an investment into the subsea HVDC cable manufacturer XLCC to develop a new factory in Hunterston, with the capacity to produce thousands of kilometres of HVDC cable annually. This project has also committed to providing over 200 apprenticeships as part of its employment process, helping to grow the skillset of the regional manufacturing base. |

### *Summary*

With a rapidly increasing number of offshore energy projects preparing to come online in the coming years, the availability of medium and high voltage cables capable of transporting power to shore will be critical. However, since the early 2000s domestic manufacturing of high voltage cables has largely ceased in the UK and the country has become wholly reliant on cable imports from a range of qualified and established European companies. This has been offset in recent years as both the UK (JDR Cables) and Scotland (SEUK and XLCC) begin to increase their domestic capability to manufacture high voltage subsea cables. This is an important step in ensuring that Scotland possesses both the strategic capability to deliver on its Net Zero ambition and the flexibility to meet a range of deployment scenarios.

| Subsea electric cables<br>Current supply chain classification | FOLLOWING THE SECTOR → | MATCHING THE SECTOR |
|---|---|---|

*Recommendations to improve supply chain capabilities*

- Given the large lead enjoyed by major competitors in the development of this subsystem, Scottish government and policymakers should carefully assess the impact of prioritising these areas over other subsystems with fewer barriers to entry. However, given the combination of recent large-scale investment into Scottish cable manufacturing capabilities and the immediate and localised market presented by future deployments in Scotland, the supply chain to support the development of this subsystem is set to undergo a rapid evolution.
- While short-term demand is likely to be met by existing European manufacturers, the medium and long-term supply of high voltage cables is more likely to be sourced from Scottish factories, adjacent to deployment sites. To prepare for the progression of this subsystem sector, Scottish government and policymakers should provide targeted support where necessary to ensure close collaboration between device developers and cable manufacturers. Investment in the necessary ancillary infrastructure, such as cable installation vessels and monitoring systems, can increase Scottish expertise and deepen associated value chains.
- While new factories have been built with the primary function of supporting offshore wind deployments in the North Sea and other large-scale projects around the UK, a steady and transparent pipeline of tidal stream deployments should constitute a customer base worthy of cable manufacturing to desired power ratings.
- Continued technology innovations, such as the development of cable hubs that enable multiple tidal stream turbines to be connected to a single export cable, allowing overall cabling requirements to be reduced, are necessary to ensure that Scotland remains at the forefront of development and deployment.
- Developing effective condition monitoring systems, which can identify potential failures and reduce turbine down time, provides a way for Scotland to build and retain value around a subsystem that they currently import.

### 5.4.5 Anchors and moorings

The role of anchors and moorings in the offshore energy industry is well-established, with technologies such as drag, pile-driven and gravity-based anchors, and the chains and synthetic lines used to connect them, understood from decades of use in other industries, such as oil and gas. However, the progression of the offshore wind, wave and tidal stream sectors has introduced a new level of industrial demand for these subsystems, that means that innovations in their design, cost, scalability and installation process need to be addressed. There is a need for new anchor, mooring and foundation designs that are able to provide more lightweight and efficient solutions that would be cheaper, locally manufactured and require smaller installation vessels.

There are several international companies, listed in Table 5.15, many of whom have a UK or Scottish presence, specialising in anchors and mooring systems, catering primarily to the needs of established industries, such as oil & gas and the offshore wind sector. In addition to this, there are a number of companies with the capabilities to provide marine operations services to the tidal stream sector, both domestically and abroad.

*Table 5.15. Examples of anchor and mooring manufacturers and/or service providers*

| Company | HQ Location | Scottish Presence | Evidence of Supply Chain Capabilities |
|---|---|---|---|
| Delmar Systems | Houston, Texas | Aberdeen | Delmar Systems has an extensive track record of supporting floating renewables, from site selection to the optimisation of mooring systems and loads. Delmar Systems has also recently expanded its manufacturing presence in Aberdeen. |
| Mooreast | Singapore | Aberdeen | Mooreast provides a wide range of anchor options for floating offshore technologies. In 2023 Mooreast signed a cooperation agreement with the Energy Transition Zone (ETZ) in Aberdeen. Under this agreement, Mooreast will work with ETZ to help support the creation of a manufacturing hub aimed at supplying future projects in the Scottish offshore energy sector. |
| InterMoor | Houston, Texas | Aberdeen, Montrose | InterMoor specialise in all aspects of mooring, including wave energy converters and floating wind turbines and are capable of delivering a customised cradle-to-grave mooring solution, from engineering and design through to offshore installation or retrieval and decommissioning of their mooring systems. InterMoor has a UK presence in both Aberdeen and Montrose, covering both offices and onshore operations. |
| Leask Marine | Kirkwall | Kirkwall | Leask Marine has extensive experience providing a range of services to the wave and tidal stream sector, including mooring system specifications, anchoring solutions and operation services. |
| Schottel Marine Technologies | Germany | Leith | Schottel Marine Technologies specialises in the production of innovative, low impact anchor solutions, designed specifically for the offshore energy sectors. Its acquisition of Edinburgh based Swift Anchors, enables previously disregarded or challenging sites to be opened up for development. |
| Subsea Micropiles | Dublin | Aberdeen | Subsea Micropiles are leading the adaption of land-based micropiling technology to create superior marine foundation and anchor solutions for the ORE sector. In 2024, Subsea Micropile was identified by Scotland's Offshore Wind Energy Council for priority assessment in its Strategic Investment Model Funding round. |

*Summary*

Currently, the majority of anchor manufacturing facilities are located outside of the UK, which compounds the supply chain challenge posed by the growing pipeline of both wind and tidal stream projects. Lead times for acquiring anchors could be increased as a result, potentially delaying the installation of tidal turbine arrays as they compete with established commercial wind farms.

The chain and synthetic material manufacturing industry is spread across Europe, with a limited presence in Scotland. However, given the relatively low-technology barriers to entry, there is the potential for Scotland to invest and build within this market.

| **Anchors and moorings**<br>**Current supply chain classification** | **FOLLOWING THE SECTOR** → | **ALL TO PLAY FOR** |
|---|---|---|

*Recommendations to improve supply chain capabilities*

- Continued financial support for companies driving the development and uptake of the next generation of low-impact anchoring systems. This can be reinforced by implementing more robust environmental impact assessments requirements in Scottish waters, increasing uptake and potentially reinforcing the Scottish market.
- Ensure that Scottish capabilities with regards to installation fleets evolve alongside anchor development and match the requirements of the sector.
- Integrate the development of remote operated vehicles for anchor installation and maintenance, like that employed by Schottel Marine Technologies, into standard practice where possible.
- Aim for increased collaboration between the tidal stream and wind sectors and accredited research institutions to accelerate the development and qualification of moorings and anchors, helping to lower cost and associated risk.
- Ensure that sustained innovation support for the tidal stream sector is complimented by a collaborative learning process with the floating offshore wind sector who are actively pursuing innovation in the same areas.
- Ensure that lessons with regards to best practice, deployment protocols, maintenance and monitoring are learned from sectors with extensive experience, such as the oil and gas sectors.

## Areas of expertise

### 5.4.6 Development and testing of devices

Building up a national skillset with regards to the research, development and testing of devices is a necessary step in becoming an established leader in the tidal stream sector. This will require strategic and significant financial investment into key underpinning infrastructure and hardware by national government and private investors, to deliver a variety of testing infrastructures capable of supporting the sector.

A primary focus is the establishment of qualified and well-resourced test centres, capable of providing device developers with the opportunity to perform accelerated testing in a controlled and managed environment both for full scale components or subsystems, and scale testing for others. Accelerated life tests may be required for certification of certain components, while scale model testing is useful for understanding device hydrodynamic behaviour.

This is a challenging task given the complex metocean conditions that the sector must deploy and operate devices in. It will also require large amounts of up-front capital and expenditure to lay the groundwork, waiting for future customers and income. However, this up-front investment is essential to ensure that Scotland remains the preferred testing location of device developers around the world.

*Summary*

As the leading nation in the development of tidal stream devices, Scotland has over the previous decades demonstrated its ability to provide a pathway for potential device developers to follow from the inception of ideas to the implementation of concept and designs. This has included, but is not limited to, the building of strong links between device developers and the supply chain; the provision of direct innovation funding; and facilitating interactions with national governments on policy support programmes. In addition to this, Scotland is home to a range of highly innovative and mature tidal stream technology developers who have been successful in bringing their technology to market and in accessing funding at national and European levels. Finally, Scotland possesses a truly world-class testing facility in the European Marine Energy Centre (EMEC), with the capabilities to act as innovation catalyst and accelerate technologies to the market. EMEC is the world's first accredited wave and tidal test centre, with more ocean energy devices tested in Orkney, Scotland, than at any other site. Scotland also possesses a range of test facilities, such as the Kelvin Hydrodynamics Laboratory and FloWave test tank, where scaled devices can be tested in simulated-at-sea conditions, plus the Fastblade facility, with the capabilities to test composite blades.

**Development and testing of devices**
**Current supply chain classification**

**LEADING THE SECTOR**

*Recommendations to improve supply chain capabilities*

- Provide ongoing tasking and funding to existing innovation and support organisations to oversee the well-coordinated and accelerated delivery of device research and development and overall improvements in Scottish supply chain capabilities.
- A primary focus should be to ensure that Scotland is able to provide and promote the capabilities of its testing facilities to bring in prospective developers from around the world.
- Engage in ongoing dialogue with national and international funding agencies to prolong and shape high-level innovation funding support for device developers and the supply chain.
- To help sustain the role of test centres such as EMEC, a clear pipeline of projects should be established and commit to progressing from prototype demonstrations to array deployments over the coming decade.

### 5.4.7 Overall device manufacture/assembly and subsystem integration

While the preceding sections of this report have considered the Scottish capacity to manufacture individual device subsystems, there is also a need to consider the actions required to enhance Scottish device developers' ability to act as a device manufacturer/subsystem integrator across the supply chain. As the tidal stream sector prepares for the deployment of tidal stream devices at an array-scale, careful consideration should be given to the possibility of Scottish device developers obtaining space to complete the overall device manufacture and developing the necessary underpinning skillsets to establish Scotland as the primary location for the integration of various key device subsystems. Although the development of this capability may not be conventionally viewed as part of the supply chain, development of skills and expertise is vital to ensuring that a portion of the supply chain value, and accompanying GVA and jobs, is always retained within Scotland, even as device export value increases.

Many Scottish tidal stream device developers are expressing a desire to maximise local content. There is therefore a compelling case for developing overall device manufacture and subsystem integration capabilities now, while order quantities remain relatively low and developers can afford a high level of oversight. However, as the sector grows to meet the potential deployment trajectory outlined in this report, there will need to be a level of investment into facilities and workforce capabilities to ensure that Scotland remains competitive with other countries who may have similar capabilities gained from other complimentary sectors. This may include the development of factories that offer high levels of automation, procedural efficiency, and storage.

**Device manufacture and subsystem integration**
**Current supply chain classification** — **MATCHING THE SECTOR**

*Recommendations to improve supply chain capabilities*

- Support Scottish device developers to establish and maintain factory facilities where subsystems can be delivered, stored, assembled, tested and shipped. This should be underpinned by requisite investment in state-of-the-art facilities, allowing for automation in the testing and certification of the device and enhanced training and upskilling of workers.
- A highly visible and transparent market will provide the confidence for both tidal stream developers and supply chain manufacturers to secure large-scale investment into requisite factories and facilities.
- Actively pursuing the potential sharing of assembly and storage infrastructure with more established renewable technologies may help to maximise access to already congested portside space.
- Ensuring that any site chosen is well connected by transport links and other supporting infrastructure can increase overall procurement efficiency, helping to ensure that subsystem integrators can proceed at speeds required to match deployment forecasts.

### 5.4.8 Project development

Many energy projects are developed from early feasibility studies through planning and consenting by one or more project developers, supported by a range of consultants and specialists. This can be a long process, and not all projects will make it to construction. Tidal farms, in common with other energy projects, will require environmental impact assessment. In turn, this will require a range of specialist surveys and analysis. Project development requires expertise in a wide range of areas. These include resource and metocean assessment, farm layout optimisation, securing the seabed lease and grid connection, plus dealing with the commercial aspects including securing financing and power purchase agreement, plus market support where available.

Historically and currently, many tidal stream device developers are also acting as project developers, consenting sites to demonstrate their own devices, however this is expected to change as the sector matures. The development of tidal farms will have many commonalities with other forms of renewable energy, especially offshore. Projects developers currently focusing on other sectors are likely to consider tidal stream energy projects too in due course, as the technology continues to mature.

*Summary*

Few project developers are focusing on tidal stream at present given the emerging status of the technology. However, with CfD support in recent years, there is a growing pipeline of projects being developed in Scotland, both by technology developers, but also by SAE Renewables. Many companies are developing offshore wind projects in Scotland, focusing on both fixed bottom and floating windfarms. There are many complimentary skillsets between the development of ocean energy projects, regardless of the technology in question. These can include instances of best practice on the technical, environmental, health and safety, legal and commercial aspects of project development.

Given the high concentration of ocean energy projects in its waters, and the presence of accredited test centres, Scotland is well positioned to establish itself as a world-leader in the development of tidal stream energy projects. As the sector continues to mature, Scotland has an opportunity to export this expertise to other locations, building upon its advantage as an early adopter of tidal stream technologies.

**Project development**
**Current supply chain classification**

**ALL TO PLAY FOR**

*Recommendations to improve supply chain capabilities*

- Establishment and promotion of guidelines for project development in the tidal stream energy sector, informed by a range of actors, including technology developers, test centres and support agencies.
- Direct engagement with technology developers who are leading on the development of projects to showcase their devices, providing support where necessary.
- Support device developers to engage directly with project developers to streamline the development of large-scale tidal stream projects.

- Emphasis on enabling existing companies involved in the value chain of project development across the renewables sector, including surveys and environmental assessments, to also engage and work in the tidal stream sector.

### 5.4.9 Installation, Operations and Maintenance of Devices

Installation of the device covers the towing/shipping of the device to the point where it will be deployed and its connection, via electric cables and moorings. Operations and maintenance (O&M) cover the ongoing services associated with the upkeep and servicing of all components of a tidal turbine farm, including the vessels required to fulfil these tasks, throughout its lifetime. It may also cover other non-hardware aspects, such as providing marine operation services or software requirements. All of these tasks require a highly specialised skillset with regards to training, equipment and vessel use. Within the offshore wind sector, O&M provision is largely handled by the wind turbine OEM, in line with any associated equipment warranties which can often tie OEMs to the project for a set number of years. The tidal stream sector is widely expected to follow a similar model of O&M management as that of the offshore wind sector. This will mean that individual device developers will aim to keep responsibility for O&M within their own organisational structures, enabling the growth of their in-house capabilities and maintaining associated revenue streams.

*Summary*

Scotland has an established reputation as expert in tidal O&M, honed by the success of domestic testing centres like the European Marine Energy Centre and high deployment rates in national waters. This strong base has led to the development of a competitive edge in areas such as environmental services, asset management and expertise in installation vessels. Scotland is currently able to leverage this position as a tool to draw developers from outside the UK to its waters for both early-stage testing and longer at-sea trial periods. Given the establishment of a number of offshore wind projects in Scottish waters, combined with the historic presence of the oil and gas sector, Scotland is well positioned to continue developing expertise in this area.

**Installation, operations and maintenance**
**Current supply chain classification** — **LEADING THE SECTOR**

*Recommendations to improve supply chain capabilities*

- Continued support for Scottish O&M facilitators to develop new and more efficient methods for O&M, such as remote monitoring and inspection, digital twins and increased number of appropriate-sized O&M vessels.
- Ensure adequate facilities are available for O&M logistics, which will be vital for attracting investment and sector-leading companies. This may include sustained development and upgrading of existing port and harbour facilities; the development of a comprehensive O&M base network; development of the supply chain that supports the delivery; and provision of spare and replacement parts for deployment vessels.
- Identify which ports and harbours are most strategically positioned to act as bases for O&M activities.

- Ensure that the workforce underpinning this sector continues to grow in line with scheduled deployments, ensuring that equal focus is given to both vocational training and the transiting of workers for ancillary sectors.
- Work proactively with those engaged in environmental monitoring and consenting to ensure appropriate use of regulation that helps, not hinders, development of the tidal stream sector.
- SMEs are particularly well suited to exploit opportunities that require a local presence, commercial/technical flexibility or specialist/ innovative solutions. Several UK SMEs have already been successful in this market but there is considerable scope for further involvement, which should be delivered specifically to SMEs.

## 5.5 Summary of recommendations

Scotland's position as a pioneer of tidal stream technology is well understood and is reflected in a high concentration of Scottish device developers, collectively demonstrating sustained levels of technological innovation. However, as the sector continues to grow and planned deployments move from single devices to array-scale farms, there will be a concurrent growth in the need for specific tidal stream device subsystems and areas of expertise. While significant progress has been made in the development of the Scottish tidal stream sector, the supply chain remains relatively small, and some of the of the companies listed above are still in the early stage of development.

As is outlined in the previous sections of this report, Scotland currently possesses a range of capabilities in the manufacturer and development of these device subsystems. By strategically targeting subsystems where there is either overlap with existing Scottish expertise or a potential market that can be leveraged to draw outside expertise and investment into the country, Scotland is well situated to capitalise on the manufacture of specific subsystems. Similarly, the development of skills and facilities to underpin critical areas of expertise should also be an area of strategic importance. It is important to note that much of the benefit that can potentially be accrued, through the growth of GVA and jobs, is highly contingent on ensuring that Scotland develops a robust domestic supply chain that delivers high levels of Scottish content to projects deployed in Scottish waters.

Finally, when attempting to attract established companies to Scotland, careful consideration must be given to the pros and cons of establishing conditions that they might find attractive to invest in. Evaluating which incentives Scotland can offer, preferred manufacturing locations and access to port and harbour facilities to preferential tax rates, must be balanced against the potential GVA it can provide to the Scottish economy.

Table 5.16 provides a summary of the classification's given to the each of the supply chain categories withing this section. For many of the categories, an arrow has been used to show where there is potential for a certain category to move from one classification to another, should the correct support be provided. However, even for those categories that were given a single classification, sustained support will be required to ensure that this position does not drop to a lower classification.

*Table 5.16. Summary of supply chain classification*

| Subsystem | Classification |
|---|---|
| Device subsystems | |
| Device hull and sub-structures | Matching the Sector |
| Blades | All to Play For |
| Power take-off and electrical systems: | |
| *Generators* | Following the Sector → Matching the Sector |
| *Gearboxes* | Following the Sector |
| *Pitch systems* | All to Play For |
| *Power conditioning system* | Following the Sector → Matching the Sector |
| Subsea electric cables | Following the Sector → Matching the Sector |
| Anchors and moorings | Following the Sector → All to Play For |
| Areas of expertise | |
| Development and testing of devices | Leading the Sector |
| Overall device manufacture/assembly and subsystem integration | Matching the Sector |
| Project development | All to Play For |
| Installation, operations and maintenance of devices | Leading the Sector |

Section 6 of this report will now build upon the subsystem classification established in section 5, summarised in Table 5.16, and is intended to guide prospective policymakers in the identification of priority supply chain categories and the policies required to support their continued growth and development.

# 6 Summary and recommendations

## 6.1 The potential for Scotland

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

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

### Contributing to a Net Zero energy system

Many tidal stream projects are now being developed to harness this predictable renewable energy supply. **A pipeline of over 80 MW of tidal stream farms is due to be constructed in Scotland by 2029**, supported by the UK Government's Contracts for Difference (CfD) scheme. Further projects are also being developed beyond this. Modelling shows that with appropriate market and innovation support, there is the potential for tidal stream to provide a meaningful contribution towards a future Net Zero energy system across the UK and strengthen our overall energy security.

There is the potential for **6.2 GW of tidal stream devices to be deployed in the UK by 2050**, of which **70% (4.3 GW) of deployments could be in Scottish waters**.

### Fuelling economic growth

There is a time-sensitive opportunity for Scotland to establish itself as a world-leading location for the development, deployment, maintenance and decommissioning of tidal stream energy devices. This will require correct and long-term decisions be taken now, with regards to supporting device developers and their underpinning supply chain, tying future GVA and jobs to a strong domestic tidal stream market.

The economic analysis within this report shows the potential for domestic deployment of tidal stream devices and farms to generate **over £4.4bn GVA by 2050** to the Scottish economy. There is also the potential for significant **additional GVA of up to £11.8bn from export markets** associated with successful Scottish companies.

### Delivering on Just Transition commitments

By establishing a successful commercial tidal stream sector, underpinned by a robust supply chain, Scotland also has the potential to provide high-skilled jobs across the country, in sectors from the manufacture and fabrication of subsystems to the ongoing operation and maintenance of tidal stream devices in farms.

The analysis in this report also demonstrates that by 2050, there is the potential for **almost 6 000 FTE jobs, resulting from domestic projects in Scotland and the UK**. Many of these high-value jobs could be located in coastal communities around Scotland. With greater uncertainty, there is **significant additional potential from export markets** of up to **20 000 jobs associated with Scottish companies**.

## 6.2 An end to business as usual

It is important to note that the **economic benefits highlighted in this study should not be taken for granted**, nor are they indicative of a business-as-usual approach to technology development and deployment. **Significant effort, financial support and policy interventions will be essential**, even to reach the lower ambition scenarios outlined in this report. Without taking proactive and targeted steps, there is the very real possibility that the significant socioeconomic benefits associated with these tidal stream developments could be led by, or even lost completely to, overseas competition.

To ensure that Scotland secures these economic 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 device developers continue to develop innovative and cost-competitive technologies**, both in Scotland and across the globe.

Sustained support is also required to ensure that the **domestic supply chain is equipped to underpin device manufactures projects competitively and at increased volume**. This will require significant targeted investments in Scottish manufacturing capability to help realise significant supply chain opportunities for Scotland. This should be focused on the key device subsystems and areas of expertise identified in section 5. Investment will be required in a range of areas, including supply chain automation and digitalisation, future skills and training, plus the upgrading and modernising of manufacturing facilities. There should also be a focus on the continued development and promotion of Scotland's role as a services provider, opening up the opportunity to export Scottish expertise in a range of supporting sectors. Finally, opportunities to identify any technological overlaps or facilities development with other mature energy sectors, such as the offshore wind sector should also be prioritised.

The recent Clean Power 2030 Action Plan [13] also underlines the sense of urgency associated with the need to ensure the deployment of a diverse and robust energy system, in which emerging renewable technologies, including tidal stream, have a meaningful role to play. The tidal stream sector should be acutely aware of the scale of this opportunity, but should not take it for granted. A similar sense of urgency should also be felt by those developing the supply chain, for which the resulting GVA and jobs outlined in this report rely upon.

The following two sections provides a series of recommendations designed to guide and inform prospective policymakers on possible policy interventions, both for enabling the tidal stream sector and for developing the underpinning infrastructure to support these developments. Many of these will also be relevant for the emerging wave energy sector in future, which could potentially bring similar levels of additional benefits to Scotland [8]. The future supply chain for wave energy projects will likely have significant overlap with that of the tidal stream and offshore energy sectors.

## 6.3 Recommendations to enable the tidal stream sector

The first three recommendations, detailed below, aim to enable the development and growth of the tidal energy sector. These recommendations target the challenges directly facing the capabilities and capacities of both tidal stream de vice developers and the supply chain that supports the sector.

### Working with UK Government to support the future tidal stream market

This report has primarily focused on analysing the GVA and jobs associated with the deployment of 4.3 GW of tidal stream in Scotland and has examined the capacity of the Scottish supply chain to underpin this. However, it is important to underline the necessity of government-led financial support in realising and achieving these potential benefits. The UK Government's CfD scheme has so far played an important role in establishing a secure market for tidal stream developers. The ringfence for tidal stream projects has proved effective, with over 120 MW of contracts awarded across the UK in the past three auctions. As this is a UK Government policy, the Scottish Government needs to continue to collaborate closely with the UK Government to ensure there is an adequate and long-term market support mechanism in place. This could be the continuation and possible expansion of the CfD scheme and appropriate technology ringfence funds or the adoption of a new market pull mechanism with a similar aim to facilitate greater and faster deployment of tidal stream devices.

**Recommendation 1**

The continuation of **a well-funded market support mechanism**, such as the CfD, is the foundational step to **ensuring a market into which Scottish tidal stream developers can supply and deploy their devices**. This should be coupled with the **establishment of a highly visible and accountable future deployment ambition**, which will bolster the growth of the domestic market, provide clarity with regards to supply chain requirements and increase investor confidence in a range of supporting sectors.

## Sustaining innovation across Scottish tidal stream device developers

Alongside market support, significant innovation funding, drawing from both public and private sources, is required to enable incremental innovation to the already highly innovative market-leading tidal stream devices. This is vital to ensure that Scottish device developers continue to win projects, both here in Scotland and across the globe, maintaining and solidifying Scotland's position as a world-leader in tidal stream development.

**Recommendation 2**

**Targeted and sustained research and innovation support for tidal stream technology developers is essential** to ensure that Scotland builds upon and maintains the competitive edge that it has established in this sector. This is vital to ensure that **Scottish companies continue to innovate, reduce costs, win projects and deploy their devices,** in both domestic and international markets.

## Increasing the capabilities of Scottish supply chains

Supporting the development of the companies and organisations within the underlying supply chain, who ultimately will be responsible for the building of key subsystems and developing skills in relevant areas of expertise, is a complex task. Therefore, to ensure the sustained competitiveness of the sector and deliver high levels of Scottish content in future projects, with associated domestic GVA and jobs, it is vital that that support programmes prioritise the modernisation of the underpinning Scottish supply chain. While there is a clear need to strategically invest in the manufacture of key device subsystems, priority should also be given to sustaining and advancing Scottish areas of expertise in the marine operations service industry. Tackling both issues is particularly important so that the supply chain can competitively supply developers at the volumes required to support predicted sector growth.

**Recommendation 3**

**The modernisation of Scottish supply chain capabilities**, from the manufacture and utilisation of novel materials to the adoption of automation and digitalisation, should be **embraced and supported at all levels of the supply chain.** 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**. In areas of subsystem manufacture with **no clear market leader**, Scotland should position itself to maximise the benefit of investments into supply chain sophistication and **seize these all-to-play-for markets**. Policy support should be tailored to ensure that there is a **straightforward route towards the commercialisation of new ideas**, translating early-stage innovation into supply chain expertise and manufacturing capability.

## 6.4 Recommendations to develop underpinning infrastructure

The next three recommendations aim to target the challenges surrounding the development of infrastructure that underpins the future of both tidal stream device developers and the supply chain that supports them. These will also apply for wave energy projects in due course, giving additional benefits.

### Preparing a pipeline of sector-specific skills

Prioritising the development of soft infrastructures, for example, by ensuring that a visible pipeline of skilled workers will be readily available is a key consideration of any growing sector. This should also ensure that appropriate consideration has been given to the needs of both device developers and the companies and organisations that comprise the sector supply chain.

**Recommendation 4**

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 the roles of apprenticeships and existing workers transitioning from oil & gas and other relevant sectors, who often have transferable skillsets and exposure to the challenges of working in a marine environment.

### Fostering cross-sector collaboration

The high levels of investment already provided to support and grow other offshore energy sectors, such as the offshore wind sector, should be closely examined both for instances of potential collaboration and for examples of best practice and lessons learned.

**Recommendation 5**

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

### Development of necessary supporting infrastructure

The development of hard infrastructure, such as ports and harbours, will be required to build these projects, together with electricity grid upgrades to connect them. Grid constraints in Scotland are mostly from the north to south, both exporting renewable generation from the Highlands and Islands to the major load in the central belt, but also exporting that power from all of Scotland over the border into England. Early visibility of likely locations for tidal stream projects around Scotland's coast, together with geographical understanding of the resource, will help infrastructure planners accommodate their future requirements.

Recommendation 6

**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 also factor in the requirements and potential energy system benefits of the tidal stream sector**. **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.

## 6.5 Delivery of recommendations

The final recommendation, detailed below, outlines a potential pathway by which the successful delivery of the previous six recommendations can be led and championed by existing enterprise and innovation agencies within Scotland.

### Delivering innovation support in Scotland

The goals of sustained deployment of highly innovative tidal stream devices and the modernisation and enhancement of domestic supply chain capabilities are a complex task that will require ongoing oversight and coordination. Scotland is well positioned to utilise the experience of several well-established enterprise and focused innovation support organisations who have demonstrated multiple successful instances of managing the delivery of innovative technologies and devices at an accelerated and cost-effective rate. While this report lays out several areas where the application of targeted and high-level policy recommendations could be effective, these enterprise and innovation support organisations should establish a sector-specific strategic innovation programme with more granular detail and detailed policy actions.

Recommendation 7

Tasking and funding **existing innovation and support organisations** to oversee the **well-coordinated and accelerated delivery** of innovation in domestic tidal stream devices 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 projects** with high Scottish supply chain content.

# Closing message

This report outlines the potential economic benefit for Scotland from a successful tidal stream energy sector. These benefits accrue from developing, building and operating tidal stream projects, in Scotland, the rest of the UK, and from the global export market. There is the potential for 4.3 GW of tidal stream energy to be deployed in Scottish waters by 2050, contributing to 6.2 GW in the UK and 120 GW globally. Economic analysis in this report shows, that given the development of a robust domestic supply chain, there is the potential for domestic projects in Scotland and the rest of the UK to create over £4.4bn in GVA to the Scottish economy by 2050, and support almost 6,000 FTE jobs in 2050. Export markets offer even greater opportunity, of up to £11.8bn in GVA and 20,000 jobs associated with successful Scottish companies.

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

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 lead to the progression of the tidal stream sector overseas, 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 a sector that stands on the brink of large-scale commercialisation. It is therefore vital that in the coming years, Scotland works efficiently and collaboratively to maintain this position. In doing so it can establish a reputation as the premier location for the tidal stream sector 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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