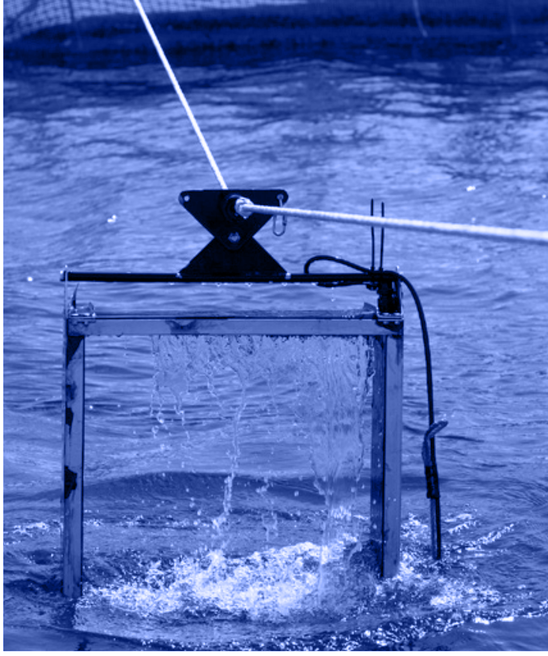
MAXiMAR:
MAXIMISING THE MARINE ECONOMY IN THE HIGHLANDS AND ISLANDS

A Science and Innovation Audit Report sponsored by the Department for Business, Energy and Industrial Strategy



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FOREWORD

The marine resource of the Highlands and Islands is an enviable and unique asset, not only for the region, but for Scotland and the whole United Kingdom. It has created and maintained valuable economic opportunities for generations, in sectors as varied as aquaculture, fisheries, life sciences, tourism and renewable energy. With the right strategic approach, and carefully targeted investment, we believe it has the potential to deliver much more, playing a key role in the contribution made by Scotland's rural economy and supporting a sustainable future for hundreds of communities around its coasts.

By setting out the remarkable variety and scale of activities that are currently supported by our marine resource, this audit provides a valuable frame of reference, and a platform for planning sustainable and inclusive economic growth.

Six months of consultation among industry, academic and public sector partners, has confirmed that the Highlands and Islands' marine-related sectors provide unique areas of specialisation, economic value, and demonstration opportunities for new, innovative technologies in the UK.

This had already been demonstrated within the wave and tidal energy sector by the world-leading European Marine Energy Centre in Orkney. The opportunity to build on this global asset and at the same time broaden the ambitions for aquaculture and marine biotechnology is significant.
The natural assets, including almost two thirds (61%) of the UK coastline and marine biological and physical resources, make the region second to none. The specialism is clear, and undertaking this Science and Innovation Audit (SIA) has awarded the opportunity to test it.

The marine economy of the Highlands and Islands spans multiple interdependent industries with well-established sectoral clusters and supply chains. Its growth faces significant challenges – including geography, which can make access difficult, and distance from Scotland's major universities. Seeking to identify the synergies between all the industries working under the sea is sensible and will help Scotland to unlock more cost-effective ways of operating, create more resilience within these industries and grow a more productive marine economy.

Specifically, Scotland's wave and tidal industries continue to push the boundaries in both technology and project development. While the sectors continue to face challenges finding a route to market, the publication of the UK Government's Industrial Strategy and the Scottish Government's draft Energy Strategy provide new opportunities to promote these industries and the progress they are making.

Aquaculture in Scotland is diverse, from the farming of salmon and other finfish species, to the production of mussels and oysters, to the harvesting of seaweed. It contributes over £1.8bn annually to Scotland's economy and sustains the economic and social fabric of the Highlands and Islands in particular. But the potential contribution of farming Scotland's seas is far greater.

By combining the most innovative and technology-hungry sectors, enhancing the scientific, industrial and physical assets, and focusing sharply on workforce requirements, the Highlands and Islands can become recognised as a driver of the UK's marine economy.

This audit is particularly timely given other current complementary developments including regional growth deals across the Islands, Moray and Argyll; Industrial Strategy challenge funding bids focused on food security and clean energy; and phase two planning for Scotland's Innovation Centres. The recently launched Future of the Sea Report also provides excellent direction through a strong set of well-aligned recommendations.

The SIA proves that the marine resource is already contributing significantly to national economic growth, and shines a light on its capacity to deliver even more. Maximising the enormous value of that resource is an opportunity that has the potential to benefit the whole country, both now and for future generations. We, the industry voice of these key marine sectors, strongly commend this report to you, and in doing so, congratulate the MAXiMAR consortium members on their excellent work to date, and spur them on, with our support, to address the key targeted opportunities identified.

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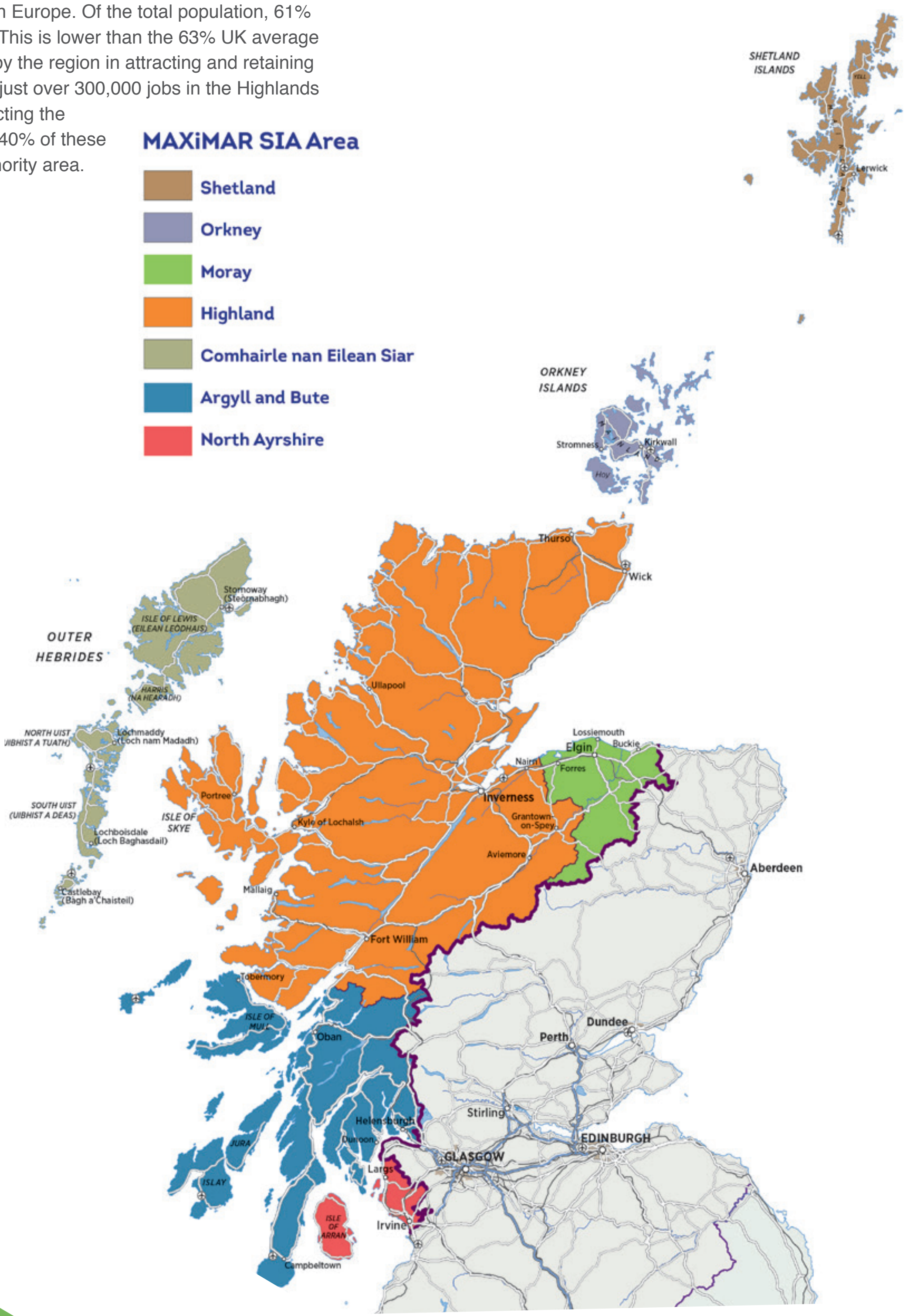
EXECUTIVE SUMMARY

At just over 40,000km^2, the Highlands and Islands region stretches from Shetland in the north to Campbeltown at the southern tip of Argyll, and from the Western Isles to Moray in the East.

In 2016 the total population for the Highlands and Islands SIA region was just over 625,000. It is a largely rural and sparsely populated area. With a population density of around 12 people per km^2, in comparison to 129 per km^2 in the rest of Scotland, the region has the lowest population density in the UK, and one of the lowest in Europe. Of the total population, 61% are of working age (aged 16-64). This is lower than the 63% UK average and reflects the difficulties faced by the region in attracting and retaining young people. In total there were just over 300,000 jobs in the Highlands and Islands region in 2016. Reflecting the concentration of population, over 40% of these were based in Highland local authority area.



INTRODUCTION AND CONTEXT

In Autumn 2015 the UK Government announced regional Science and Innovation Audits (SIAs) to catalyse a new approach to regional economic development. SIAs enable local consortia to focus on analysing regional strengths and identify mechanisms to realise their potential. In the Highlands and Islands, a consortium was formed in October 2016 to focus on our strength in the marine economy. This report presents the results which includes broad-ranging analysis of the Highlands and Islands marine economy capabilities, the challenges and the substantial opportunities for future economic growth.

There is worldwide recognition of the potential of the marine economy, for example for food security, for clean energy and to provide new solutions and a wide range of applications. It also has an enormous contribution to make to the circular economy agenda. The Highlands and Islands has an outstanding marine environment and contains almost two thirds of the UK's coastline and coastal waters. It is home to world class marine science and innovation.

The focus of the SIA is on aquaculture, wave and tidal energy and marine biotechnology which are the most highly innovative sectors in the region's marine economy. They offer the greatest growth potential and the opportunity to accelerate economic growth through strategic, focussed effort built on technological innovation.

- **Wave and tidal energy:** Scotland is the global leader of wave and tidal energy innovation, with the world's first commercial scale projects in development[1] and excellence across the supply chain. By harnessing the marine power of the Highlands and Islands region the UK will be able to position itself at the forefront of one of the untapped global clean energy industries of the future.
- **Aquaculture:** The Highlands and Islands is the largest aquaculture region in the UK, and the third largest salmon producer in the world[2], with the best premium for its produce. The increasing demand for fish protein is being driven by global population growth and rising affluence in developing countries. There is tremendous scope to increase sustainable production through the development and application of new science and technology.
- **Marine biotechnology:** The pristine marine environment, described as 'a huge and diverse 'underwater forest' is an extremely valuable but currently underused resource in the Highlands and Islands. It presents a huge growth opportunity with a diverse range of innovative applications in high growth, high value sectors such as health and life sciences, and energy.

Combining wave and tidal energy, aquaculture and marine biotechnology into a marine economy strategic framework will add value to each sector as well as to the region, and the UK overall. Investing now will secure Scotland's long-term position as a global leader in this field. The SIA demonstrates how the marine economy will take a place-based approach to deliver against the themes of the UK Industrial Strategy[3] and the Foresight Future of the Seas report. [4]It articulates the strategic opportunities for the marine economy and shows that innovators, infrastructure, capabilities and ideas are concentrated in the region. It also confirms that the region has the capacity to provide the necessary skills and assets for sustainable growth.

VISION

With our unique marine environment and our collective strengths in science and innovation, we will work collaboratively to accelerate the economic opportunities of the marine economy to benefit the Highlands and Islands, Scotland and the UK. In doing so, we will protect and respect the communities that are the custodians of this world-class resource.

[1] http://www.orkneymarinerenewables.com/crown-estate-leasing-round
[2] http://marineharvest.com/globalassets/investors/handbook/salmon-industry-handbook-2017.pdf

KEY STRENGTHS

The Highlands and Islands has a rich base of marine economy science, innovation and capabilities across a number of institutions and in industry. This, combined with its natural marine assets, makes it an unparalleled destination and resource for research, and the development of new ideas. The activities in the region act as a catalyst for new, often disruptive technologies.

There is a commitment to, and strong examples of, clustering and collaboration, cross-sectorally, and between industry and research. The region has an established and strong science and innovation infrastructure with a high degree of specialism in the marine economy. As a result it has a global reputation for research excellence and has attracted significant funding, along with world-class talent.

It is an enterprising region with a highly qualified workforce and a significant concentration of marine-economy based businesses. Growing the marine economy will increase the supply of higher value jobs and activities and will be a key component in realising UK growth ambitions. It will deliver economic and social benefits to the Highlands and Islands and help to support the sustainability of fragile communities.

GROWTH OPPORTUNITIES

The three sectors that comprise the marine economy are at different stages of development but for each, there is significant and demonstrable potential for growth. Though the sectors will grow at different rates, evidence points to a total value of the marine economy in Scotland of £5bn by 2035. Estimates suggest this is an approximate seven-fold increase on current values.

In aquaculture, the scale of the salmon industry drives much of the innovation investment, both for expansion (new cage design, smolt (young salmon) production, sites in more challenging locations) and tackling challenges (disease control). The industry in Scotland aims to double the value of production by 2030 to £3.6bn. Key to achieving the expansion will be tackling the issues through science and innovation.

Wave and tidal energy is moving into a new phase of innovation where it is seeking to commercialise and export knowledge, to 'capture the value' of new device innovation and systems learning to date. Current estimates indicate a potential value to the UK of £800m by 2035.

In marine biotechnology, significant applications are in early development and could impact across a range of high profile and important areas such as energy, human health, and food production. The potential value to the Highlands and Islands is expected to be £600m by 2030.

But it is not just the Highlands and Islands that will benefit, the marine economy in the region drives activities in, and impacts on, other parts of Scotland and across the UK. It also supports an extensive and diverse supply chain generating economic benefits and providing a wide range of employment opportunities.

Interdisciplinary capacity and the recognition of translational research opportunities are key to accelerated progress in the marine economy. The relatively small size of Scotland and the existing channels of communication make this more readily achievable. Smart technology in terms of unmanned vehicles, miniaturised sensors, data capture and pre-processing, and the handling of large datasets are core abilities that translate across each sector. Examples already include environmental and oceanographic monitoring, survey and planning.

GAP ANALYSIS

There is undoubtedly enormous potential for the development of the marine economy in the Highlands and Islands. However if the benefits for the UK are to be maximised and the economic benefits realised, there are some clear challenges that must be addressed. Failing to do so will inhibit growth and have a negative impact on the economic and social health of the Highlands and Islands.

There is currently a lack of clear routes to commercialise innovations and new technologies; there are some skills and gaps that will need to be addressed to make sure there is an adequate workforce to fuel sector growth; and current planning and regulation is working against innovation, commercialisation and expansion. There are some good examples of cross sector science, innovation and operational activities. However there is enormous scope to make much, much more of this by catalysing, clustering and capitalising on the wide range of the known, as well as the currently unanticipated opportunities.

With these gaps and issues in mind, four hypotheses of the MAXiMAR SIA were developed to provide a holistic and systematic framework to address the challenges in terms of:

- Having the mechanisms in place to support the commercialisation of the marine economy science and innovation assets and so realise the economic potential for the region, for Scotland and for the UK.
- Implementing a planning and regulatory framework that supports and encourages innovation and development, balanced with environmental sustainability and the needs of different user groups.
- Identifying opportunities and developing marine economy clusters in science, innovation and operations building on the strong networks and relationships in the region.
- Making sure that the right skills, education and workforce development opportunities, science and infrastructure are in place to fuel marine economy growth.

This is all achievable, it is within our grasp and there is the determination amongst the stakeholders across Scotland to work together to ensure that the opportunities are maximised.

[w] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693129/future-of-the-sea-report.pdf

TARGETED OPPORTUNITIES

The Targeted Opportunities have been developed with industry, education, the public sector and other key stakeholders working collaboratively. They address the particular challenges for the marine economy in the region. They are based on identified need, rather than being developed to target particular funding streams, however, they align with regional, Scottish and UK policy objectives. They will also be aligned with the developing Regional Deals in the Islands (Orkney, Shetland and the Outer Hebrides), Argyll & the Isles, and Moray. By driving these forward, the marine economy will contribute to the transformation of food production and clean affordable energy. Marine biotechnology also has a potential role in helping to meet the needs of an ageing population through innovations in human health.

Overarching the opportunities is the proposition that the marine economy should be developed by taking a whole-sector approach, for example to strategic planning, science and innovation, operations, funding and problem-solving. There is a great deal of intelligence, knowledge and experience in each sector. However, it is largely kept within each sector and in many cases, within individual institutions. Integrating the three sectors and adopting a strategic approach for the marine economy will enable this knowledge to be better shared between industry, academia and the public sector. Importantly, the community will form the fourth element of this quadruple helix so that the marine economy works with communities where possible and appropriate.

Flowing from the SIA will be a strategic plan for accessing funding for science, innovation and growth of the marine economy. There will also be opportunity to support and influence the development of a Sector Deal for the Marine Economy. We have developed four Targeted Opportunities; the first has three strands flowing from it.

1: REGIONAL CLUSTER MODEL FOR MARINE INNOVATION, TECHNOLOGY AND SKILLS	
THE CASE	Industry has expressed a need for access to high quality, state-of-the-art facilities, equipment and wider infrastructure to drive enhanced R&D and aid clustering, close to the marine environment. A number of key locations in the region host research and technology organisations which already support this, but they are not currently sufficiently resourced. There is a strong case for a major cluster development incorporating technology and sea-trial testing facilities and industry support mechanisms. It will incorporate enhanced marine training and skills development provision which will scale up training provision in the Highlands and Islands, and will align with other training providers across Scotland. There is an opportunity to develop an innovative partnership model that builds on the combined existing infrastructure to better meet the needs of industry, grow innovation in the sector, extend and expand the skills base, and attract new business to the region. A key element will be a pilot test site to explore the potential for, benefits of, and associated risks of clustering marine economy activity across the sectors, for example, use of drones and robotics in areas that offer different marine characteristics. New approaches would be developed, deployed and monitored, and lessons learnt and applied in the region and further afield. The regional cluster model would create the conditions to maximise innovation and support growth of the marine economy. It would facilitate collaboration and cross-sectoral working, provide a route to market for innovation and research, encourage entrepreneurship and business development. It would also add value to the existing innovation-supporting infrastructure. Underpinning the regional cluster model will be three critical strands: • 1a: Workforce development • 1b: Blue economy infrastructure investment plan • 1c: Science, research and industry: scale and alignment

1A: WORKFORCE DEVELOPMENT

There is potential to better exploit and facilitate cross-sectoral working, training and development, as well as workforce movement between sectors. There is also a need to understand current and emerging skills gaps and training requirements. This requires scaling up the provision of education and learning in the Highlands and Islands to anchor skills development in the region, align need with opportunity, and address both replacement and expansion demand in the labour market. This, along with upskilling the existing workforce to keep pace with new processes and developments is a key issue identified by industry and public sector partners, and one that the current skills system is not meeting. It will capitalise on the activities and partnership working of the network of marine training centres across Scotland.

1B: A MARINE ECONOMY INNOVATION INFRASTRUCTURE PLAN FOR SCOTLAND

Mapping the existing infrastructure to better understand current provision, and how it aligns with need will be critical in developing a targeted and proactive plan to ensure appropriate infrastructure is in place to develop and grow the marine economy science and innovation opportunity. This will be integral to the regional cluster model and will be driven by industry needs. It will identify the infrastructure, equipment, facilities, incubation and soft-landing space required across the three sectors, and include costed proposals targeting appropriate funding opportunities. The economic impact of a well-researched innovation infrastructure investment plan will be measured in terms of employment, productivity and GVA over a 30-50 year period, and this planned approach will accelerate realisation of the economic and social benefits generated by the marine economy.

The required capital investment will link to existing regional strategic infrastructure such as the European Marine Science Park, the European Marine Energy Centre and the Orkney Research & Innovation Campus.

1C: SCIENCE, RESEARCH AND INDUSTRY: SCALE AND ALIGNMENT

Marine economy research undertaken in institutions is often not well-aligned with the current and emerging needs of industry. There is a perceived imbalance between science that focuses on environmental factors and that which focuses on technology, process and product development. The current scale of research taking place in the region is also insufficient to meet the needs of the sector and so needs to be increased as well as better aligned. Academic research, located in close proximity to industrial activity, is a proven requirement. The regional cluster model will be central to delivering this. Two key components are required to ensure proper alignment of the science and research base in the region – ensuring it is industry-driven and ensuring that there is capacity to broaden the research activity. Both have been identified as key to accelerating the use of new technologies across the three sectors.

This will require growing the number of principal investigator and post-doctoral opportunities in the region at the various innovation sites, and providing collaborative challenge funding to encourage industry engagement and ensure focus is on the right industry challenges.

2: ROUTES TO MARKET	
THE CASE	The marine economy in the MAXiMAR SIA region has enormous potential with an international reach. However, each of the three sectors faces challenges in terms of realising the potential and commercialising innovation. The Highlands and Islands has the potential to produce large quantities of wave and tidal energy and contribute significantly to the development and provision of clean energy to UK and international markets. New technology is being developed and tested in the region and there is a need to optimise its value. However, the dated infrastructure to get the energy to market is inhibiting production, innovation, testing and development. There are four elements to this opportunity: connecting the production areas to the National Grid; providing a range of 'routes to market' support mechanism for example through Contracts for Difference, time limited enhanced fee tariffs and/or through the tax system; bringing activities that need power to the source, rather than relying on the power being routed to the activities; capturing the potential of hydrogen production from wave and tidal as a power source. Marine biotechnology is the least developed of the three sectors and has enormous largely untapped potential. Despite its assets, the UK trade balance for marine biotechnology is negative and worsening as a result of persistent failure to remove the barriers and challenges to commercialisation of marine biotechnology science and innovation. The Targeted Opportunities in in the SIA will be an important toolkit for addressing some of the barriers i.e. planning and regulation and an innovation cluster. However, specific mechanisms will be established to support marine biology enterprises to develop and take their products to market. It will include specialist scale-up support and support to access financial investment and de-risking strategies. Aquaculture is relatively well established as a sector and very well established in the region, with many large vertically integrated producers. However, small scale innovative companies and entrepreneurs in Scotland face structural and geographical barriers to access the Scottish market. They frequently have to take their innovations overseas and sell them into competitor markets. This impacts on the companies and means that the UK and the sector in Scotland is losing the benefits of the innovations and potential gains in efficiency and productivity, and subsequently losing global market share. Increasing the active support for collaboration between the small innovators and the larger companies will raise awareness of the innovative work and opportunities, leading to joint projects. In addition, financial mechanisms to temporarily reduce the cost to larger companies of testing new innovations would help to remove some of the barriers. This opportunity and the objectives and activities within it will increase the economic value of the Scottish marine economy. It will allow more enterprises to commercialise their innovations and increase the number of enterprises active in the market. It will also help to exploit international markets

3: REFRESHED PLANNING AND REGULATION FRAMEWORK FOR THE MARINE ECONOMY	
THE CASE	There is important learning from other countries on developing and implementing proactive planning and regulation that supports sustainable development. A strategic, refreshed framework is key to facilitating innovation, research and development, taking an active management approach, through a process of survey, deploy and monitor, supporting a collaborative approach between regulator(s) and science, innovation and industry. This will require the acceleration of decision-making and reduced costs from a refreshed regulatory framework agreed to the public and private sector. This would lead to the faster realisation of economic benefits generated by the industry, as well as increased productivity through a reduction in unnecessary regulatory costs. A highly successful process for the planning and regulation to support the deployment of wave and tidal machines in our coastal waters in Scotland is already being implemented. Learning from this and applying new approaches across the wider marine sector could be advantageous.

4: A REGIONAL MARINE ECONOMY PROSPECTUS	
THE CASE	The Highlands and Islands has very strong, and in many ways unique marine economy research capabilities, opportunities and assets. It also has a global reputation for some of its activities and products, but crucially there is a lack of informed knowledge and detailed understanding, worldwide, about its marine specialisation. There is also a lack of an accurate understanding about the research and career opportunities offered by the marine economy in the region amongst both local residents and those living, working and studying out with the Highlands and Islands. The prospectus will help the region promote itself globally to a range of audiences. It will also be a tool for individual organisations, including industry partners, to use. This will help to attract new research and innovation, inward investment, new enterprises, business growth and in talent recruitment and retention.

CLOSING REMARKS

The SIA has been an extremely helpful process and has highlighted the opportunities for the marine economy and the challenges that the public sector, industry and academia will work together to address. New relationships have been established and existing partnerships galvanised.

Through it, we have a very clear, evidence-based understanding of the marine economy and a definitive and agreed agenda to develop it in cross-sectoral partnership. We will work collectively for the long term to realise the ambitions of the SIA and respond positively to the changing context which we will undoubtedly face. We will advance science and innovation to benefit people in the Highlands and Islands, businesses and the wider economy. However, the reach of the SIA's benefits will go far beyond our geographic boundaries, to Scotland, the UK and internationally.

Developing the SIA has demonstrated our combined ability to think innovatively, challenge assumptions and be confident in the unique opportunity that we have in the Highlands and Islands. We are now ready to realise that opportunity.

1: INTRODUCTION TO THE REGION AND SIA AREA

THE MARINE ECONOMY IN THE HIGHLANDS AND ISLANDS: THE HEADLINES

- The Science and Innovation Audit (SIA) reflects the consortium's ambition for the sustainable growth and development of the marine economy, based on the strengths and assets of the Highlands and Islands and the wider strengths in Scotland.
- The focus of the SIA is on aquaculture, marine biotechnology and wave and tidal energy as the most highly innovative sectors in the marine economy with the highest growth potential.
- The scale and combination of its natural marine assets, enterprise, science and innovation capabilities make it a unique place to conduct research, develop new technologies and grow the marine economy in a sustainable way.
- These assets and capabilities drive research and economic activity in other parts of Scotland and across the UK.
- Partners in the region, across industry, education, research and the public sector, have strong and established relationships. There is a dispersed network of expertise with the commitment to pull together and build on the region's assets.
- There is a single agreed plan, with clear objectives and priorities to tackle challenges, remove barriers and maximise the combined economic contribution of aquaculture, marine biotechnology and wave and tidal energy.
- The consortium's focus is on commercialising innovations by aligning science and research with the needs and opportunities in industry.
- The marine economy in the Highlands and Islands is ideally positioned to deliver against the UK Industrial Strategy. Our ambitions are international, capitalising on the steep growth of the blue economy.

1.1: THE HIGHLANDS AND ISLANDS SIA REGION

Overview

1.1.1 The Highlands and Islands has an outstanding marine environment and contains almost two thirds of the UK's coastline and coastal waters. It is not only a global destination for its beauty and natural assets, it is also home to world class in marine science and innovation. The focus of the SIA is on aquaculture, marine biotechnology and wave and tidal energy which are the most highly innovative sectors in the marine economy. They offer the highest growth potential and the opportunity to accelerate economic growth through strategic, focussed effort built on technological innovation.

- **Aquaculture:** The Highlands and Islands is the largest aquaculture region in the UK, and the third largest salmon producer in the world[1], with the best premium for its produce. The increasing demand for fish protein is being driven by global population growth and rising affluence in developing countries.
- **Marine biotechnology:** The relatively pristine marine environment described as 'a huge and diverse 'underwater forest' is an extremely valuable resource that is currently underused. It presents a high growth opportunity with multiple innovative applications in high growth, high value sectors such as health and life sciences, and energy.
- **Wave and tidal energy:** Scotland is the global leader of wave and tidal energy innovation, with the world's first commercial scale projects in development[2] in surrounding waters and excellence across the supply chain. By harnessing the marine power of the Highlands and Islands region the UK will be able to position itself at the forefront of one of the untapped global clean energy industries of the future.

1.1.2 The marine economy in the Highlands and Islands spans a diverse range of primary, manufacturing and research activities. There is a continuing trend towards technological developments, with increased use of robotics, automation, digitalisation and advanced control over production systems. It is the innovation capabilities, the strengths of these sectors and the cross-sectoral opportunities that the outcomes of the MAXiMAR SIA will capture and build on.

1.1.3 The SIA demonstrates how the marine economy will take a place-based approach to deliver against the themes of the UK Industrial Strategy[3] and the Foresight Future of the Seas report. [4]It articulates the strategic opportunities for the marine economy and shows that innovators, infrastructure, capabilities and ideas are concentrated in the region. It also confirms that the region has the capacity to provide the necessary skills and assets for sustainable growth.

1.1.4 Combining aquaculture, marine biotechnology and wave and tidal energy into a marine economy strategic framework will add value to each sector as well as to the region, and the UK overall. Investing now will secure Scotland's long-term position as a global leader in the marine economy.

[1]http://marineharvest.com/globalassets/investors/handbook/salmon-industry-handbook-2017.pdf
[2]http://www.orkneymarinerenewables.com/crown-estate-leasing-round

The SIA Region

1.1.5 Whilst the Highlands and Islands shares some characteristics with other rural and coastal regions of the UK, its combination of isolated communities, environmental, social and economic characteristics makes it unique. Reflecting this, its industrial strategy must encompass social development and demographics along with the necessary infrastructure and opportunities so that people can and will choose to work in this exceptional environment.

1.1.6 Attracting and retaining young people[5], skills and talent is a priority for public and private organisations and recent estimates suggest that 80,800 new workers will be required in the region by 2028 to meet replacement and growth demand. [6]Around half will be filled by people qualified to SCQF level 7 or above. Compounding this are the implications of Brexit on the supply of labour in the region and in key industries such as aquaculture. Specific to the SIA, the Skills Investment Plan for the Highlands and Islands highlights a shortage of engineering skills in the marine and energy sectors.[7]

1.1.7 The region's population has been growing slightly, but ageing. In 2016, the region had a population of just over 625,000 people[8] and around 61% were of working age. Research for Highlands and Islands Enterprise (HIE) demonstrates that there is scope to attract and retain a young workforce. The research, based on a sample of 4,400 found that many young people from and in the Highlands and Islands are committed to staying in the region to work, if the opportunities are there to allow them to do so. A significant number of young people are aware of and interested in working in the growth sectors, and would like to live and work in their local communities. This would provide an available workforce for marine economy employers to recruit from.[9,10]

1.1.8 There were just over 300,000 jobs based in the Highlands and Islands in 2016 and average annual earnings of residents was slightly behind the UK and Scottish averages. Associated with this, low productivity is a persistent challenge. At £22,629 in 2015, it is close to but below the Scottish average of just over £23,500, but substantially lower than the UK average which is £25,351. Gross Value Added (GVA) for the Highlands and Islands was £12,540m, however its resource base and upstream activity is the catalyst of many Scottish sectors, including energy, food and drink (e.g. whisky and salmon) and tourism, and so its contribution is more significant than GVA might suggest.

1.1.9 Businesses in the Highlands and Islands invest less in research and development (R&D) than businesses in the UK and Scotland. This will impact negatively on growth and productivity. In 2015, 265 businesses in the Highlands and Islands were involved in R&D[11] accounting for 9% of the Scottish total. This is less than the region's share of the national business base (13%) so points to relatively low R&D activity. In 2016, Business Enterprise Research and Development (BERD) expenditure in the region (a measure of R&D investment by industry) was just under £40m, 3% of total Scottish BERD. Per head of population it was £63, compared to £198 in Scotland and £339 in the UK. [12]From 2001 to 2011, BERD increased in the region but has since declined sharply. Encouraging industry investment in R&D through the priorities and activities flowing from the SIA will be a very positive outcome.

1.1.10 The sub-regions of the Highlands and Islands vary in geography, population, infrastructure, and the extent and characteristics of their marine space. A map of the region and its local authority areas and a map of Scotland's territorial waters are provided at Appendices 1a and 1b. Oban is the population and geographic centre in the south west. It is a centre for research, primarily through the University of the Highlands and Islands' **Scottish Association for Marine Science (SAMS UHI)** which specialises in marine environment research. Oban is also a hub for private sector marine economy activity with a range of research-active enterprises based on the **European Marine Science Park (EMSP)**. Further north, Fort William and the West Highlands coast has vibrant marine activity including new investments in salmon feed processing, genetics research, diving and robotics. Internationally renowned training of an international subsea workforce has been taking place at the Underwater Centre in Fort William for over 40 years, and the facilities, technical support and technology have been used more recently for hosting subsea trials. Orkney is a hub for wave and tidal energy research and Shetland has a specialism in shellfish production. The **North Atlantic Fisheries College (NAFC)** Marine Centre is also based in Shetland. In marine biotechnology, BASF Pharma is a key asset. It has operations on the Isle of Lewis, and attracts researchers and pharmaceutical companies to use its facilities. This dispersed and wide-ranging capacity provides valuable learning opportunities and diverse environments for science, research and the strategic, integrated development of the marine economy. Despite the variations and dispersal, there is a coherence and tangible synergies across the activities and sectors.

3 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
4 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693129/future-of-the-sea-report.pdf
5 http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/youth-migration.html
6 Regional Skills Assessment for the Highlands and Islands, Skills Development Scotland, 2017
7 Skills Investment Plan for Highlands and Islands, Skills Development Scotland and HIE, 2014
8 The SIA area is comprised up of the seven local authorities wholly, or partly, making up the Highlands and Islands. Socio-demographic data used to describe the SIA area represents the cumulative total of the local authority areas, rather than the NUTS 2 level data more typically used.
9 ekosgen, Whitewall, Reference Economics/HIE (2015) Our Next Generation: Young people and the Highlands and Islands: Attitudes and aspirations research
10 ekosgen/HIE (2016) The Young Workforce in the Highlands and Islands: Supporting Inward Investment
11 BERD Survey, ONS and Scottish Government
12 BERD Survey, ONS and Scottish Government

1.2: RATIONALE FOR THE SIA AND THE HYPOTHESES

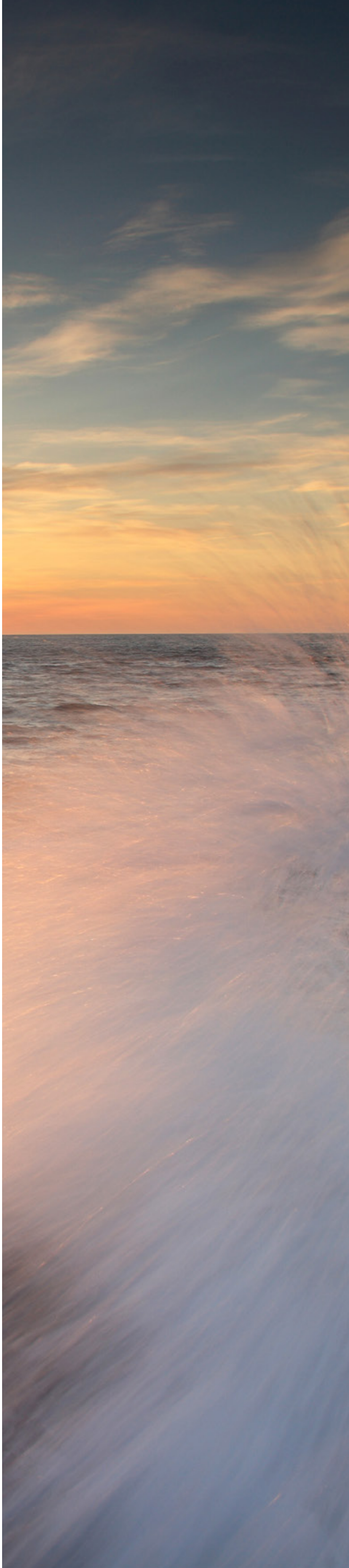
1.2.1 There is worldwide recognition of the potential of the marine, or 'blue' economy, for example, for food security to feed the growing population, for clean energy, and to provide new solutions and diverse applications through capturing the opportunities of marine biotechnology. Illustrating this, the European Union's (EU's) Blue Growth Strategy[13] sets out its long-term plan to support the sustainable growth of the marine and maritime sector. Covering the three MAXiMAR SIA sectors, the strategy recognises the importance of the seas and oceans as economic drivers and the potential for innovation and growth.

1.2.2 The marine environment in the Highlands and Islands provides a high quality, abundant and underused resource. Its assets are among the best in the world, giving the region, Scotland and the whole of the UK incredible potential to generate substantial economic growth. Marine economy research organisations and industry are in place in the region and in the wider Scottish ecosystem. They are already working collaboratively and this collaboration between industry, the public sector and research organisations has been integral to the SIA process. There are heat spots of concentrated effort and clustering of science, research and innovation. The research capabilities, organisational dynamics and the natural resource, makes it an unparalleled place to conduct marine economy research and it has a global reputation as a research destination. The Highlands and Islands is therefore ideally positioned to provide place-based innovation and development in the marine economy. It will also be a major contributor to the UK's ambitions set out in the Future of the Seas report.[14]

1.2.3 Despite these undoubted strengths, there is work to do to realise the potential, and scope to add value through careful and planned strategic development combining cross-cutting themes, moving towards a marine economy Sector Deal. [15]

1.2.4 The island areas have particular regulatory systems other areas in the UK can learn from. Shetland, for example, has had greater autonomy on planning and revenues from development, and the effectiveness of this has demonstrated where other parts of the region may benefit from more control over marine development in future. This thinking has informed the Islands (Scotland) Bill which intends to establish a National Islands Plan. [16]Through this plan the islands will assume various administrative powers and determine their own community and economic priorities. Argyll and Bute is currently exploring the option of an Argyll and Bute Rural Growth Deal, an 'Islands Deal' is planned, and the Inverness and Highlands City Region Deal was signed in 2017. There are clear opportunities for the marine economy within these deals. The move towards regionalisation is reflected in the National Marine Plan (NMP) process which is now moving towards regional marine planning.

1.2.5 In thinking about the potential of the marine economy, it is important to consider the strong economic and scientific linkages with other parts of Scotland and the UK. Many of the wealth generating activities in aquaculture, marine biotechnology and wave and tidal energy are located in the Highlands and Islands to be close to the natural capital of the coastline. In practice, these businesses along with science and research activities can often be based and registered in, or drive activity from Scotland's Central Belt (Glasgow, Stirling, Edinburgh) or Aberdeen's oil and gas community. This leads to under-attribution of activities and successes to the Highlands and Islands, whilst it is acting as a research and economic catalyst for growth more widely. For example, Atlantic salmon exports coming out of the Highlands and Islands now stand at £600m[17], though many salmon producers are headquartered outside the region and downstream processing and logistics stretch across Scotland and as far as Grimsby and Heathrow. The added value that could be delivered through the SIA will therefore have far-reaching benefits.



[13] EU Blue Growth Strategy (2012) Government Office for Science (2018) Foresight: Future of the Sea
[14] Government Office for Science (2018) Foresight: Future of the Sea
[15] https://www.gov.uk/government/publications/industrial-strategy-sector-deals/introduction-to-sector-deals
[16] https://digitalpublications.parliament.scot/ResearchBriefings/Report/2017/9/4/Islands--Scotland--Bill-1
[17] http://scottishsalmon.co.uk/salmon-exports-reach-record-600m/

1.2.6 The development of the SIA is based on four hypotheses developed by the consortium and tested with stakeholders. They are summarised here and provided in full in Appendix 2.

1	Capturing the value of the marine economy	The marine economy is a significant engine for economic and social development and will grow and become economically and environmentally sustainable pillars of the Scottish and UK economy over the next 20 years if managed appropriately.
2	Planning, Policy and Regulatory frameworks	The development of a flexible, responsive and collaborative regulatory framework, as can be seen with renewables, across the whole marine environment will stimulate innovation and economic growth while protecting the natural environment.
3	Cross-sector clustering	Creating multi-sector clusters of marine energy, biotechnology and aquaculture organisations (incorporating industry and academia) will result in significantly increased growth and innovation rates for the marine sector.
4	People, Education, Science and Infrastructure	Growth of the marine economy is outpacing the current availability of a skilled workforce and the availability of appropriate training and education within the region: a multi-faceted strategy of investment in skills, education, science and innovation is required.

1.2.7 The MAXiMAR SIA covers the factors relating to marine economy current capability and future potential at three levels:

- At a macro level it considers demographic requirements, including talent retention and attraction; infrastructure; and connectivity.
- At a sectoral level, it looks at science and research assets and activities that are driving game-changing innovation; the value of the supply chain; skills and workforce development; and planning and regulation.
- At a micro or site level, the SIA identifies scope for science, innovation and operational clustering; the circular economy; and knowledge exchange.

1.3: SCIENCE AND INNOVATION ACTIVITIES

1.3.1 The region's science and innovation assets are mapped in Appendices 1c and 1d. The maps illustrate how the assets are dispersed across the region as well as the heat spots of research clustering.

2: STRENGTHS IN SCIENCE AND INNOVATION

STRENGTHS IN SCIENCE AND INNOVATION: THE HEADLINES

- The region has a proven track record of building and exploiting strengths in research, innovation and industry.
- We develop innovative solutions to the issues that face our region including service delivery in rural areas (e.g. education and business support), partnership working and infrastructure.
- It is an enterprising region with a highly qualified workforce and a significant concentration in marine economy businesses and employment.
- We have an established and strong science and innovation infrastructure with a high degree of specialism in the marine economy through our world class centres and people. This has attracted major funding and a diverse range of international research collaborations.
- By growing the marine economy, we will increase the supply of high value jobs and activities located in the region.
- The consortium will develop value adding clusters, from cross-sectoral science and innovation, through to clustering of operational activities and strategic approaches to addressing structural challenges such as talent attraction and infrastructure.

2.1: EXCELLENCE IN SCIENCE AND RESEARCH

A strong basis

2.1.1 The Highlands and Islands has a rich base of marine economy science and innovation assets. There is strong collaboration between research centres in the region, as well as nationally and internationally. There is an active and ongoing commitment for cross-sectoral research between aquaculture, marine biotechnology and wave and tidal energy. This has the potential to address shared challenges, apply and build on learning through knowledge exchange and develop inter-sector solutions.

2.1.2 Underpinning the research are the opportunities provided by the region's natural assets that make it a destination and resource for marine economy-related researchers from outside the region and outside the UK. It is a catalyst and attractor for new research and innovative ideas and developments, including potentially disruptive technologies. With this concentration of assets and capability, and examples of sector clustering, the Highlands and Islands is building a global reputation for marine economy research. It offers unparalleled opportunities to realise the UK's ambitions for growth, including those set out in the Foresight Future of the Seas report.[18]

Science and innovation

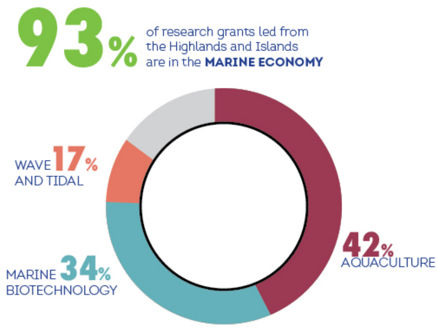
2.1.3 Further and Higher Education (FE and HE) and research in the Highlands and Islands is currently shaped according to the individual sectors and disciplines through the education providers set out in Appendix 3. In the region, almost 100 organisations participated a total of 322 times in publicly funded research projects (2007 to 2017). However, these 100 organisations participated less often than counterparts in other parts of Scotland, suggesting they are less intensively involved in publicly funded research. In the same period 41 organisations from the Highlands and Islands participated almost 100 times in EU funded research. This equates to 11% and 4% of the total for Scotland, pointing to the heavier reliance in the region on EU rather than UK funding.

2.1.4 Demonstrating the Highlands and Islands' marine economy research specialism approximately three quarters of the organisations from the region who have taken part in EU Framework Programme funded research work in aquaculture, marine biotechnology or wave and tidal energy. Added to this, approximately 40% of organisations from the Highlands and Islands who have participated in UK publicly funded research work in the marine economy.

2.1.5 It is clear then that research specialisation of the marine economy in the SIA region is highly concentrated. The three sectors combined account for 93% of all research grants being led by organisations from the Highlands and Islands. This is reflected in the very high location quotients (LQs) for populations active in these topics in the Highlands and Islands evidencing the high concentration of research activity.

2.1.6 Though by no means exclusively, a sizeable proportion of the marine economy research in the Highlands and Islands involves SAMS UHI. Specialising in research and postgraduate HE, SAMS UHI focuses on the marine environment, examining how it functions, how this is changing and how it can be better used and managed to minimise environmental impact. Between 2007 and 2017 SAMS UHI participated in 51 marine biotechnology projects, 46 aquaculture projects, and 31 wave and tidal-related projects, accounting for 44% of all marine economy projects involving organisations in the Highlands and Islands.[19]

2.1.7 For UK publicly funded research, apart from SAMS UHI the only other organisations in the Highlands and Islands that have participated in more than seven projects are Scottish and Southern Energy and UHI (in its entirety). [20]Both organisations undertake research relevant to the SIA.



[18] Government Office for Science (2018) Foresight: Future of the Sea
[19] Gateway to Research, 2018; Technopolis analysis
[20] SAMS and UHI are identified separately as UHI includes as 13 academic partners, and will include research awarded centrally via the executive office.

2.1.8 In addition to the research capacity in the diverse and specialised UHI partner colleges, other universities base and conduct research in the region through collaboration, institutes and campuses. For example, **Heriot-Watt University** has the **International Centre for Island Technology (ICIT)** in Orkney, and the **Stirling Institute of Aquaculture** operates the **Marine Environmental Research Laboratory (MERL)** at Machrihanish. MERL is one of the largest Marine Aquaculture research facilities in Europe. It provides contract research services and hires facilities to industry and academic institutions. It recently received a grant to increase the number of research tanks[21] and a commercial wrasse hatchery is planned for the site.[22]

2.1.9 Between 2007 and 2017, 150 Highlands and Islands-led projects received £31.12m in funding from UK research councils. This includes 41 Innovate UK projects, which received £3.16m funding. A further 80 EU Framework Programme funded research projects were led from the Highlands and Islands, these projects received £368.33m in funding. The number of participations is higher than the number of Highlands and Islands led projects as participations includes projects that have been led from outside the region but have included Highlands and Islands based organisations on the research team. Smaller research units operate privately, including FAI Farms at Ardtoe and North Bay Shellfish.

2.1.10 In 2015, 50 blue growth businesses located in the region were performing R&D activities accounting for a total expenditure of almost £3.5m and employing over 50 full-time equivalents (FTEs). A higher share of blue growth industry businesses, with 10 or more employees, based in the Highlands and Islands are actively innovating than in the industry across Scotland (56% v 52%). This is also above the share of businesses across all sectors in Scotland, with ten or more employees, actively innovating (50%).[23]

2.1.11 Just under 60 large-scale R&D grants have been secured by companies in the Highlands and Islands working in related sectors. In total 59 aquaculture, marine science and energy (including marine energy) projects have received just under €33m from the EU FP7 and Horizon 2020 programmes. Aquaculture, marine science and energy projects account for approximately 95% of the total value of FP7 and Horizon 2020 funding received in the region. [24]Further, marine economy related companies have received HIE Regional Selective Assistance, discretionary grants for developing projects in Scotland that will directly create or safeguard jobs. In total over £24m in funding has been provided to companies within blue growth industries.

2.1.12 Sectoral research and innovation is strongly influenced by sector specific innovation centres and facilities namely: the Scottish Aquaculture Innovation Centre (SAIC) for aquaculture, European Marine Energy Centre (EMEC) for wave and tidal energy, and the Industrial Biotechnology Innovation Centre (IBioIC) for marine biotechnology (although it operates across biotechnology). These are strong entry points for the marine economy, having strong links with industry and being an important component of the continuum between science, innovation and the market.

2.1.13 A list of active organisations within each of the marine economy sectors is provided in Appendix 4 and covered more fully in the thematic chapters. These include universities and innovating companies as well as UK publicly funded research.

2.2: INNOVATION STRENGTHS AND GROWTH POINTS

2.2.1 Business growth can be critical for innovation. In 2017 there were 22,295 enterprises across the Highlands and Islands, giving a ratio of 57.0 companies per 1,000 of the adult (16+) population, significantly higher than the Scottish and UK rates (39.3 and 49.4 respectively).[25] Business start-ups can be particularly important for innovation. Across the region there were 32.8 start-ups per 10,000 of the adult (16+) population in 2015, notably higher than the Scottish average of 26.2. In the Highlands and Islands, all local authority areas bar Shetland and Eilean Siar have a higher rate of business starts than the Scottish average, highest in Highland (38.6) and Orkney (38.0).[26]

2.2.2 Each of the three sectors of the marine economy are at different stages of development and they all have strengths as well as opportunities in current science and innovation that should be exploited.

2.2.3 In aquaculture, the scale of the salmon industry drives much of the innovation investment in the sector, both for expansion (new cage design, smolt (young salmon) production, sites in more challenging locations) and tackling challenges (disease control). The industry in Scotland aims to double the value of production by 2030, and achieving this will require a high degree of innovation across the sector.

2.2.4 Wave and tidal energy is moving into a new phase of innovation where it is seeking to commercialise and export knowledge, to 'capture the value' of new device innovation and systems learning to date.

2.2.5 In marine biotechnology, significant applications are in early development and could impact across a range of high profile and important areas such as energy, human health, and food production.

> There are potential synergistic benefits for marine economy sectors, and the wider marine environment of researching bio-remediation techniques to deal with man-made contaminants such as plastics.

[21] http://news.hie.co.uk/all-news/expansion-planned-for-argyll-based-international-research-facility/
[22] https://www.fishfarmingexpert.com/article/planners-give-green-light-for-wrasse-hatchery/
[23] Business Enterprise Research and Development Survey, ONS and Scottish Government; from HIE/REID Consulting (2017) Business Cluster Specialisation in the Highlands and Islands
[24] These including to public and private sector beneficiaries such as UHI, SAMS, EMEC, Western Isles Council, Viking Fish Farms Ltd, Hebridean Seaweed Company Ltd and Fusion Marine Ltd. AWS Ocean Energy Ltd (£15.4m, 2012), Scotrenewables Tidal Power Ltd (£7.2m, 2012) and Sustainable Marine Energy Ltd (£2.4m, 2015) all received significant SMART Scotland grant awards for feasibility projects.
[25] IDBR 2017 and National Records of Scotland Mid-Year Estimates 2016.
[26] Committee of Scottish Clearing Bankers, 2015 and National Records of Scotland 2015 Mid-Year Estimates.

2.2.6 Interdisciplinary capacity and the recognition of translational research opportunities are key to accelerated progress. The relatively small size of Scotland and the existing communication channels make this more readily achievable. Smart technology in terms of unmanned vehicles, miniaturised sensors, data capture and pre-processing, and the handling of large datasets are core abilities that translate across each sector. Examples already include environmental and oceanographic monitoring, survey and planning.

2.2.7 The marine economy is supported by a strong innovation network infrastructure and there is an ethos of co-operation among research organisations. UHI hosts a number of research centres with specialisms that span the marine economy including the NAFC Marine Centre, SAMS, and the **Environmental Research Institution (ERI)**. HIE operates a number of facilities to support innovation in this field, such as the EMSP. EMEC provides world-leading facilities for applied marine energy R&D projects. The **Marine Alliance for Science and Technology for Scotland (MASTS)** is a consortium of 15 marine science research organisations that aims to improve co-ordination and collaboration and so secure Scotland's place as an international player.

Highlands and Islands Enterprise support for innovation

2.2.8 HIE, alongside the Scottish Funding Council (SFC) and Scottish Enterprise (SE), established Scotland's eight Innovation Centres, including SAIC and IBioIC. HIE's innovation team supports around 400 businesses annually and its Northern Innovation Hub supports small and medium enterprises to grow through product, process and systems innovation. Intensive innovation support and Intellectual Property advice is provided to account managed business and the Co-Innovate project encourages businesses and institutions in the Highlands and Islands to take part in cross border collaborations with Ireland including renewables, agri-tech and life sciences.

2.2.9 HIE has also been working with the **Scottish Centre of Excellence** in Satellite Applications (SoXSA) who are exploring economic development applications for satellite-derived data including mapping seaweed resources, monitoring fish farms and surveying wave and tidal arrays.

Major public and private innovation assets

2.2.10 The region has high quality and diverse science and innovation assets that are valuable building blocks for the development of the marine economy. Whilst many of these are located in the region or have operations there, there is also significant capacity in other parts of Scotland that adds value to research and the marine economy in the Highlands and Islands. Examples include **SAIC, MASTS, the Offshore Renewable Energy (ORE) Catapult, IBioIC, and Marine Scotland Science (MSS).** Achieving the undoubted potential will require investment and collaboration across the public, private and research sectors within and outwith the region.

2.2.11 UHI comprises 13 partner colleges and research centres across the region. Marine science is a key research and curriculum theme for UHI and the partner colleges. The NAFC Marine Centre is the largest marine training provider in Scotland, while other UHI institutions in Orkney and the Scottish mainland provide education, research and training across the Highlands and Islands.

2.2.12 The ERI, part of North Highland College and UHI, is a centre for environmental research, a major theme being renewable energy and the environment. This includes marine energy resource assessment and is a good example of where research in one sector, for example hydrodynamic modelling or remotely operated vehicles, is transferable to another sector. Many of these assets and core capabilities are driving innovation in non-research specific areas of the supply chain. The Underwater Centre in Fort William is an example of where private provision of core industry skills and test and demonstration capabilities has cut across a range of sub-sectors in the marine economy.

2.2.13 EMEC has supported the delivery of over 100 collaborative marine energy R&D projects, with the total project value over £200m. A significant cluster of activity is emerging in Orkney around EMEC and complementary services and research organisations, and a new Research and Innovation Campus (ORIC) to focus on marine renewables, energy and the low carbon sector will be based there. Announced in March 2018, this £6.5m project includes investment from HIE, Orkney Islands Council and the Scottish Government.

2.2.14 Despite overall low industry spend in R&D in the region, marine economy companies are important innovation assets – the private sector plays a key role in innovation. Aquaculture, with over £1bn of Scottish supply chain, includes large international players who co-fund innovation across the sector through SAIC. SAIC supports public and privately funded research projects to address pressing research needs faced by industry, predominantly operating in the Highlands and Islands region. So far it has enabled the delivery of 21 collaborative projects with a total value of £18m.

2.2.15 The University of Aberdeen's **Lighthouse Field Station's** work on how natural and man-made changes in environmental conditions influence the biology of marine mammals and seabirds; its **Marine Biodiscovery Centre**; and **Scotland's Rural University College (SRUC)** epidemiology and AgriMetrics team in Inverness, bring additional scientific expertise to the region's marine economy.

> There is potential to use biotechnology to prevent corrosion in the marine environment which would benefit aquaculture, wave and tidal energy and marine biotechnology.

2.2.16 The major research assets located in the Highlands and Islands and undertaking research in the marine economy are set out at Table 2.1.

2.2.17 It is clear that the MAXiMAR SIA region has significant strengths in marine economy science and innovation. It has a huge, largely untapped natural resource and a worldwide profile that attracts research and talent. However, the key message is that whilst it has all of these strengths, it faces some challenges in optimising the potential. If the SIA helps to release this potential then it will have regional, national and global impact.

Table 2.1: Research Entry Points in the SIA Region

NAME	ABBREVIATION	SECTORAL RELEVANCE	TYPE	LOCATION
Lighthouse Field Station, University of Aberdeen		Marine biology, sea mammals	Research Field Station	Cromarty & Aberdeen
Environmental Research Institution, UHI	ERI	Wave and tidal energy	Non-profit environmental research (including marine energy)	Thurso
European Marine Energy Centre	EMEC	Wave and tidal energy	Research & Innovation Test and Demonstration Centre	Stromness, Orkney
Highlands and Islands Enterprise	HIE	Marine economy supply-chain and Highlands and Islands development	Regional economic and community development agency	Across Highlands and Islands (HQ in Inverness)
Industrial Biotechnology Innovation Centre	IBioIC	Marine biotechnology	Innovation Centre	Glasgow (supporting Highlands and Islands research initiatives)
International Centre for Island Technology Heriot Watt University	ICIT	Wave and tidal energy, physical marine environment	Higher Education	Stromness, Orkney
Marine Alliance for Science and Technology for Scotland	MASTS	Aquaculture, energy, environment, monitoring data and analysis	Research Consortia	Across Scotland
Marine Environmental Research Laboratory, University of Stirling	MERL	Aquaculture	Research Institute	Machrihanish (part of University of Stirling Institute of Aquaculture)
Marine Scotland Science Scottish Government	MSS	All marine activities	Government Department	Aberdeen, Edinburgh & across Scotland
NAFC Marine Centre, UHI	NAFC	Marine training and research	Higher Education	Shetland Isles
Scotland's Rural University College	SRUC	Aquaculture	Research Institute	Inverness & across Scotland
Scottish Aquaculture Innovation Centre	SAIC	Aquaculture	Innovation Centre	Stirling (operating programmes across the Highlands and Islands)
Scottish Association for Marine Science, UHI	SAMS	Aquaculture, marine biotechnology, energy	Higher Education	By Oban
Wave Energy Scotland	WES	Wave energy	Technology development body	Across Scotland (HQ in Inverness)

Source: Technopolis data

2.3: PEOPLE AND TALENT

2.3.1 The supply of people with the right skills is key for the development of the marine economy. This includes the need to attract and retain high-quality research and innovation talent as well as operational skills. Attracting high quality skills has been successful where there is clear intent and ambition, for example attracting people to Oban as a result of specialisms at SAMS, UHI, and the EMSP, and in Orkney, as a world centre for wave and tidal research.

2.3.2 In 2016, 3.63% of employees in the Highlands and Islands were science, research, engineering and technology professionals compared to a UK average of 5.60% and a Scottish average of 6.0%. A further 1.73% were science, research, engineering and technology associate professionals compared to 2.0% in Scotland and 1.80% in UK. In terms of people working within research, a total of 68.1 FTE researchers based in the Highlands and Islands were submitted to the 2014 Research Excellence Framework (REF) return and so it is clear that there is a high growth potential here.

2.3.3 The Highlands and Islands has a highly qualified workforce with over 44% of the working age population holding a qualification at National Vocational Qualification (NVQ) Level 4 (Higher National Diploma (HND) / Bachelor's degree) or higher. This is slightly above the UK average of 43.5% but behind the Scottish average of 49.3%. The proportion of working age population holding a qualification at NVQ Level 4 or higher is highest in Eilean Siar (48.9%) and lowest in Moray (37%).

2.3.4 Training up a sectoral core capacity in marine skills will underpin research and innovation (and commercial success). In 2016/17 there were just under 3,000 enrolments on marine economy related courses at UHI and North Ayrshire colleges in the Highlands and Islands region, accounting for 10% of total enrolments at colleges in the region. In terms of student numbers, there were just under 2,500 students and just under 700 FTE students studying marine economy subjects in the Highlands and Islands meaning marine economy related courses accounted for 10% of total students and 8% of total FTEs in the region. In 2017/18 across Scotland, 922 people started a Modern Apprenticeship (MA) in Frameworks related to the marine economy accounting for 5% of total MA starts. This represents a potential pipeline of skills for the region, if they can be attracted to live and work there.

2.4: ADDING VALUE IN THE MARINE ECONOMY

2.4.1 The marine economy sectors each demonstrate some clustering of activity which does, and can, add value by maximising knowledge exchange, focusing research, contributing to the circular economy agenda, using resources more efficiently and taking a strategic approach to realising the value of the marine economy. HIE's research on business cluster specialisation in the Highlands and Islands[27] identifies wave and tidal energy and aquaculture and marine products (including seaweed harvesting and cultivation) as clusters of distinction, meaning that they define and brand a local economy and a particular place. Wave and tidal energy is geographically focused in Orkney and Caithness. Aquaculture and marine products, scientific and business activities are highly concentrated in the region that contributes to and benefits from the Scottish seafood brand. There is also a cluster of marine biotechnology research and business activity in and around Oban.

2.4.2 In terms of clustering, there are commercial as well as research opportunities across the three sectors. Fish waste from aquaculture can be used to produce biomass; seaweeds can be used for bioremediation and electricity from wave and tidal energy can be used to power aquaculture and marine biotechnology operations. There are also opportunities to take a more strategic, clustered approach to developing the skills required across the marine economy and to develop, test and operate equipment and processes. Clustering to achieve these sorts of synergies and for the circular economy agenda is a key aspiration of the SIA. There are significant opportunities for growth and circular economy innovation and development across the marine economy and the SIA will help to achieve these.

27 http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/business-cluster-specialisation-in-the-highlands-and-islands.html

3: AQUACULTURE

AQUACULTURE: THE HEADLINES

- Aquaculture is an extremely valuable sector for the Highlands and Islands. Contributing nearly £2bn GVA to the UK economy, it is an important asset for both Scotland and the UK.
- The UK's seven largest aquaculture producers all operate and invest heavily in the Highlands and Islands. These companies account for 97% of total Scottish production.
- Aquaculture plays a vital role in sustaining Scotland's most rural and fragile communities. It is an anchor industry, providing high-quality, year-round, well-paid jobs in remote areas and contributing to the viability of many communities.
- UK salmon production and processing are heavily concentrated in Scotland – the Highlands and Islands is the third largest salmon producer in the world. Central Scotland processes and exports most of the fish and shellfish produced.
- The pristine marine environment and our best-practice production processes secure a premium quality and price for Scottish produce.
- The trend of growing global demand for fish and shellfish as a source of protein (8% Compound Annual Growth Rate (CAGR)) is set to continue. It presents considerable opportunities for the Highlands and Islands, Scotland and the UK.
- The Highlands and Islands is a major contributor to aquaculture science, innovation and research, supported by academic and other research technology organisation assets based elsewhere in Scotland.
- The Scottish aquaculture industry is highly innovative and is ambitious to grow in terms of production volumes, exports, revenue and job creation. This is grounded in the principle of sustainable growth aligned with Scottish Government regulation.
- Science and innovation are key to tackling challenges in the sector and to unlock its enormous growth potential, estimated to double GVA to £3.6bn by 2030.
- Addressing regulatory, planning and financial constraints will help to overcome barriers to realising these ambitions.

3.1: NATIONAL AND INTERNATIONAL TRENDS AND SIZE OF GLOBAL MARKETS

Aquaculture in Scotland

3.1.1 Comprising finfish and shellfish, aquaculture is vital to Scotland's economy, helping to sustain economic growth, particularly in our rural, coastal and island communities. It is the largest sub-sector in Scotland's Food and Drink sector and is one of the Scottish Government's target sectors for driving economic growth. In 2014/15 aquaculture contributed £620m GVA to the Scottish economy and employed over 12,000 FTEs through the supply chain, including jobs in the production, processing and transport sectors. Salmon was the UK's single largest food export in 2017, with exports going to over 60 countries and valued at >£600m. The main markets are USA, France and China.[28] Aquaculture contributes up to £1.8bn per annum to the UK economy and the majority, £1.4bn of this, is within the Scottish economy.

3.1.2 Salmon production accounted for 95% (171,000 tonnes) of Scottish finfish production in 2015 (a 35% increase from 2005). The volume fell slightly in 2016, partly due to issues associated with sea lice, which meant that harvesting was brought forward to a point before fish were fully grown. Other fish species produced in Scotland include rainbow trout, halibut, and brown/sea trout. Alongside this, the production of 'cleaner' fish (fish that provide biological control on the fish stock) is increasing. Mussels and Pacific oysters are the highest-volume species in shellfish production. Total mussel production was 7,732 tonnes in 2016.

3.1.3 By 2050 the world population is projected to reach 9.7bn and with wild fisheries stagnating, Scottish aquaculture products will have a major role to play in meeting global food demands. It therefore is an important component of Scotland's internationalisation agenda, a key policy focus. The industry-led ambition is to double aquaculture's economic contribution to the Scottish economy by 2030 and grow employment to 18,000 jobs. [29]Research for HIE estimates that even a more cautious growth scenario would mean that Scottish aquaculture could have an annual GVA of £740m and support just under 14,500 jobs by 2030[30]. As well as being a driver of growth in the Highlands and Islands, the sector plays a broader role across Scotland and the wider UK economy, with many cleaner fish, processing, distribution and export businesses located elsewhere in the UK.

Aquaculture contributes

£1.8bn

per annum to the UK economy

the majority

£1.4bn

is within the Scottish economy

[28] Marine Scotland, HIE / Imani Development, Steve Westbrook (2017) The value of Aquaculture to Scotland
[29] Food and Drink Scotland (2017) Aquaculture Growth to 2030: A strategic plan for farming Scotland's seas
[30] Marine Scotland, HIE / Imani Development, Steve Westbrook (2017) The value of Aquaculture to Scotland

3.1.4 Along with its financial value, aquaculture plays an important socio-economic role in some of Scotland's fragile rural communities. It acts as an 'anchor industry', providing year-round jobs and income in remote areas where employment opportunities may be scarce. This contributes to the sustainability of communities, for example by increasing the number of families in rural and remote areas and supporting infrastructure such as schools, shops and services.

3.1.5 There are around 225 aquaculture businesses in Scotland. In the Highlands and Islands there has been significant consolidation in salmon production meaning that a relatively small number of large organisations now produce most of the premium Scottish salmon. Efficiencies have enhanced productivity by 58% in rainbow trout production (though this accounts for a small proportion of the sector overall), and 6% in salmon production between 2010 and 2016.[31] Major salmon producers include Marine Harvest, Scottish Sea Farms, Scottish Salmon Company, Cooke Aquaculture, Grieg Seafoods, Loch Duart and Wester Ross. Trout producers include Dawnfresh and Kames. Shellfish is characterised by a larger number of small, often artisanal, operators, although there are some larger producers, for example in Shetland. The Scottish Shellfish Marketing Group (SSMG)[32] is a co-operative that brings together lead and smaller producers to achieve the benefits of scale, supplying all the UK food retail multiples, and exporting.

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AQUACULTURE BUSINESSES IN SCOTLAND

3.1.6 The SIA region has particular assets which will support the sector's growth ambitions, such as climate, geography and high quality growing waters. Aquaculture in Scotland has excellent sustainability credentials, for example high feed conversion ratios, edible protein yields, and low CO2 emissions and water usage compared to land-farmed animals. Scotland is a world leader in using our pristine habitats for sustainable, high quality aquaculture. These strengths have led to global recognition of the quality of Scottish salmon and a price premium for the product.

3.1.7 Science and innovation are key to tackling challenges facing the sector and unlocking the enormous growth potential. This includes improved genetic selection and breeding programmes for finfish and shellfish; addressing emerging biological and environmental challenges; addressing planning issues relating to social licence to operate; updating regulatory production models to align with latest hydrodynamic modelling techniques; and regulatory alignment across public agencies. Unlocking growth potential will also require building the workforce and skills capacity.

SCOTTISH SALMON is the most **HIGHLY TRACEABLE** salmon in the world

Global trends

3.1.8 Aquaculture is of huge global importance for food security and is key to supporting the world's increasing protein requirements. The United Nations Food and Agriculture Organisation has noted the vital role that the sea and inland waters play in food provision and the UK Government Office for Science has highlighted the critical role of aquaculture in satisfying the food demands of an expanding population.

3.1.9 As well as population growth, rising incomes in developing countries have led to increased demand for high quality protein, primarily from meat and fish. As a result, fish has become one of the largest traded food commodities in the world, and aquaculture has been one of the fastest growing food production sectors in the past 20 years.[33] Globally, between 2008 and 2015, aquaculture production rose 54% from around 69m tonnes to approximately 106m tonnes[34] and it now provides more fish for human consumption than wild capture fisheries. In the past three decades global aquaculture production expanded by an annual average rate of 8%, and by 2030 the industry is projected to provide over 60% of fish for human consumption.[35]

3.1.10 In the EU, aquaculture was estimated to be worth €4.1bn in 2015, a 20% increase from 2008.[36] Over this period, the value of the UK's aquaculture sector increased in value by 47%, from €678.5m to €995.3m demonstrating that the UK is an increasingly major player in Europe's aquaculture industry. In 2015, it accounted for 16.8% of the EU's total production, the second largest share of any member country; and 24.1% of EU Aquaculture's economic value, the largest amount of any member country.

3.1.11 While the growth potential of Scottish aquaculture is indisputable, it is not a given. The rate of production growth for salmon in Scotland has been lower than competitor countries. This is primarily due to regulatory constraints and has culminated in a reduction in global market share from 10% in 2005 to less than 7% in 2017.[37] To capture the potential value, Scotland must maintain and extend its already strong position and exploit new technology to drive productivity. Scotland has significant potential to expand its market share as there remain large areas of untapped resource, for example in shellfish farming and in diversifying to other finfish species. There are also opportunities to increase the scale of salmon farming and boost production volumes. Expansion must however, not be at the expense of quality and should be balanced with environmental impacts.

> "Given growing global demand for food, it is likely that aquaculture will become increasingly important for global food security"

[31] http://www.gov.scot/Topics/marine/Fish-Shellfish/FHI/surveys
[32] http://www.scottishshellfish.co.uk/
[33] Financial Times (2017) Global fish industry set to scale record in 2017. Internet: https://www.ft.com/content/0a04ff90-9312-11e7-bdfa-eda243196c2c (accessed 1 March 2018)
[34] World Bank Open Data. Available at https://data.worldbank.org/indicator/ER.FSH.AQUA.MT (accessed 26 February 2018)
[35] Government Office for Science (2018) Foresight: Future of the Sea; from: The World Bank (2013) Fish to 2030: Prospects for Fisheries and Aquaculture.
[36] Eurostat, available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Aquaculture_statistics#cite_note-2 (accessed 26 February 2018)
[37] Food and Drink Scotland (2017) Aquaculture Growth to 2030: A strategic plan for farming Scotland's seas

Challenges in responding to increased global demand

3.1.12 The majority of Scottish aquaculture production sites are in near-shore or inshore waters and developing larger open water (off-shore) production sites would help boost production. Oceanographic conditions and regulatory processes currently constrain expansion into more exposed and offshore sites. Streamlining the planning policy and consenting process for aquaculture sites would help to develop operations in new open water locations. Innovation is vitally important, for example, to develop equipment and processes suited to the harsher conditions. Aquaculture planning currently sits within land use planning in local authorities which can create disconnect in working with other marine planning regimes. Whilst planning authorities quite rightly apply stringent processes to protect the marine environment, it can stifle the development required to exploit innovation opportunities, and realise the growth potential. There is scope to strike a new balance and for planning and regulation to work more closely with research and industry to solve issues and respond to concerns and challenges on both sides. Central to this is the 'precautionary principle' to environmental impact currently applied by regulators. Aquaculture will soon be covered by Regional Marine Plans through the Marine Plan Framework currently under development which may help work towards a solution.

3.1.13 To incentivise salmon production at open water sites, a number of issues will need to be addressed, including marine engineering and technological solutions to ensure asset security (e.g. minimising damage to cages, nets and moorings), fish welfare, and health and safety in working in a more exposed marine environment. Refined methods of determining the environmental impact of open water farming are also needed to support regulatory approvals and balance them with the potential risks. Current regulatory models are being updated by regulators in partnership with industry, and there is a need develop better predictive hydrodynamic models that will enable industry growth and produce more accurate predictive outputs.

3.1.14 There is scope to improve productivity and unlock growth constraints by increasing biomass limits at existing sites through better models and by addressing fish health/ biological issues to increase fish survival, and making efficiencies in feed production. For shellfish, mussels and oysters, securing continuity of spat supply would lead to greater stability and predictability in production levels, unlocking production bottlenecks and increasing Scotland's global market share.

3.1.15 Current Scottish Environmental Protection Agency (SEPA) regulations set a limit of 2,500 tonnes of biomass per site. The aim is to minimise waste accumulation on the seabed and reduce the risk of decreasing biodiversity. In some cases, for example sites that are more exposed with strong tides that disperse waste before they build up on the sea bed, the 2,500-tonne limit is considered over-precautionary. To address this SEPA is introducing the new Deposition Zone of Regulation (DZR) in aquaculture licensing and refinements of the current regulatory model, New Depomod. This will enable industry to increase stocking at some existing and new sites, provided evidence demonstrates that the environment can sustain it. Farming at off-shore sites is more expensive so being able to increase production above 2,500 tonnes per site will make it more viable.

3.1.16 Biological conditions in Scotland's water are changing and are likely to continue to do so as a result of climate change. Ocean warming may create new opportunities to diversify into farming new species, but it will also bring risks. Higher sea water temperatures may lead to the emergence of new diseases and increase the prevalence of existing parasites and pathogens. Warmer waters may also be contributing to increasing occurrence of harmful algal bloom events, which can cause mass finfish mortalities. Sea lice, amoebic gill disease and other pathogens pose increasing threats to aquaculture[38] and industry has invested heavily into research and development in this area (estimated at £30m pa over the past five years). This investment is aimed at preventing, mitigating and reducing the effect of disease threats, and to improve production efficiency and effectiveness.

3.1.17 Access to finance is an issue, and a particular challenge for the shellfish sector. There is a lack of understanding of the industry and its growth potential amongst banks. This was reflected in the Aquaculture Growth to 2030 report which recommended an export finance scheme and a dedicated fund for aquaculture. Scottish equipment manufacturers are hampered by their overseas competitor's ability to access finance. In contrast to Norway, where equipment and licences are accepted as assets by banks in the loan process, company assets are not considered collateral by UK institutions. This constrains access to financing for innovation and growth for Scottish aquaculture companies. However, some companies have recently secured Scottish bank finance, which may point to improved access. Multinational companies operating in Scotland can raise investment capital elsewhere if they are confident that the Scottish Government will support them to farm in a way which will deliver long-term revenue returns. In terms of investment, there may be a role for the proposed Scottish National Investment Bank to provide support and so unlock potential.

3.1.18 The volume of Scottish salmon production is not sufficient to satisfy demand either domestically or in export markets.[39] Continued constrained supply will limit the development of existing and new markets and Scotland will lose out on opportunities whilst other countries, such as Norway and Chile, have the capacity to grow and keep pace with international demand. International competitors have been able to scale up industry to keep up with global demand in part because of flexibility in their regulatory regimes and government support. Supply constraints in Scotland need to be addressed as a matter of urgency if we are to retain and grow our global market share.[40] This is a key challenge identified by both the UK's Industrial Strategy[41] and the UK Government's research report on the future potential of the sea.[42] It is also central to Hypothesis 1 of the SIA.

[38] Government Office for Science (2018) Foresight: Future of the Sea
[39] Imani Development, SRSL/HIE, SAIC (2017) Scottish Aquaculture: a view towards 2030
[40] Steve Westbrook/ Imani Development, HIE, Marine Scotland (2017) The value of Aquaculture to Scotland
[41] HM Government (2017) Industrial Strategy: building a Britain fit for the future
[42] Government Office for Science (2018) Foresight: Future of the Sea

3.2: LOCAL SCIENCE AND INNOVATION ASSETS

3.2.1 The Highlands and Islands is a major contributor to aquaculture science, innovation and research, and it is highly concentrated in the region. Institutes in the Highlands and Islands are involved in 20% of all Scottish aquaculture research projects, and 42% of all research and innovation grants in the region are for aquaculture. For projects led from the SIA region, its share is 13 times the UK average;[43] for projects participated in, it is 10 times the UK average. This is a high proportion considering that much research in aquaculture is channelled through SAIC and the University of Stirling which are based elsewhere in Scotland. However, a sizeable proportion of the University of Stirling's research is conducted at Machrihanish in Argyll and Bute. It demonstrates that the natural resources and assets in the region are major drivers of science and innovation in aquaculture across Scotland.

Public and academic assets in the Highlands and Islands

3.2.2 The Marine environment, and related disciplines in Environmental Science and Engineering are key research themes for UHI. Aquaculture forms a significant part of UHI's expertise. Research in this sphere is largely conducted across three UHI institutions: SAMS; the RLI; and the NAFC Marine Centre.[44] UHI is currently exploring options for establishing a Chair in Seafood Industries, to provide strategic academic leadership across aquaculture and fisheries, greater co-ordination of UHI activity, and to encourage enhanced industry-academic collaboration.

Scottish Association for Marine Science (SAMS UHI), UHI

3.2.3 SAMS UHI aims to promote a sustainable aquaculture industry that operates in a healthy and diverse marine environment. It focuses on building the sector's ability to produce healthy seafood and develop systems to farm a variety of species together to increase environmental and economic resilience by farming a range of marine food species, mimicking ecosystems where waste products of one species become the food for another. This is a key area of cross-sector clustering with marine biotechnology.

3.2.4 At the 2008 Research Assessment Exercise (RAE), 90% of research from SAMS UHI was judged to be internationally recognised. It is currently undertaking a number of high profile projects, for example it is part of an EU Horizons 2020 research consortium to develop an ecosystem approach to increase the availability of high quality water for aquaculture. It also has a collaborative agreement with Texas A&M University Corpus Christi (TAMU-CC)[45] and strong links with industry, in particular through the marine science cluster at EMSP.

NAFC Marine Centre, UHI

3.2.5 The NAFC Marine Centre is a specialist institute providing education, research and consultancy, and advisory services to maritime industries. Its industry-focused research has developed international partnerships, e.g. with the National University of Ireland and the Institute of Marine Research in Norway. It has carried out research on algal toxins and seaweed cultivation, with the aim of reducing the impact of harmful algal bloom events on the shellfish industry. It houses the Shellfish Hatchery Stepping Stone project which is part of a collaborative research and innovation project to test the commercial viability of a Scottish mussel hatchery. It includes algal culture and water treatment facilities along with tank room resources for spawning, larvae incubation and grow-out. There is capacity and demand to raise production substantially, if the hatchery can deliver new technologies and expertise to provide a secure supply of mussel spat (juvenile mussels).

Rivers and Lochs Institute, Inverness College UHI

3.2.6 The RLI supports biodiversity management and undertakes research on fish and genetic biodiversity monitoring and catchment management. Projects include DNA-based metagenomic methods for monitoring the seabed below salmon cages, developed in partnership with Marine Harvest and SEPA,[46] and a project to identify genomic markers of domestication in Atlantic salmon to assess introgression of farm genes into wild salmon populations. Research funded by Scottish Natural Heritage (SNH) and European Structural Investment Funds (ESIF) looked at developing methods for surveying cryptic and endangered pearl mussel populations, which could is applicable in the wider aquaculture arena.

Extra-regional assets

3.2.7 There are a number of UK research organisations and institutes based outside of the region but operating in, and informing work in the Highlands and Islands. Scottish examples include the Universities of Aberdeen, Edinburgh, Glasgow, St Andrews, and Heriot Watt. Stirling in particular is home to a critical and growing cluster of aquaculture expertise.

3.2.8 More widely, the region benefits from and provides benefits for, the research capabilities of organisations such as the Centre for Environment, Fisheries and Aquaculture Science, the University of Portsmouth, and the Centre for Sustainable Aquatic Research (Swansea University). The critical mass of aquaculture capability in the UK is globally significant and a key asset for the industry and for the Highlands and Islands. There are many examples where these organisations have or are collaborating with UHI, through research or strategic partnerships.

24 AQUACULTURE RESEARCH ORGANISATIONS operating in the Highlands and Islands.

[43] Gateway to Research, 2018; Technopolis analysis
[44] https://www.uhi.ac.uk/en/research-enterprise/res-themes/mese/
[45] https://www.sams.ac.uk/
[46] https://www.inverness.uhi.ac.uk/research/centres/rivers-and-lochs-institute

University of Stirling

3.2.9 The Institute of Aquaculture is a world-leading aquaculture research and teaching centre. Its research focus is on breeding and genetic improvement, nutrition, health, welfare and behaviour, and aquaculture systems. The Institute works in collaboration with industry, for example on a project to develop insect processing solutions for aquafeed. As part of the Stirling and Clackmannanshire City Region Deal, the University will receive £17m capital funding to expand its capacity and develop a national centre of excellence for aquaculture. The University is planning further investment and expansion at MERL, and is preparing proposals under the Argyll and Bute Rural Growth Deal.

The Scottish Aquaculture Innovation Centre (Stirling University Innovation Park)

3.2.10 SAIC brings together industry, academia and other stakeholders to stimulate and support commercially-relevant collaboration projects and promote growth in aquaculture and the supply chain. Its four priority innovation areas (PIAs) are: addressing environmental and health challenges, particularly sea lice and algal gill disease; developing feeds that optimise fish health and nutrition; unlocking additional capacity through innovative, evidence-based approaches; and establishing a reliable supply of mollusc spat. SAIC also contributes to skills development and supporting the talent pipeline.

Marine Alliance for Science and Technology Scotland (MASTS), University of St. Andrews

3.2.11 The MASTS marine science research consortium is funded by the SFC. It helps to co-ordinate marine science capacity and assist organisations to be more productive through collaborative rather than competitive working and by funding and managing research projects. MASTS has three research themes: dynamics and properties of marine systems; productive seas; and marine biodiversity industry R&D and innovation assets.

The Private Sector

3.2.12 There are also a number of key private sector aquaculture R&D and innovation assets in the SIA region, and elsewhere in Scotland. In fact, all the major aquaculture producers are active in R&D and innovation including Marine Harvest Scotland, Cooke Aquaculture Scotland, Scottish Sea Farms, the Scottish Salmon Company, Dawnfresh, Loch Duart, Wester Ross Salmon and Grieg Seafood.

3.2.13 FAI Aquaculture, a company focused on the development of aquaculture science and technology, operates at the Ardtoe Marine Research Facility. Focusing on marine fish and cleaner fish, it provides a facility for genetic, feed and disease trials, and offers a range of research services to industry and the public-sector, including expertise on algal culture and using algae as feedstocks in aquaculture.[47]

3.2.14 Xelect, based in St. Andrews, a spin-out from the University of St Andrews, offers specialist genetics support for aquaculture. It provides laboratory facilities to production companies, breeders and feed manufacturers across genotyping, metagenomics and gene and protein expression for Scottish, UK and international clients.[48] Akva Group[49], a Norwegian company specialising in technology and advanced services and equipment for aquaculture, has a technological development team in Inverness. This team leads on Akva Group's technological development for its global operations outside of Norway. Akva is looking to expand its team and capabilities.

3.2.15 Gael Force is a Scottish marine equipment, technology and engineering business with operations in the Highlands and Islands, as well as in other parts of Scotland and the UK. It is very active in R&D and recently announced over £1m investment in capacity expansion and new product innovation during 2018. The company's turnover and workforce has grown steeply in recent years and attributes this growth almost entirely to orders from Scottish salmon producers. Its investment in innovation will be focused on new products and services for these producers, helping to ensure that technology continues to meet the innovation needs within the sector, for example in feeding systems and underwater monitoring equipment.

3.2.16 The Fish Vet Group and Aqua Pharma are located on Inverness Campus. The latter has research expertise in aquatic chemistry and seafood processing, and supplies the Scottish aquaculture industry with innovative treatments for parasite control. The location of these companies on Inverness Campus offers links to wider research and innovation activity around Life Sciences, as well as more collaborative opportunities with the RLI, for example.

3.2.17 Some smaller companies also undertake science and innovation. These include production focused companies such as Orkney Sustainable Fisheries, a number of marine service vessel and wellboat operators such as Inverlussa, Johnson Marine and Leask Marine, and specialist transport companies such as Solvay, Migdale and Ferguson Transport.

Drivers of science and innovation

3.2.18 A key innovation driver in aquaculture is the scale and speed of technological change, to keep pace with rising global demand for high quality salmon protein. This has been, at least in part, driven by industry expansion and intensification as producers have sought to increase production. Processes such as feeding are now much more automated. Fish stock monitoring also makes more use of digital technology including cameras and remote sensing of environmental conditions such as oxygen levels.

3.2.19 R&D and innovation in the sector has also been in response to other challenges such as disease and fish health management. Increased innovation is required to drive future growth ambitions of the sector, ultimately requiring more and higher skill levels. In terms of future offshore development, ongoing research and investment is needed in developing large-scale technology for offshore equipment (such as cages). This will range from innovation in cage design, to offshore renewable power generation, to remote cameras and sensors to monitor higher rates of wear and tear. New offshore models are under development and will require a potentially large shift in skills and technology.

3.2.20 The Scottish Aquaculture: a view towards 2030[50] report identifies a need to review enablers of innovation within aquaculture. This will help to address the innovation constraints and provide a roadmap for innovation in the sector going forward. This could include the promotion of Scottish entrepreneurs and new entrants to the sector; encouragement of cross-sector partnerships (Oil & Gas); and enabling access to markets, particularly for SMEs. The report also sets out recommendations for growth, and the Aquaculture Industry Leadership Group (AILG) is working through the recommendations to deliver change.

[47] http://www.faifarms.com/our-locations/scotland/
[48] https://xelect.co.uk/
[49] http://www.akvagroup.com/
[50] http://scottishsalmon.co.uk/wp-content/uploads/2016/10/aquaculture-growth-to-2030.pdf

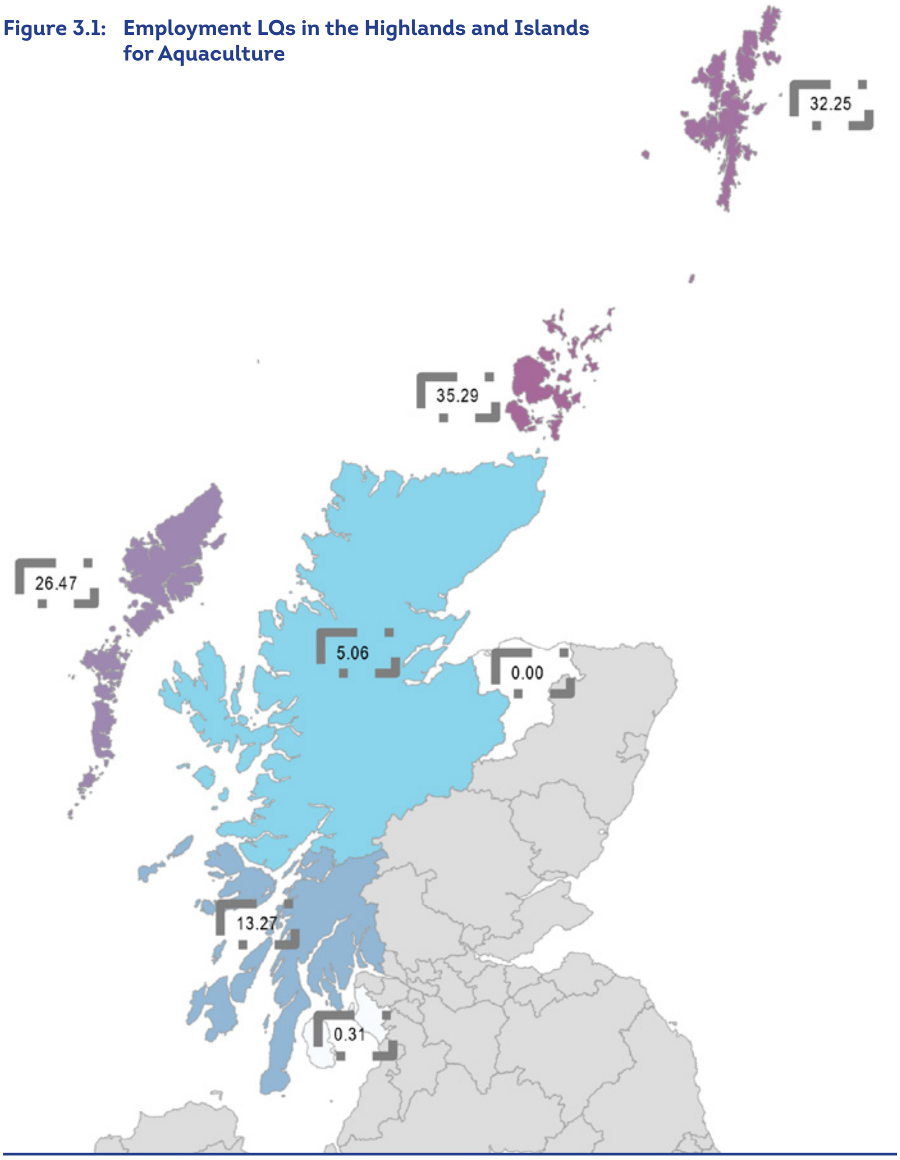
3.3: LOCAL SCIENCE AND INNOVATION TALENT

Current workforce

3.3.1 Marine Scotland data from its annual survey of aquaculture producers show that in 2016, 2,279 people in Scotland were employed in production. The vast majority (86%) were employed in finfish farming. Aquaculture is by no means a high-volume employment sector; however, it accounts for a high proportion of the Scottish and UK aquaculture workforce. In employment terms, there is a LQ of over 19 regionally[51], with higher concentrations in particular sub-regions (particularly the islands, and Argyll and Bute). This demonstrates the importance of this sector to the region and the importance of the region to the sector.

3.3.2 However, there are critical skills gaps and issues in aquaculture that must be addressed, as identified by recent research conducted for HIE.[52] Skills demand is greatest in production rather than other parts of the sector. Leadership and organisational management skills are in demand, along with boat-skills and engineering skills, in part led by consolidation in the sector. The demand for finfish has driven the need for farm management skills. There is also a strong need for high level technical skills, for example fish health/husbandry skills, and digital skills, driven by expansion, automation and intensification of production within the industry. Similar skills are increasingly in demand in the supply chain. Currently, the primary skills requirement in shellfish is new workers entering the sector to maintain and grow production. Succession planning is driving replacement demand as people retire and leave the sector. In the future, demand for technical skills is expected to increase, with more specialist and niche skills required as the industry develops and adopts more sophisticated techniques and technology. Softer, transferable skills are required both now and in future to be able to continually adapt to changes within the sector.

Figure 3.1: Employment LQs in the Highlands and Islands for Aquaculture



12,000
JOBS IN AQUACULTURE
and its supply chain in Scotland

[51] This uses BRES data, which estimates employment in Aquaculture differently as it relies on SIC codes, rather than registration with Marine Scotland
[52] Ekosgen/Imani Development, HIE (2018) Skills Review for the Aquaculture Sector

3.3.3 There is a shortage of workers, in particular experienced workers. This is in part a factor of the remote location of production sites, where a lack of infrastructure and amenities can be a barrier to attracting potential employees and their families. However recent investment in communities e.g. housing is beginning to address this.

3.3.4 Companies are piloting new ways of working to make the sector more attractive, such as alternative shift patterns, similar to oil and gas. With increasing automation, digitalisation, artificial intelligence, and the introduction of new processes, the sector is less labour intensive and working tasks and conditions have been changing, becoming more attractive to a wider potential workforce. Producers are moving away from manual handling and manual operations with fish. Examples include in feeding, counting, biomass estimation, harvest, transport, pumping vaccination, environmental monitoring, morts recovery (removing dead fish from cages), gutting, bleeding, stunning, and packing. All of this needs a highly skilled and educated workforce.

Skills pipeline

3.3.5 Just over 1,400 students were studying aquaculture-relevant[53] subjects in Scotland in 2016/17. Twenty-four percent of these students were studying at postgraduate level, with the remaining 76% at undergraduate level. The SIA region specialises in postgraduate aquaculture-relevant education, but numbers are currently quite limited; despite the importance of the sector in the region, aquaculture accounts for around 1% of current students. These are all at postgraduate level, and all at SAMS UHI. The majority are from outwith the UK, and so retaining their skills within Scotland will be important. The need for an effective response to skills challenges in the region, particularly after Brexit, is highlighted in the Regional Skills Assessment produced by Skills Development Scotland (SDS).[54]

3.3.6 There were also 417 graduates with aquaculture-relevant degrees across Scotland in 2016/17, qualifying from nine HE institutions. Thirty-six percent of these graduated with a postgraduate qualification. In the Highlands and Islands, eight students graduated in 2016/17, all postgraduate level from SAMS UHI. This number does not reflect the importance of the sector to the region, and is linked to low levels of provision built upon historic student funding dispersal.

3.3.7 The Highlands and Islands is one of only two of Scotland's 13 college regions that deliver aquaculture-relevant FE education. It accounts for the majority of provision: around 95% of the 435 FE enrolments in Scotland in 2015/16 were in the region. Of these, 75% were at the NAFC Marine Centre, with the remainder at Inverness College and SRUC in Inverness, Lews Castle College in Stornoway, and Orkney College. Aquaculture-specific courses delivered in other parts of Scotland and the UK form part of the skills pipeline for the Highlands and Islands. Examples include at the Institute of Aquaculture (University of Stirling), and Aberdeen, Dundee and Heriot Watt Universities.

3.3.8 Delivering Apprenticeship is a key part of the NAFC Marine Centre offer and it co-ordinates delivery of Aquaculture MAs across the region[55]. In Scotland, 50 people started the MA Aquaculture Framework in 2016/2017 (MA Level 2-5), accounting for 0.2% of all MA intakes.

3.3.9 In 2017, the delivery of a new Technical MA in Aquaculture Management at SCQF Level 9 (SVQ Level 4) was launched at the NAFC Marine Centre, with 14 starts. Aimed at providing the skills required for farm management, it was developed in consultation with aquaculture employers and industry bodies. It is anticipated that Inverness College UHI and Polaris Learning may also deliver this in future.[56] The introduction of the Aquaculture Management Technical Apprenticeship begins to address the demand for more vocational training. However, recent HIE research indicates need for further vocational education and training provision, as well as courses at all levels with a significant work-based learning component.[57]

[53] These include the following HESA codes: Aquaculture, Environmental biology, Environmental chemistry, Freshwater biology, Marine biology, Marine/freshwater biology, Marine zoology, and Zoology.
[54] Skills Development Scotland (2017) Regional Skills Assessment: Highlands and Islands Insight Report
[55] https://www.inverness.uhi.ac.uk/courses
[56] Lantra (2015) Scottish Higher Level Apprenticeships: A Technical Apprenticeship in Aquaculture Management at SCQF 9 – Framework Document for Scotland
[57] Ekosgen/Imani Development, HIE (2018) Skills Review for the Aquaculture Sector

3.4: NATIONAL AND INTERNATIONAL ENGAGEMENT

3.4.1 A key priority for the sector has been the formation of the AILG, which is tasked with outlining priorities and delivering progress against the issues and priorities identified in the Aquaculture Growth to 2030 strategy, and the Scottish Aquaculture: a view towards 2030 innovation roadmap, as well as reviewing and updating these, over time. The AILG is key in trying to overcome the various challenges and in creating opportunities for the wider sector. This includes promoting the development of innovation sites, improving the regulatory regime and assessing social impacts and technological developments.

3.4.2 The Aquaculture Knowledge Exchange Hub drives UHI's industry engagement in the sector. It is made up of academics and knowledge exchange practitioners across the UHI network, and engages with industry and regulators to increase business collaboration and research impact. The MASTS network gives participating research organisations access to almost 700 academics across the partner organisations for research collaboration and knowledge exchange opportunities.

3.4.3 There has also been significant participation in EU-funded projects, which has connected aquaculture research institutes and strategic partners with European and international expertise. For example, AquaSpace[58] is an EU Horizon 2020 project co-ordinated by SAMS UHI, linking with partners from countries including Spain, Italy, Norway, Hungary and Canada. The project aimed to understand spatial and socio-economic constraints to the expansion of aquaculture, and to test tools to help overcome these. In doing so, it sought to effect the implementation of the Ecosystem Approach to Aquaculture (EAA) and Marine Spatial Planning (MSP). The Multi-Use in European Seas (MUSES) project is a Horizon 2020 funded project that is exploring the opportunities for Multi-Use in European Seas across five EU sea basins (Baltic Sea, North Sea, Mediterranean Sea, Black Sea and Eastern Atlantic) and is led by MSS.

3.4.4 The NAFC Marine Centre is involved in a number of collaborations and international projects for example the shellfish hatchery project. As a partner of SAIC, UHI has collaborated on a number of research projects with industry partners, including a project examining the potential for increasing capacity for salmon farming in exposed sites.[59]

3.4.5 Many aquaculture production and supply chain companies operating in Scotland are owned by global companies with headquarters outside the UK. Much of the R&D expertise in aquaculture and its supply chain is owned and takes place outside of Scotland, for example in Norway. This means that a considerable proportion of the R&D capacity in Scotland is effectively imported, detrimentally impacting on R&D capacity in Scotland. Consequently, there are examples of successful technological innovations in Norway, where there is significant investment in offshore technology, which are not yet viable in Scotland. These can be very different to the current operational model (for example, see Salmar's trial site, Ocean Farm 1[60]) but they are not expected to be significant in volume delivery in the next decade: rather more immediate and viable is the expansion of the current pen model into more exposed sites. Nevertheless, the flow of Norwegian innovation IP presents a key learning opportunity for Scottish Aquaculture in future. Since the publication of the Aquaculture Growth to 2030 and Innovation Roadmap to 2030 reports, there have been developments in offshore cage technology that have been granted development licenses to trial the concepts.[61]

[58] http://www.aquaspace-h2020.eu
[59] http://scottishaquaculture.com/scottish_aquaculture_projects/co-funded-projects/pia-3/increasing-capacity-for-salmon-farming-in-areas-of-high-dispersion/
[60] https://www.salmar.no/en/offshore-fish-farming-a-new-era/
[61] https://www.undercurrentnews.com/2017/06/02/marine-harvest-given-greenlight-for-offshore-egg-farm-concept/

3.5: DEVELOPMENTS IN THE WIDER FUNDING AND REGULATORY LANDSCAPE

Funding

Existing funding

3.5.1 Current funding for aquaculture focuses on project funding, and addressing specific scientific or innovation challenges. Funding is available through UK research councils and Innovate UK, with some funding available directly from the Scottish Government (e.g. MSS). Between 2007 and 2017, 16 public and private organisations in the SIA region have participated in a total of 77 aquaculture projects funded through research councils and Innovate UK, totally approximately £37.5m.

3.5.2 Both the NERC and BBSRC have funded a variety of aquaculture related projects. In 2014, they jointly announced a three year, £6m call for Sustainable Aquaculture collaborative research proposals, in collaboration with the Agri-Food and Biosciences Institute, Marine Scotland, the Centre for Environment, Fisheries and Aquaculture Studies and the Food Standards Agency. The 21 projects supported between 2014 and 2017 included a number from UHI (including SAMS) and the University of Aberdeen, such as studies into minimising the risk to aquaculture and human health from harmful algal blooms (HABs); research into the role of gut microbiota in sustainable aquaculture; and the impact of climate change on infection of salmonid fish.

3.5.3 SAIC provides innovation funding to industry-academic collaborative partnerships, testing technology and approaches within technology readiness levels (TRLs) 4-7. Investment is made across four priority areas targeting environmental health challenges, fish health and nutrition, unlocking aquaculture development capacity, and mollusc spat supply. It is currently supporting 21 projects across these priorities. To date, SAIC has supported a total of 25 core collaborative projects with a total project value of approximately £35m, including two projects in conjunction with industry and the EMFF, which attracted £3.8m from EMFF. SAIC aims to focus science towards addressing the real-world problems and challenges faced by industry.

3.5.4 HIE is the strategic lead enterprise agency for aquaculture, and has supported aquaculture companies and projects through a number of recent grants. It currently supports the industry through the Accelerate Aquaculture Innovation Fund, delivered jointly with SAIC.[62] The fund provides match funding to help commercialise innovative new processes, products, services or technologies.

3.5.5 The UK Government's Industrial Strategy Challenge Fund provides funding and support to UK businesses and researchers. The fund is part of the government's £4.7bn increase in research and development over four years and identifies a number of key challenges. Of relevance to aquaculture is the Wave 2 Transforming food production challenge, aimed at supporting using precision technologies to transform food production while reducing emissions, pollution, waste and soil erosion.[63]

3.5.6 There are also a number of European funding streams of relevance to aquaculture. For example, the Interreg Vb North Sea Region programme[64] funds projects in eco-innovation and sustainability in the North Sea Region (which includes protecting animals and reducing pollutants in the North Sea). The Interreg Vb Northern Periphery and Arctic Programme is supporting a number of aquaculture and food safety projects, including the Smart Fish project, partnered by the Ardtoe Marine Research Facility, which aims to create systems to improve seafood packaging and enhance product quality.[65] Horizon 2020 has nearly €80bn available from 2014-20. It is a financial instrument aimed at securing Europe's global competitiveness whilst driving economic growth and creating jobs in Member States.[66] Blue growth is a focus theme in Horizon 2020 and marine biotechnology is one of the five focus areas within this.118 One of the Societal Challenges focus areas in Horizon 2020's work programme is 'food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy67, which has a budget of €1.3bn for the 2018-2020 period. Some of the focused calls of this programme include optimising the sustainable contribution of fisheries and aquaculture to food security, boosting innovation through blue biotechnologies and encouraging marine and maritime collaborative research to harness the potential of seas for economic growth.[68] In the current programme period, €243m was allocated to the UK, of which €101m of funding was devolved to Scotland. Some funding is also available directly through DG MARE. It is clear that if the loss of EU funding is not replaced by some other mechanism, research activity and output in this sector will be constrained.

62 http://news.hie.co.uk/all-news/aquaculture-supply-chain-1m-innovation-fund-opens/
63 https://www.gov.uk/government/collections/industrial-strategy-challenge-fund-joint-research-and-innovation
64 http://www.northsearegion.eu/
65 http://www.interreg-npa.eu/projects/funded-projects/project/149/
66 https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020
67 https://ec.europa.eu/programmes/horizon2020/h2020-sections
68 https://ec.europa.eu/programmes/horizon2020/en/h2020-section/food-security-sustainable-agriculture-and-forestry-marine-maritime-and-inland-water#Article

3.5.7 A key feature of current funding regimes is that they are highly competitive and typically in project cycles of three years or less. This presents difficulties for smaller research units, and ultimately makes it riskier to recruit new permanent research staff. With larger research awards, it is increasingly risky to take the lead in proposals which require a large upfront investment in time with increasingly smaller likelihood of success. This therefore favours large institutions typically located outside the region.

A changing landscape

3.5.8 There are substantial changes underway in the UK funding landscape. The consolidation of the UK's research councils and Innovate UK under UK Research and Innovation (UKRI) will undoubtedly alter funding arrangements. Though there will be a learning curve in terms of understanding research areas and funding requirements, the changes will provide new research opportunities.

3.5.9 More widely, Brexit will possibly mean loss of access to European funding sources such as Horizon 2020 R&D funding and EMFF. It is anticipated that there will be a shift in focus to opportunities with Official Development Assistance (ODA) eligible countries as a result. Though the UK Government has committed to "establishing a far-reaching science and innovation pact with the EU, facilitating the exchange of ideas and researchers", this nevertheless poses a threat to future funding revenue streams for research and innovation beyond the 2014-2020 programme period. It is unclear what access UK organisations will have to the European Commission's (EC's) future research framework programme. The Convention of the Highlands and Islands (CoHI) has highlighted the need for 'immediate and direct replacement' of European Regional Development Fund (ERDF) and other EU structural support in order to support infrastructure development.[69] Following Brexit, the UK will no longer receive EU Structural Funds and detail on future funding is unclear. HIE's view, shared by regional partners, is that future UK regional policy should focus "on improving regional competitiveness and inclusion" and funds should be "available over the long term at a level commensurate with the scale of challenge".[70]

Under favourable growing conditions micro-algae can develop in vast numbers – a so called algal bloom. Some species produce toxins resulting in harmful algal bloom (HAB). This is a hazard to finfish and shellfish production, often leading to a loss of stock. The toxins can accumulate in shellfish and then passed on to consumers who risk being poisoned, sometimes fatally. Funded by the Food Standards Agencies, testing water samples from aquaculture sites is technically demanding and time-consuming. Research is underway in the Highlands and Islands to use satellite data to provide early warning of HABs so that action can be taken swiftly and cost effectively.

[69] Convention on the Highlands and Islands (2017) COHI Paper 10/17-X Highlands and Islands Post 2020
[70] http:/www.parliament.scot/S5_EconomyJobsFairWork/Inquiries/ESIF-036-HIE.pdf

Regulatory framework

3.5.10 Current constraints in the planning and regulatory systems that govern the development of aquaculture could potentially be overcome by adopting a more joined-up approach between regulators. Changes are necessary to enable innovation, and ultimately growth in production outputs. The various regulatory systems within which aquaculture operates will need to work together more effectively. This will necessarily mean a more pro-active approach to identifying and consenting new aquaculture production locations, with full industry engagement to allow for early foresighting of technologies and proposals by planners. This would particularly be the case for sites where multi-use and cross-sector marine economy activity is proposed.

3.5.11 Consideration could be given to supporting regulatory agencies to revise the current regulatory system to ensure that policies are consistently commensurate with risk. For example, lower risk sites, or pilots for new technologies could adopt a ‘survey, deploy, monitor’ approach, taking advantage of advances in remote sensing technology to be able to monitor and manage impacts in real time. Such approaches will, of course, require more resources but there is an appetite amongst all relevant stakeholders to become more proactive.

SCOTTISH AQUACULTURE IS THE **MOST HEAVILY REGULATED AQUACULTURE SECTOR IN THE WORLD** IN TERMS OF ENVIRONMENTAL IMPACT

[71] NB: IBIOIC noted that ‘underutilised’ is the correct word to describe it being used for another purpose than its natural / passive one.
[72] https://scottishmarineinstitute-.my.sharepoint.com/:w:/r/personal/sa02ca_sams_ac_uk/_layouts/15/Doc.aspx?sourcedoc=%7B615141e1-7af8-4381-8284-2434264d308d%7D&action=default
[73] Zero Waste Scotland (2015) Circular Economy: Sector study on beer, whisky and fish, Final Report June 2015

4: MARINE BIOTECHNOLOGY

MARINE BIOTECHNOLOGY: THE HEADLINES

- The pristine natural resource base in the Highlands and Islands has enormous potential but there are challenges that mean its value is not being realised.
- Across academia and industry, there is world class, ground-breaking science and innovation in the region and strong research and industry clusters.
- As a global industry, organisations in the Highlands and Islands are involved in a range of high profile international collaborations.
- There is a breadth of diverse applications for marine biotechnology, particularly in high value, high growth sectors such as health and life sciences, and clean energy, for example biofuels to transform transportation.
- The industry is at an early stage in its development and the Highlands and Islands has the ambition and is ideally placed to capture current and future market value. There is enormous scope for growth.
- The potential value of marine biotechnology in the Highlands and Islands is estimated to be £600m by 2030.
- Our marine biotechnology expertise and capability spans research institutions as well as innovation in the private sector.

4.1: NATIONAL AND INTERNATIONAL TRENDS AND SIZE OF GLOBAL MARKETS

Marine biotechnology in the SIA region

4.1.1 Marine biotechnology is the application of any type of marine resource in a commercial biotechnology application, primarily marine micro-organisms (such as algae and bacteria) and macro-algae (e.g. seaweeds) in, for example, human health and pharmaceuticals, food supply, cosmetics and biomass (energy). It has the potential to contribute billions to Gross Domestic Product (GDP), but is still on the cusp of large scale commercialisation. Seaweed cultivation is undergoing rapid global expansion and is a commercial activity ideally suited to the sheltered, nutrient-rich waters of the west coast of Scotland. A long-term vision and coherent policy (industrial strategy) is essential to de-risk developments and provide clarity for investment.

4.1.2 The Highlands and Islands has a vast and underused[71] natural resource in seaweed. Recent research that mapped the kelp specie Laminaria in Scotland indicated a total biomass of 20m tonnes for Laminaria hyperborea, 2.5m tonnes for Saccharina latissima, 0.19m tonnes for Saccorhiza polyschides and 0.16m tonnes for Laminaria digitata. Laminaria hyperborea is particularly abundant in three Marine Scotland Atlas regions: West of the Outer Hebrides, the Minch and Inner Hebrides, and the north coast of Orkney[72]. The region also has the natural resources and conditions required to cultivate seaweed. Scotland's summer warm water temperatures seldom exceed 16 degrees and they are clear and rich in nutrients. These factors, combined with long daylight hours mean that we have excellent and high quality kelp growth.

4.1.3 The region's aquaculture sector also has the potential to provide by-product (e.g. use of salmon heads, tails and viscera to extract purified amino acids for the production of dietary supplements).[73] The region, and Scotland has a growing biotechnology ecosystem coupled with well-established science and innovation assets.

4.1.4 Marine biotechnology has applications from diverse low volume, high value products in increasing demand in pharmaceuticals and food; to large volume, lower value processes for waste treatment and biomass. Seaweeds have been used industrially in the Highlands and Islands for hundreds of years, from burning it for potash, to using collected seaweed for high quality foodstuffs, soaps and as a botanical ingredient in gin, a growth product in food and drink.

4.1.5 Alginate is used for its combination of viscosity and solubility in foods and medicines (e.g. Gaviscon), and for delivering active medical ingredients. Production of alginates is a core part of the marine biotechnology potential and has existed for many decades in the Highlands and Islands. It has weathered some negative industry changes but there is once again the potential and conditions for full scale production. It is a high quality and high value product. Quality, provenance and strong standards compliance are important in the alginate market, all of which the Highlands and Islands can deliver. Exploiting the potential of alginates requires a staged approach to: compliance (hand-gathered seaweed on the beach is different to cultivating or harvesting seaweed underwater); volume production; and market segmentation. Another strand of the sector in Scotland is using marine invertebrates (shellfish) for bioremediation (i.e. cleaning waste products from water).

4.1.6 For each market opportunity in marine biotechnology, it is important to consider the volume versus value ratio. Some products such as fertilisers and fuels derived from algae require high volumes of feedstock for relatively low value returns, whereas there are cosmetic products both existing and under development which require much lower volumes for considerably higher value.

4.1.7 The diversity of applications presents enormous opportunities but can also be challenging when it comes to defining the sector by activity. The cultivation and harvesting of seaweed is determined as an aquaculture-type activity, while the downstream biotechnology activity is subject to landside and sectoral regulations for chemical or biomass processing.

4.1.8 Estimates from IBioIC indicate that the value of marine biotechnology for the region could amount to around £600m per annum by 2030, comprising:

- Extractives from seaweed: £350m;
- Fish protein from whisky waste: £100m;
- Microalgae opportunities: £100m;
- Fish and shell fish waste: £50m.

Global trends

4.1.9 Although the Highlands and Islands undoubtedly has an enormous but largely unexploited natural marine resource that could be developed into a global marine biotechnology industry, there is little data to accurately define and benchmark market prospects. Some research has attempted to compare the UK's position relative to other nations. Global production in marine biotechnology products is largely concentrated in the EU and USA, with the EU comprising 49% of global production, of which the UK comprises the largest proportion of products at 16%. The USA accounts for over a third of world production at 35%.[74] Industry experts recognise that China and South Asia has a large supply of seaweed although it is of a lesser quality and is likely to have some different applications to Scottish seaweed.

4.1.10 The global marine biotechnology sector has demonstrated significant growth in recent years. Estimated to be worth €2.8bn in 2010 ($3.7bn in 2010 prices)[75], it is expected to continue to grow.[76] An important driver of activity has been bioprospecting which is the systematic search for marine organisms (both micro-organisms and larger organisms) to identify components, compounds or genres with applications across a very wide range of products or processes.[77]

4.1.11 The largest market for marine biotechnology is the US where R&D projects have tended to focus on the production of algae-derived bioenergy.[78] The UK's main export markets in terms of value are currently in Western Europe but the UK imports more globally, from countries such as India and Thailand.[79] The UK trade balance for marine biotechnology is negative and has been worsening reflecting the UK's persistent failure to remove the barriers and challenges to commercialisation. The UK is currently under-utilising its natural resources, failing to develop downstream processing and so is missing out on valuable and strategically important market opportunities.

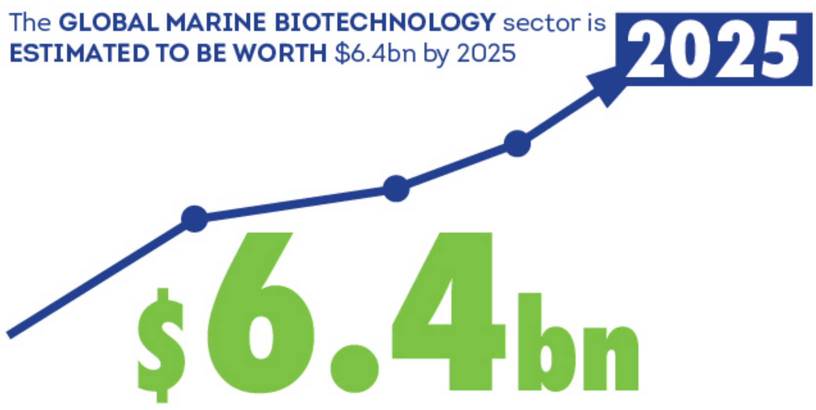
4.1.12 The quality of the raw materials does and will drive the types of application and markets for the product. For example, there is a global constraint on agar used in the pharmaceutical and medical sectors. It is largely produced in Morocco from red seaweed, but increased demand from the food sector has caused the price to rise steeply. There is now a risk of shortages for pharmaceutical and medical applications and inflationary pressures on product prices.[80] Seaweed around the coast of the Highlands and Islands is expected to have the compounds necessary for agar production but despite the obvious potential, it remains a nascent industry that requires support and concentrated, strategic input to be realised.

4.1.13 The process of drug discovery can have long lead times, calling for strategic vision and catalytic investment to bring products to market. Given the relatively unexplored resources in marine ecosystems and the UK pharmaceutical capacity, it is a valuable frontier to develop. This is illustrated in the Foresight Future of the Seas report[81] where the Marine Genetic Resource (MGR) is cited as a growth area:

"Annual global sales of marine biotechnology products are upwards of US$1 billion, and there are 4,900 patents associated with the genes of marine organisms, a figure that is growing by 12% per year."

Future global market demand

4.1.14 The global market for marine biotechnology is growing at 5-6% annually and is forecast to be worth $4.8bn by 2020 and $6.4bn by 2025. This will be driven by a rising focus on environmental sustainability and a subsequent increase in investments in marine biotechnology research along with growing demands for aquaculture and hydrocolloid technologies (dressings for wounds).8[2,83] Other research suggests, more ambitiously, that the sector will reach around $5.9bn by 2022, growing at a compound annual rate of 6.8% during 2016-2022.[84] Another paper states that the Asia-Pacific market is forecast to grow at a compound annual growth rate of 5.4% between 2015 and 2020.[85] It is expected that Europe will also be a major regional market and in line with the picture in the Highlands and Islands, its marine resources are currently under-used and under-explored[86].



74 Greco, G.R. and Cinquegrani, M. (2016) Firms Plunge into the Sea. Marine Biotechnology Industry, a First Investigation. Internet: https://www.frontiersin.org/articles/10.3389/fmars.2015.00124/full (accessed 1 March 2018)
75 Børreson et al (2010) cited in Commonwealth Secretariat (2016) Blue Biotechnology: Commonwealth Blue Economy Series, No.5, p. 7. Internet: http://thecommonwealth.org/sites default/files/inline/Blue%2BBiotechnology_UPDF.pdf (accessed 1 March 2018)
76 Global Industry Analysts (2015) Marine biotechnology Market Trends. Internet: http://www.strategyr.com/MarketResearch/Marine_Biotechnology_Market_Trends.asp (accessed 1 March 2018)
77 Ibid.
78 Global Industry Analysts (2015) Marine biotechnology Market Trends.
79 Technopolis analysis of United Nations COMTRADE data, 2018
80 https://www.independent.co.uk/news/science/seaweed-shortage-prompts-calls-to-ration-use-of-vital-scientific-resource-a6794291.html
81 Pg 57, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693129/future-of-the-sea-report.pdf
82 Smithers Rapra (2015) Global market for marine biotechnology has potential to each $6.4 billion by 2025.
83 Ibid and Smithers Rapra (2015) global market for marine biotechnology has potential to each $6.4 billion by 2025. Internet: https://www.smithersrapra.com/news/2015/october/market-for-marine-biotechnology
84 Cision PR Newswire (2016) Market Insights & Opportunities, 2022 – Market is Anticipated to Grow Around $5.9 Billion – Research and Markets. Internet: https://www.prnewswire.com/news-releases/global-marine-biotechnology-market-insights--opportunities-2022---market-is-anticipated-to-grow-around--59-billion---research-and-markets-300286436.html
85 Ibid.
86 Global Industry Analysts (2015) Marine biotechnology Market Trends.
87 Main points include the following sources: Grysole. J. (2017) Marine Biotechnology: International Perspectives. Presentation to BioTech Annecto – May 2nd 2017. Internet: http://www.expansionstrategies.ca/wp-content/uploads/2017/05/Biotech-Annecto-2-mai-2017.pdf See for instance, Guillerme, J.B, Couteau, C. and Coiffard, L. (2017) Applications for Marine Resources in Cosmetics in 'Cosmetics,' 4 (35). ScotGrad (2018) Marine Biotechnology is Blooming in the Highlands. Internet: https://www.scotgrad.co.uk/news/graduates-and-students/marine-biotech-is-blooming-in-the-highlands
88 Imani Development analysis, 2014, for the Assessment of the Benefits to Scotland of Aquaculture: http://www.gov.scot/Resource/0045/00450799.pdf.
89 https://www.ft.com/content/f5e8c5aa-d8ee-11e7-9504-59efdb70e12f
90 Smithers Rapra (2015) The Future of Marine Biotechnology for Industrial Applications to 2025. Internet: https://www.smithersrapra.com/market-reports/biobased-materials-industry-market-reports/the-future-of-marine-biotechnology-for-industrial (accessed 1 March 2018)
91 https://www.scottish-enterprise.com/knowledge-hub/articles/comment/biorefinery-roadmap

There is significant untapped synergy between aquaculture and biotechnology. Integrated Multi-Trophic Aquaculture (using byproducts, including waste, from one species as inputs e.g. food and fertliser for another) can be developed to absorb the increase in soluble nutrient concentrations from farmed fish production. By growing and harvesting selected seaweeds or macro-algae and other species near the fish-farm, these excess nutrients can be captured by the kelp which can in turn be harvested for their high value extractives.

Opportunities and challenges

4.1.15 There is growing need for industries to become more sustainable and more efficient in the use of resources. Also, there is increased consumer interest in using and purchasing sustainable products. As a result, there is an increasing opportunity for marine biotechnology and a need for R&D. The primary opportunities that exist for development are as follows.[87] The figure in Appendix 5 illustrates the current capacity and pricing of products from micro- and macroalgae.

- **Health and life sciences:** the use of marine biotechnologies in pharmaceuticals (e.g. novel applications for new medicines) and biomaterials (e.g. wound dressings, dental biomaterials, and medical devices). Analysis from research and markets indicates that the increasing use of seaweeds across a variety of applications will be an important future driver. The marine resource is seen as an important source for new types of antibiotics.
- **Cosmetics:** both functional ingredients (e.g. preservatives, and sebum regulation) and raw materials (e.g. algae extracts and pigments) have potential for further development into new applications. There is also growing interest in the use of marine-derived enzymes in the cosmetic industry, for instance marine fish-derived collagen.
- **Foods and food-related products:** Food security is a growing issue and marine biotechnology is part of the solution. It has an important contribution to make to transforming food production for example through food supplements, ingredients, and packaging. The market for human food and supplement consumption is increasing although with slower uptake in the UK where it is not a traditional part of our diet. There is also significant potential around animal feeds, particularly for aquaculture fish feeds. Algae presents a potential opportunity to replace fish meal protein and fish oil in farmed fish diets whilst maintaining the nutritional profile of fish oil, as micro algae produces essential fatty acids DPA and EPA found in fish oil. However, exploiting this will require economies of scale to make sure it is price competitive against other marine derived supplies. It is an area that is still under development and so is currently difficult to quantify with any accuracy.
- **Aquaculture:** As well as the potential for feeds in aquaculture, there is significant potential to innovate to culture algae to help develop shellfish seed production, an emerging area in using gene based technologies and bacteriophage technology for fish vaccination for the treatment of aquatic disease and water treatment systems. Recirculation Aquaculture Systems (RAS) is highly developed for salmonid production and biotech is playing an important role in maintaining homeostatis and remediation in RAS, as well as in waste water treatment. RAS technologies are being developed for other species in the SIA area, notably for vanomid prawns and for Siberian Sturgeon.
- **Marine environmental health and biodegradable food wrapping (as with use in paints):** With the growing concern over plastic pollution in the world's waters, there is now greater focus on finding materials for shopping bags and food wraps that are naturally derived and biodegradable. Some companies, such as CuanTec in Motherwell and Oban have examined more sustainable materials such as extracting chemicals from langoustine shells.
- **Energy:** development of clean, renewable energy processes, and industrial additives. Much of the recent growth of the sector has come from the use of marine algae and micro algae in biofuel production and this is likely to continue being an important future opportunity area (as identified by Highlands and Islands stakeholders). However, biofuels are still very much in development and face a number of challenges around scalability and economic viability of current models which need to be overcome in the short term.

4.1.16 Other areas for development include horticulture and fertiliser, however these both have limited scale and are relatively low-value products in comparison to other potential uses.

4.1.17 The Highlands and Islands has enormous potential to capture current and future market value in marine biotechnology by capitalising on the diverse and growing worldwide demand in the areas identified. There are also cross-sectoral opportunities in the marine economy. In aquaculture, there are input opportunities (using algae as a base for marine proteins for the vast feed market, estimated at £250-300m[88]), and output opportunities through capturing waste products for biomass. Wave and tidal energy (and other renewables) are abundant and could be used in marine biotechnology processes: for example, by generating hydrogen and oxygen (as demonstrated in Orkney[89]), which can be used as power and inputs for aerobic digestion of waste, drying seaweed, and growing algae for proteins and sugars for various applications.[90] Sugars are an important commodity worldwide, for example for energy and in the production of penicillin. The sustainability and provenance of the sugar supply is increasingly important for pharmaceutical firms and presents an enormous opportunity for marine biotechnology.

4.1.18 The biorefining sector is an important opportunity for Scotland, using seaweed, forest and whisky by-products (among others). Recognising its potential, SE launched its Biofinery Roadmap for Scotland in 2015.[91]

4.1.19 SAMS UHI is leading the way in Europe in seaweed cultivation, and holds a large stock of different seaweed species and has access to experimental farming facilities across two sites which focus on species including Alaria esculenta, Saccharina latissima, Laminaria hyperborea, Palmaria palmata and Ulva. This stock and associated research potential, provides the opportunity to build on the knowledge base of what is available and further examine the potential of these species on a small scale, before commercial scale is required. Having access to this resource is allowing researchers to identify which species are the most advantageous for culture, further develop cultivation and harvesting techniques, explore how to identify and control seaweed pathogens, and to consider the policies needed to enable sustainable industry development.[92]

4.1.20 The EMSP houses a world class cluster of companies involved in device manufacturing and genetic/biological processes with established competencies in the global drug and pharmaceutical markets such as Glycomar, Xanthella Ltd and Lallemand Aquapharm.[93] Production of alginates for both pharmaceutical and food uses is an important opportunity for the commercial partners and for scale development of the industry, though this could take place in a number of locations in the Highlands and Islands depending on specific needs, and draw on the EMSP technological development.

4.1.21 The principal opportunities for marine biotechnology provided in the NERC-TSB UK Roadmap for Algal Technologies (2013)[94], is illustrated in Appendix 6. The Highlands and Islands already has companies operating across these and so is well placed to deliver more and diversely across the sector. As an example, marine biotechnology and bioenergy is already being trialled at Ardnamurchan on the West Coast with an investment of £1m, using bioenergy for the cultivation of microalgae.

4.1.22 Multi-component extraction reflects the 'circular economy' process whereby very high value products may be a small percentage targeted in micro or macro-algae, leaving residual materials that can be put to other uses. Each component class will have a different estimated derivable value: one industry estimate summarises the potential in the Highlands and Islands to be as set out in Table 4.1.[95] The sales revenue total is accepted as an average value for an optimistic sector or industry development.

4.1.23 Brown seaweeds have several potential end uses including animal feed, human foods, horticulture, fertiliser, chemicals (mainly alginate), personal care products and biofuels. This demonstrates the versatility of the resource and the breadth of the market but it is also important to consider that each of these products/markets have potential limitations and individual factors to consider in their development. Other seaweed species will have other applications (as with agar from red seaweeds) and these species will likely have volumes of waste that can be used in lower value processes within a circular economy.

4.1.24 As with aquaculture and wave and tidal energy, marine biotechnology can commercialise and export its supply chain skills and manufacturing expertise, for example a company in Oban manufactures and exports photobioreactors, used for growing algae. BASF is renowned for its production of key fatty acids of Omega-3, which are exported globally. It recently received a Scottish Life Sciences Award, winning the Export and International Trade category.[96]

4.1.25 Marine biotechnology faces challenges to sector development and growth. For example, licensing and management of seaweed harvesting must take account of other overlapping marine activities: this has restricted large scale industry growth in kelp (Laminaria hyperborea) derived products. There are also skills issues (e.g. in bioprocessing), lack of scale-up facilities, and an unfavourable investment landscape to progress science and innovation into commercial production. This reflects that there are early stage projects in an early stage sector, which, as with wave and tidal industry support, may benefit from defined industrial strategy activities to realise potential.

4.1.26 None of these challenges are insurmountable. They can be addressed through active public-sector engagement to develop a suitable policy and support environment to catalyse investment. For example, a marine biotechnology firm is looking to develop a large alginate operation in Scotland as close to the Highlands and Islands kelp resource as possible. The company is currently seeking clarity on acceptable extraction methods and licensing implications. This requires active investigation on public and private actors to understand potential impacts, and create a resource management framework that is fit for purpose. If such challenges can be unlocked, the potential reward for Scotland could be an industry of £200-500m per annum on one set of seaweed applications alone.

[**Note**: In November 2018, prior to publication of the SIA report, the Scottish Government introduced a ban on the mechanical harvesting of kelp for any commercial applications and announced a review on all seaweed practises in Scotland. This presents a substantial challenge and potential loss to the sector as industry predicted that high value seaweed extractives could contribute up to £300 million per annum by 2030. Despite the significant impact this will have on the nearer term ambitions of the marine biotechnology sector, it is anticipated that advances in seaweed cultivation and other marine biotechnology applications (for example with micro algae) will mean that the longer term ambition of a thriving marine biotechnology sector in the Highlands and Islands remains achievable.]

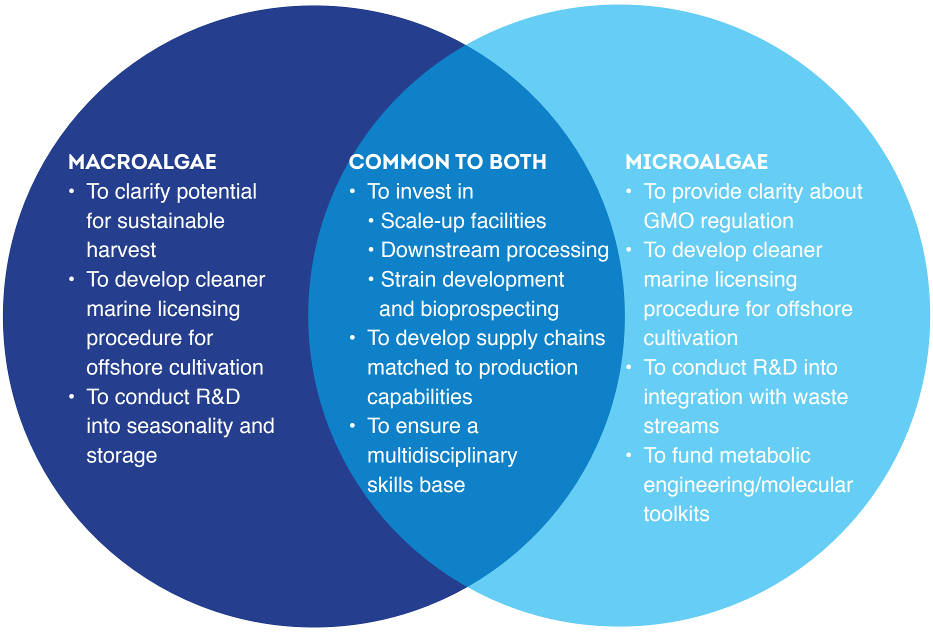
TABLE 4.1: COMPONENTS DERIVED FROM SEAWEED - INDUSTRY POTENTIAL FOR HIGHLANDS AND ISLANDS REGION

COMPONENT CLASS	ANNUAL SALES VOLUME (KT)	SALES REVENUE (£M/YR)
Functional Poly-saccharides	14.2	228
Neutral Poly-saccharides	6.7	64
Anti-oxidants	0.9	44
Others (total)	8.1	16
Total	29.9	352

Source: Marine Biopolymers (2016) estimates, validated as indicative by IBioIC

92 https://www.sams.ac.uk/facilities/seaweed-farms/
93 http://www.europeanmarinesciencepark.co.uk/
94 https://connect.innovateuk.org/documents/3312976/3726818/AB_SIG+Roadmap.pdf
95 MBL estimates (2016), validated as indicative by IBIOIC (2018)
96 http://www.europeanmarinesciencepark.co.uk/news-events/2017/basf-hits-gold-at-scottish-life-sciences-awards-2017/

Figure 4.1: Challenges for marine biotechnology development in the UK
Source: A UK Roadmap for Algal Technologies NERC-TSB May 2013



4.2: LOCAL SCIENCE AND INNOVATION ASSETS

4.2.1 The Scottish Highlands and Islands is home to a growing marine biotechnology sector. As well as providing world-class expertise in aquaculture, SAMS UHI is equally renowned for its work in marine biotechnology. It has the largest culture collection of algae and protozoa in Europe which is effectively a 'nursery' for the industry'. Through its Centre for Marine Biotechnology, SAMS UHI undertakes research and provides services, training and education to support the development of the marine biotechnology sector in the UK and across Europe. SAMS UHI's work in marine biotechnology spans sustainable production of natural resources for human nutrition and life sciences, bioremediation (including in aquaculture), and bioenergy. Exploiting this expertise, it works with the industry to provide seeded line technologies as well as expertise on farm location and disease management.

4.2.2 The EMSP, co-located with SAMS UHI, is home to a cluster of marine biotechnology companies such as Xanthella, mentioned above, and GlycoMar, who use the active ingredients in marine feedstocks for pharmaceutical and cosmetic products.[97] This gives the location a lead in technologies as well as research and culture collection.

4.2.3 Global chemicals company BASF is a key asset for the region. Its lipid development plant is used by researchers and pharmaceutical companies to develop active pharmaceutical ingredients. Its R&D is focused on the use of high purity lipids in cardiology, neurology and oncology, as well as novel application in diabetic neuropathy and inflammation.[98]

4.2.4 IBioIC[99] seeks to stimulate the growth of the industrial biotechnology sector (including marine biotechnology) in Scotland to £900m by 2025. IBioIC connects industry, academia and government and facilitates collaborations, provides scale up capabilities, creates networks and develops skills – the marine opportunities will be based largely in the Highlands and Islands, and IBioIC recognises the role of marine biotechnology in realising that ambition and impact.

4.2.5 Highlands and Islands-based organisations have participated in UK-research council-funded marine biotechnology projects. Some, such as GlycoMar and Xanthella[100], are private enterprises clustered around public research at SAMS UHI. Landcatch and FAI Farms (Ardtoe Marine Research Facility) are largely conducting research in the aquaculture sector but with elements of marine biotechnology. With a total of 34 patents in the region, biotechnology accounts for 12% of all patents in the Highlands and Islands. No specific marine biotechnology data is available.[101]

4.2.6 The Highlands and Islands is attracting international investment with the recent location of (Canadian multinational) Acadian Seaplants in Uist, acquiring Uist Asco.[102] BASF has also recently expanded facilities in partnership with HIE, with the objective of increasing exports.[103]

97 http://www.europeanmarinesciencepark.co.uk/
98 https://www.basf.com/gb/en/company/about-us/BASF-in-the-United-Kingdom/BASF-Pharma--Callanish--Limited.html
99 Industrial Biotechnology Innovation Centre
100 http://www.xanthella.co.uk/about-us/videos/
101 HIE Cluster Data
102 http://www.europeanmarinesciencepark.co.uk/news-events/2017/global-biotech-company-buys-into-uist-seaweed-company-to-expand-their-european-presence/?page=4
102 http://news.hie.co.uk/all-news/investment-will-boost-export-ambitions-for-basf-on-lewis/

4.3: LOCAL SCIENCE AND INNOVATION TALENT

4.3.1 In 2016/17, around 220 students were studying marine biotechnology-related subjects[104] at HE level in Scotland, which includes the subject codes for Bioinformatics and Biotechnology. Around three quarters of these students were studying at postgraduate level. Biotechnology accounts for the majority, at 180 students. A high proportion of students enrolled on marine biotechnology-related courses are from outside the UK. In 2016/17, 117 people graduated with relevant degrees from eight Scottish universities and, again, most (almost nine in ten) graduated at postgraduate level and the majority were domiciled outside of the UK.

4.3.2 SAMS UHI attracts and hosts a number of international students studying marine biotechnology. Some of these are through the Erasmus+ exchange programme. It currently has Erasmus exchange agreements with the University Centre in Svalbard; the University of Konstanz (Germany); Van Hall Larenstein, University of Applied Sciences (The Netherlands); University of Alicante (Spain); University of Valencia (Spain); and the University of Zadar (Croatia).[105] SAMS UHI also delivers teaching for the marine biotechnology module of the IBioIC Masters in industrial biotechnology.[106]

4.3.3 The knowledge base in the Highlands and Islands is strong, not only in the research capabilities of SAMS UHI and partners, but in the private sector. SAMS UHI reported that it employs 13 FTEs in marine biotechnology and has nine PhD and two MSc students. Hebridean Seaweed are using seaweed for products[107] such as nutraceuticals and fertiliser, and there is now a provenance-focused additive to gin[108], complementing the local food and drink sector. Such products are not only complementary to tourism and food and drink, but raise the profile of marine biotechnology and the Highlands and Islands quality and provenance brand.

4.3.4 The Scottish Seaweed Industry Association (SSIA)[109] is established and growing its membership – this will facilitate the knowledge base of the sector as it grows.

4.4: NATIONAL AND INTERNATIONAL ENGAGEMENT

4.4.1 Through the multinational companies that it hosts, including BASF, Lallemand and Acadian Seaplants, the region is already well-connected to global markets for export opportunities. The marine biotechnology sector is international and involves global collaborations. GlycoMar (located at the EMSP) is working with MicroA in Norway[110] and established a joint venture company for the manufacture of microalgal polysaccharides. It is also working with Biopol[111], based in Iceland, to develop a valuable nutritional supplement derived from fisheries by-product; and with two multinational food companies to develop novel ingredients. Xanthella works with partners in universities and industry (e.g. Wood Group) to develop photobioreactor production through the ASLEE[112] programme.

4.4.2 SAMS UHI collaborates with businesses and academic institutions globally on marine biotechnology, adding to the cluster model close to Oban. As well as institutes in Scotland, SAMS UHI has strong relationships with universities elsewhere in the UK, and worldwide, including in Germany, Mauritius, Norway, USA, and Australia. It also has strong industrial links worldwide, including with well-known multinational companies such as Unilever and Mars.

4.4.3 It currently works on a number of EU-funded collaborative projects. This includes the GENIALG project, a Horizon-2020 project led by Centre National de la Recherche Scientifique in France, that aims to increase the production and sustainable exploitation of two high biomass yielding species of European seaweed: the brown alga Saccharina latissima (also known as sugar kelp) and the green seaweed Ulva rigida (often-called sea lettuce) by combining available knowledge in seaweed biotechnology with reliable eco-friendly tools and methods to scale up current small cultivation seaweed operations.[113]

4.4.4 Aberdeen University, specifically its Marine Discovery Centre, works collaboratively with SAMS UHI and other Scottish Universities.

4.5: DEVELOPMENTS IN THE WIDER FUNDING LANDSCAPE

4.5.1 The UK Government 'Foresight: Future of the Seas' (2018)[114] report sets out the wide scope of opportunities in the blue economy. Marine biotechnology has very high potential economic value through its multiple, interlinked, and circular economic applications but these are under-recognised and under-exploited. Its development strategy must focus on anticipating future global trends and the Highlands and Islands has unique assets on which to build. The UK exiting the EU and adopting a 'Global Britain' approach may change funding channels for research which should be anticipated and planned for to ensure research assets continue to be accumulated and developed.

4.5.2 There are a range of short and long-term funding opportunities to develop the blue economy, and more specifically for addressing developments in the marine biotechnology sector. Marine biotechnology is one of the five priority areas of Horizon 2020 and its strategic approach to R&D funding and innovation.

104 These include the following HESA codes: Aquaculture, Environmental biology, Environmental chemistry, Freshwater biology, Marine biology, Marine/freshwater biology, Marine zoology, and Zoology.
105 https://www.sams.ac.uk/study/international/
106 https://www.strath.ac.uk/courses/postgraduatetaught/industrialbiotechnology/
107 http://www.hebrideanseaweed.co.uk/products.html
108 http://www.bbc.co.uk/news/av/uk-scotland-33635061/seaweed-twist-for-hebridean-gin
109 https://seaweedscotland.org/
110 http://microa.no/
111 http://biopol.is/efni/english
112 'Algal Solutions for Local Energy Economy': http://aslee.scot/
113 http://genialgproject.eu/
114 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/693129/future-of-the-sea-report.pdf

4.5.3 Public-private partnerships are key to the development of the sector in terms of innovation and funding. Working together to avoid duplication of work, co-ordinating research priorities and pooling resources [115,116] are crucial to the success of the sector. Enhancing the scientific and technological research infrastructures to support marine biotechnology developments[116] and leveraging funds to increase the impact of research investments in Europe[115] are also important. This includes industrial and academic research co-operation through technology transfer funding programmes.[117]

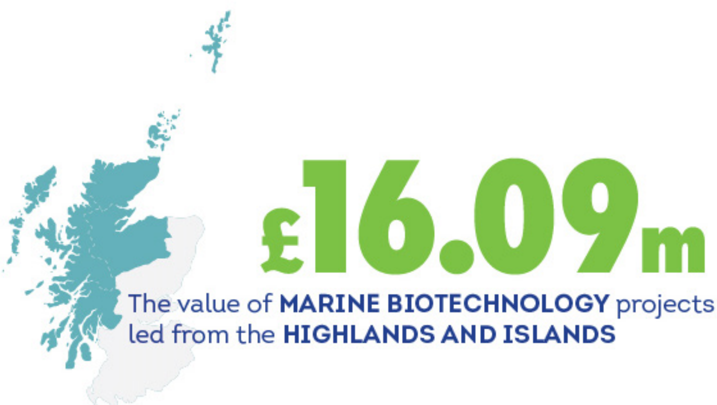
4.5.4 Marine biotechnology stakeholders depend heavily on national funding schemes and these are often the main funding sources for research institutions and universities. There is a lower, but still noticeable reliance of SMEs for this level of funding. For SMEs, European level funding is becoming the most important source and marine biotechnology stakeholders are pooling funding for their R&D.[118] However, national and transboundary rules and regulations on access and use of marine habitats and environmental regulations for harvesting marine organisms needs to be put in place in order to protect and preserve the natural habitat.

4.5.5 The uptake of marine biotechnology has its problems, but new and more substantial initiatives are being called for in order to increase the uptake and impact of marine biotechnology in Europe. The Innovation Roadmap[119] states that this could be facilitated by changes in current funding initiatives to encourage open innovation and foster public-private relationships. In the long term, the aim is to create Venture Capital funds for businesses based on marine biotechnology (2020–2030).[116]

4.5.6 At a regional level, the development of the Argyll and Bute Rural Growth Deal will provide opportunities to invest in innovation infrastructure and research programme. This will complement the activity that will be supported through the Stirling and Clackmananshire City Region Deal.

4.5.7 Arguably, increases in funding should be as a result of improvements and success stories from within the sector in order to develop further opportunities, which could provide venture capital funds[66,118] "with the confidence to recognise marine biotechnology as a central, enabling technology in the creation of high-potential, enduring investment areas based on the use of marine biological resources".[116] However, until the sector starts gaining more recognition this will remain a long-term challenge and is not seen as a viable funding stream at present.

4.5.8 Other marine biotechnology funding opportunities include the Blue Bioeconomy Public-Public Partnership which highlights the challenge of there being a lack of synergies between different sectors (i.e. range of sectors that rely on the Blue Economy including food, cosmetics, and bioenergy) and lack of adequate investments. However, scale up in the sector is extremely expensive and to achieve the economic potential of marine biotechnology and commercialise the science will require significant funding and facilities that support it. The high level of investment and skills in the marine biotechnology sector, and with wider policy, licencing and regulatory considerations, suggests that strategic funding and support is required – this approach has been successfully demonstrated to achieve results in similar sectors, such as wave and tidal energy.



[115] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-food_en.pdf
[116] http://www.marinebiotech.eu/sites/marinebiotech.eu/files/public/ERA-MBT_Roadmap_FINAL.pdf
[117] http://www.marinebiotech.eu/sites/marinebiotech.eu/files/public/ D3.5_Funding%20schemes%20and%20mapping%20of%20Marine%20Biotechnology%20financing.pdf
[118] http://www.marinebiotech.eu/sites/marinebiotech.eu/files/public/ D3.5_Funding%20schemes%20and%20mapping%20of%20Marine%20Biotechnology%20financing.pdf
[119] The Roadmap aims to position marine biotechnology within a self-sustained enterprise driven network that is supported by national and European funding agencies through the coordination of activity between different European funding bodies


FORE

5: WAVE AND TIDAL ENERGY

WAVE AND TIDAL ENERGY: THE HEADLINES

- Scotland is the global leader in wave and tidal energy innovation. By developing the sector, the UK will position itself at the forefront of one of the untapped global clean energy industries of the future.
- The capabilities and ambitions in this sector are demonstrated by the fact that there has been more deployment of wave and tidal devices at EMEC in the Highlands and Islands than in any other single location in the world.
- The global market is expected to grow steeply and could be worth as much as £75bn by 2050.
- Securing a global market lead will provide opportunities to increase the productivity of UK companies and provide reliable and secure energy for UK homes and businesses.
- An important driver for growth is the clean energy agenda which the Highlands and Islands is ideally placed to respond to. By harnessing its marine energy resource, 20% of UK electricity demand could be supplied by this indigenous predictable clean resource.
- There is significant potential for wave and tidal energy to provide energy to both aquaculture and marine biotechnology.
- To capitalise on the enormous opportunities, it is critical that there are routes to market for wave and tidal energy produced in the Highlands and Islands.

5.1: NATIONAL AND INTERNATIONAL TRENDS AND SIZE OF GLOBAL MARKETS

Market trends

5.1.1 The UK has some of the best wave and tidal natural resources in the world – a significant asset that contributes to the drive for clean growth. Around 50% of Europe's wave energy, and 35% of Europe's tidal energy is in UK waters. The UK Government estimates that wave and tidal energy has the potential to meet up to 20% of the UK's current electricity demand.[120] The ORE SIA[121] formed part of the second wave of SIAs, covering the North of England and Scotland[122]. Wave and tidal is a key part of the ORE SIA and recognising its potential, the SIA identifies a number of key market trends and opportunities. These typically focus on increasing installed capacity as the use of fossil fuels decreases with the need to create cleaner, secure energy systems. The Highlands and Islands, and indeed Scotland is arguably best placed to take advantage of this opportunity. Scotland has around 25% of Europe's tidal stream potential, equivalent to approximately 10GW, and 10% of wave resource with a potential of around 15GW.[123] The waters around the Highlands and Islands have some of the highest tidal ranges, and some of the most powerful waves in the world. There are strong synergies here with the ORE SIA. Supporting development of the wave and tidal sector in the Highlands and Islands will help to ensure that the UK retains its global market lead.

5.1.2 The Highlands and Islands is a very successful testing environment for wave and tidal devices. There have been more wave and tidal deployment in the region through EMEC than in any other single location in the world. In total 18 companies from ten countries have tested 28 marine energy devices at EMEC over the last 14 years. As of 2017, there were seven leased wave and 17 leased tidal sites for commercial farms. Although to date development at these sites has been limited, their existence will enable the development of the sector. The region is therefore well-positioned to maximise these natural resources for electricity generation and supply chain growth.[124]

120 RenewableUK (2017) Ocean Energy Race: The UK's Inside Track
121 https://www.ncl.ac.uk/media/wwwnclacuk/business/files/sia-report-offshore-energy.pdf
122 The Offshore Renewable Energy SIA was developed by a consortium comprising the Universities of Durham, Hull, Liverpool and Newcastle, four Local Enterprise Partnerships (Humber, Liverpool City Region, North-East and Tees Valley Combined Authority), SE; and the ORE Catapult.
123 HIE 92017) Marine Energy factsheet, May 2017
124 Neill, S.P. et al. (2017) The wave and tidal resource of Scotland, Renewable energy, 114(1), pp.3-17: http://dx.doi.org/10.1016/j.renene.2017.03.027

5.1.3 Despite these assets, there is a mixed picture in terms of UK trade in wave and tidal energy. Technopolis data (based on an approximation of the sector built up from SIC codes) shows that in the years to 2013, imports to the UK fell and the trade balance decreased. However, following a relatively small trade surplus in 2013 with exports at around £1.3bn, imports have increased to £1.7bn and there is currently a trade deficit in wave and tidal energy.

5.1.4 International research indicates that the global wave and tidal energy market was valued at almost $213m with expected growth of around 43% over the period 2014 to 2025.[125] In terms of revenue share, Europe currently accounts for a significant proportion: approximately 55% of total global revenue for 2016. The Asia Pacific region accounted for approximately 39%, and North America around 5%.[126] Research commissioned by HIE estimates that by 2050, the global wave and tidal market could be worth up to £75bn.[127] It is anticipated that whilst a great deal of the development will take place in Europe, the Asia-Pacific region is expected to experience considerable growth. South Korea is forecast to grow especially quickly in terms of tidal barrage operations (albeit this is a different sub-sector to the Highlands and Islands, which specialises in tidal stream), while forecasts also suggest that Australia will see large-scale developments in its wave energy sector.[128]

5.1.5 The UK's wave and tidal energy sector is expected to grow sharply, given the right support. Previous estimates by the Marine Energy Programme Board (MEPB) suggest that the wave and tidal market is expected to be worth £800m per year to the UK economy by 2035.[129] Analysis by the ORE Catapult suggests that tidal stream could generate a net cumulative benefit to the UK of £1.1bn by 2030, consisting of £1.5bn GVA from the domestic market and £900m GVA from exports, offset by £1.3bn of revenue support. This assumes 100MW of UK deployment per year from 2021/22, 3GW deployed in the rest of the world and a cost reduction in tidal energy of 70% to 2030, with a 15-year index-linked Contracts for Difference (CfD).[130]

5.1.6 However, wave and tidal energy technology is still in its early stages of technology development. Many previous studies predicated estimates on there being a Renewable Obligation that would be paid to the generators, or that wave and tidal would be ring-fenced within CfD. Recent rounds of the CfD auctions haven't specifically supported marine renewables, making the route to market for wave and tidal energy in the UK more challenging. **These market incentives are essential for the technology to break into the marketplace.** This challenge has been compounded by competition from offshore wind, a much more mature technology which has been supported by government and industry to scale up, and currently is more competitively priced.

5.1.7 Progress in the development and use of wave energy is approximately ten years behind tidal. In 2018 Orkney saw for the first time up to 7% of its electricity generated from a single tidal turbine over several weeks, proving that such variable, but predictable, output could be safely and effectively integrated into the grid as promised. This is demonstrable evidence that there is significant scope to increase wave and tidal's contribution in line with the Carbon Trust's estimate of it having the potential to meet 20% of the UK's present electricity demand [132].

5.1.8 Many of the developmental challenges faced by this sector are common across emerging energy technologies and the UK has the skills, infrastructure and supply chain capabilities required to make this a success. This is evidenced through a number of high profile projects in the region, despite the difficulties in getting to market. The MeyGen project being delivered by Atlantis Resources in the Inner Sound of the Pentland Firth is the world's largest tidal stream array projects. Supported by the Scottish Investment Bank through the Renewable Energy Investment Fund (REIF), the Crown Estate, HIE, and UK Government's Department of Energy and Climate Change (DECC), Phase 1a has been completed and consists of four tidal devices with a total capacity of 6MW. It is anticipated that a total of 269 turbines will be installed on site (86 turbines during Phase 1, and the remainder in Phase 2). In August 2017, it set a world record for monthly tidal stream power generation, of more than 700 MWh.[133] As at August 2018, in excess of 8GWh had been generated.

5.1.9 In its first year of testing, Scotrenewable's pioneering SR2000 – the world's most powerful operating tidal stream turbine – produced over 3GWh of renewable electricity. This is the equivalent annual electricity demand of around 830 UK households and more power than had been generated by the entire wave and tidal energy sectors in Scotland in the twelve years prior to the launch of the SR2000 in 2016. Along with the power generated by Meygen, this achievement demonstrates tidal power's market readiness. In addition, Nova innovation deployed the world's first fully-operational, grid-connected offshore tidal energy array, at Bluemull Sound in Shetland. The first turbine was deployed in March 2016 with two more deployed in August 2016 and 2017 respectively, and its array is expected to be doubled to six turbines through the €20m Horizon 2020 project EnFAIT, led by Nova Innovation.

125 Grand View Research (2018) wave and tidal Energy Market Size, at: https://www.grandviewresearch.com/§industry-analysis/wave-energy-market
126 Ibid.
127 HIE, RegenSW and Marine Energy Pembrokeshire (2016) Marine energy: Key steps to maintain a Great British Success Story
128 Transparency Market Research (2016) global wave and tidal Energy Market to reach US$ 11.3 Bn in 2024. at: https://www.transparencymarketresearch.com/pressrelease/wave-tidal-energy-market.htm
129 Wave Hub (2014) wave and tidal energy offers UK unprecedented opportunity for economic growth – latest findings. at: https://www.wavehub.co.uk/latest-news/wave-and-tidal-energy-offers-uk-unprecedented-opportunity-for-economic-grow
130 ORE Catapult estimates
131 Government Office for Science (2018) Foresight: Future of the Sea; from: Magagna, D. and Uihlein, A. (2015) Ocean Energy Development in Europe: Current Status and Future Perspectives. International Journal of Marine Energy 11, 84–104
132 https://www.carbontrust.com/resources/reports/technology/accelerating-marine-energy/
133 Atlantis Resources Ltd (2017) MeyGen Operation & Production Update. London: Atlantis, www.atlantisresourcesltd.com/2017/08/31/meygen-operation-production-update
134 EnFait, https://www.enfait.eu/

Global competitors

5.1.10 While South Korea has the largest installed capacity of tidal energy (as at 2015)[135], this includes tidal range (barrage). When considering tidal stream only, the UK has the largest installed capacity. France, Canada and Indonesia stand out as key players in the global marine energy market, both as potential allies and competitors, and the ORE SIA identifies France and Canada as the two most significant markets to rival the UK in tidal energy. There is increasing evidence that UK companies and companies that have used the UK's world-leading testing facilities are taking their know-how and technology to these markets, creating export economic value and high-value jobs for the UK. Other countries actively building marine energy industries include Japan, Chile, USA, South Korea, China, Netherlands, Portugal and Australia. UK companies remain at the forefront of marine energy technology development and are best-placed to capitalise on this opportunity, but this is under threat given the level of activity and financial support on offer in these countries.

5.1.11 France's tidal energy sector has received strong government support and also has up to a fifth of Europe's marine energy potential. There are two large tidal energy projects proposed in France: Normandie Hydro (led by General Electric) and Raz Blanchard (led by OpenHydro). In contrast, Canada has the largest transmission capacity for tidal power in the world with a total capacity of 64 megawatts, sufficient to power 20,000 homes at peak tidal flows.[136] Force C, a tidal power project off the coast of Nova Scotia involves a number of companies including Irish Company DP Energy. Most of the technologies to be deployed at FORCE have been previously tested at EMEC.[137] However, when considering both actual and consented marine power capabilities across both wave and tidal power, the UK markedly outperforms other industrialised nations.

5.1.12 As China turns its attention towards the global potential for marine renewable energy, they have invited EMEC and other UK industry experts to support the development of a 'blue silicon valley' in Qingdao, discussing the creation of a Chinese version of EMEC: CMEC. This has been supported through the UK Foreign and Commonwealth Office and China Britain Business Council (CBBC) to help progress policy support in China towards developing a demonstration site to facilitate innovation in wave and tidal energy. The project involves EMEC providing feasibility studies around the creation of a CMEC facility as part of a brand new £200m (2b Yuan) marine laboratory campus in Shandong Province, China. Qingdao National Laboratory for Marine Science and Technology will serve as the base for the project, drawing researchers from a number of Chinese universities. An ocean energy demonstration site has already been identified as a key aspect of the lab's innovation activities and this represents one of a number of export opportunities for skills and expertise from the Highlands and Islands region.

5.1.13 There are several more examples of wave and tidal testing sites being developed and in operation internationally. The EU FP7 MaRINET, and its Horizon 2020-supported successor MaRINET2, are test programmes for offshore renewable energy, and cover test sites around the EU.[138] Testing facilities already exist in the Republic of Ireland and others are being developed. The Lir National Ocean Test Facility offers state of the art wave tanks and electrical rigs, while SmartBay is planning to be developed as the national marine and renewable energy test and demonstration facility, offering facilities for low-cost sea trials and validation of devices and components. The Atlantic Marine Energy Test Site (AMETS) is being developed by the Sustainable Energy Authority of Ireland (SEAI) and will offer testing of full scale wave energy converters in an open ocean environment.[139]

5.1.14 The SEENEOH tidal test site in Bordeaux, France recently opened in March 2017. The floating tidal platform offers three testing beds for testing both mounted and floating tidal devices. The site also offers energy performance monitoring and certification.[140] In the USA, the Northwest National Marine Renewable Energy Center at Oregon State University is currently developing the South Energy Test Site for wave energy.[141]

5.1.15 There are also wave and tidal locations outside of the Highlands and Islands within the UK. Cornwall is a growing location for marine energy technology and is looking to expand its marine renewables related activity. There is a cluster around the Wave Hub grid connected test site off the north coast of Cornwall and Wave Hub continues to seek to attract device developers to its grid connected site. It has also looked at opportunities associated with testing floating offshore wind turbines. FaBTest in Falmouth allows for smaller and concept devices and components to be tested in the relatively sheltered bay. Wave Hub is also looking to develop a demonstrator site in South West Wales. Other pre-commercial demonstration sites include MORLAIS and Perpetuus Tidal Energy Centre (PTEC). The Welsh European Funding Office has secured EU funding of €100m to increase the number of wave and tidal devices being tested in Welsh waters.[142,143]

> There is potential to take excess electricity produced by wave and tidal energy and using an electrolyser, convert it to Hydrogen to provide an alternative fuel source for transport, heating and electrical regeneration.

135 Ocean Energy Systems (2015) Annual Report
136 Offshore Renewable Energy Science and Innovation Audit, pp. 96-98. Internet: http://www.ncl.ac.uk/media/wwwnclacuk/business/files/sia-report-offshore-energy.pdf (accessed 1 March 2018)
137 http://www.dpenergy.com/projects/tidal/canada-force-c/
138 http://www.marinet2.eu/
139 http://www.oceanenergyireland.ie/TestFacility
140 https://tidalenergytoday.com/2017/03/03/seeneoh-tidal-test-site-fully-connected/
141 http://nnmrec.oregonstate.edu/facilities/pmec-sets
142 RenewableUK (2017) ocean energy race: The UK's inside track
143 University of Edinburgh (2017) Policy and Innovation Group UK Ocean Energy Review 2017

Future opportunities

5.1.16 As the technology matures attention moves towards large-scale (tidal) array developments. As operations expand, there will be opportunities to see economies of scale across operating expenses (OPEX) and capital expenditure (CAPEX) costs of a farm. The sector will then become more competitive as production costs decrease.[144] In addition, as wave and tidal developments become more widespread and larger in scale, there will be new opportunities in the subsea supply chain as projects look for help in meeting the technical challenges associated with upscaling. [145]Since technological development remains at an early stage, there is scope for firms to enter the market through new technology development. This includes the possibility to develop expertise in the UK that can create a large export potential.[146]

5.1.17 Corrosion is a major concern for many offshore energy developers. Research suggests that anti-corrosion solutions and new materials could save over £14 billion for wave and tidal energy project developers in the EU by 2050. When the wider supply chain is considered, the anti-corrosion supply chain could be worth as much as £22 billion across the EU by 2050.[147]

5.1.18 Whilst there is an estimated supply chain of around 850 companies for the wave and tidal sector in the UK, in many cases much of the component manufacturing, e.g. turbines, remains outside of Scotland and also outside the UK. Recent research identified a lack of suppliers, as well as inadequate infrastructure in some cases could be a barrier to the development of the marine energy sector in Scotland.[148] However, several Scottish-based supplier companies were contracted to the MeyGen project in particular – including Xodus Group, James Fisher, Mackay Energy and Orkney Research Centre for Archaeology (ORCA).[149] Additionally, Atlantis Resource acquired Marine Current Turbines (MCT) from Siemens in 2015, including MCT's tidal turbine intellectual property portfolio and the designs for MCT's turbines.[150] Atlantis has established a manufacturing and assembly facility at the Nigg Energy Park in Easter Ross out of which it services the Meygen project.

5.1.19 More widely, the UK is leading the innovation and cost reduction in fields as diverse as new materials, electrical engineering and remote-controlled vessels. Anecdotal evidence suggests that UK companies constitute more than 80% of the wave and tidal energy supply chain. With delegations and trade missions from countries including France, Canada, USA, Japan, China and South Korea visiting UK projects to learn from our excellence, there is a transformative opportunity for UK technology innovators and marine energy supply chain companies. A significant proportion of future global trade is expected to be outside of the EU. Underpinning the UK's ability to capitalise on this significant export opportunity is the requirement to continue building strong expertise in blade optimisation, turbine reliability, system control, health monitoring, foundations, and operations and maintenance, through a vibrant domestic market. To maintain market sectoral leadership, the UK must do more to support innovation and promote exports and inward investment.

5.1.20 By harnessing the marine power of the Highlands and Islands, the UK will be able to position itself at the forefront of one of the untapped global clean energy industries of the future. Securing a global market lead will provide opportunities to increase the productivity of UK companies and provide reliable and secure energy for UK homes and businesses.

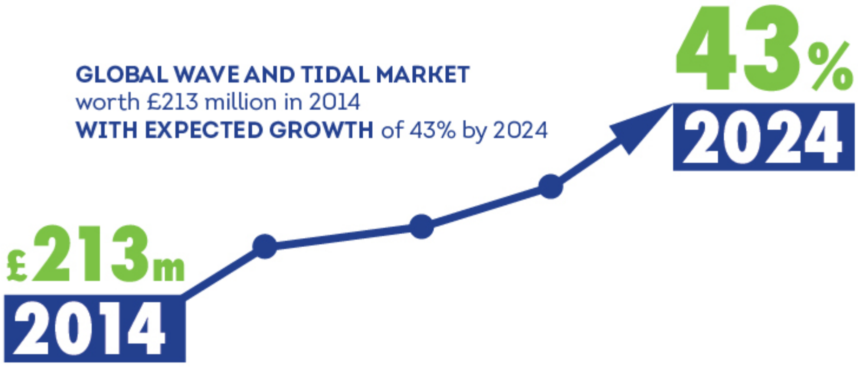
5.1.21 Denmark is an example of how adopting an early mover advantage in clean energy can secure market lead. Having secured the early technology innovation lead, 76% of the global wind energy supply chain is now based in Denmark or uses Danish services and expertise. Norway provides an example of the benefits of harnessing indigenous resources. Around 99% of Norwegian electricity is produced from hydro power constructed in the 1920s, and they now have some of the cheapest electricity prices in Europe. The UK could replicate this, by harnessing its marine energy resource; 20% of UK electricity demand could be supplied by this indigenous predictable clean resource.

5.1.22 The Highlands and Islands region is therefore in an excellent position to exploit its natural resources, the developing supply chain, the skills and expertise based here and its competitive advantage in marine energy. This would anchor the industry in Scotland and ensure the benefits are achieved and sustained. As a consortium member pointed out:

"THE INDUSTRY IS OURS TO CREATE."

Hydrogen powered fuels cells could replace diesel generators on fish farms.

144 Market Research Reports Search Engine (2018) Global wave and tidal Energy Market Analysis, Size, share, Growth, Trends, and Forecast 2016-2024.
145 Subsea UK (2017) NSRI Reveals the Challenges and Opportunities in wave and tidal Energy Sectors. Internet: https://www.subseauk.com/8982/nsri-reveals-the-challenges-and-opportunities-in-wave-and-tidal-energy-sectors (accessed 1 March 2018)
146 Cision PR Newswire (2016) Market Insights & Opportunities, 2022 – Market is Anticipated to Grow Around $5.9 Billion – Research and Markets.
147 Government Office for Science (2018) Foresight: Future of the Sea; from: The Crown Estate (n.d.) Energy, Minerals and Infrastructure: Wave and Tidal. London: Crown Estate, https://www.thecrownestate.co.uk/energy-minerals-and-infrastructure/wave-and-tidal
148 ekosgen/Scottish Enterprise (2016) Mid-Term Review of the Renewable Energy Investment Fund (REIF)
149 Ibid.
150 https://tidalenergytoday.com/2015/04/29/atlantis-acquires-siemens-marine-current-turbines/



5.2: LOCAL SCIENCE AND INNOVATION ASSETS

5.2.1 The Highlands and Islands is a critical location for testing and operational deployment of innovative wave and tidal technology. Organisations from the SIA region have led on £6.6m worth of projects (26 projects) funded through UK Research Councils and Innovate UK, and participated in £40.1m worth (56 projects) between 2007 and 2017. The region's portion of such research projects is highly concentrated, with its share of projects led and participated being almost six times the UK average.[151]

5.2.2 Creating an innovation culture is a regional and national priority, and in the Highlands and Islands EMEC is a very good example of how this can be achieved through bold aspiration and strategic commitment. However, commercialising innovation has been weak in this sector and requires urgent attention if R&D expenditure is to deliver strong return on investment.

Public and academic assets in the Highlands and Islands

5.2.3 The marine environment, and related disciplines in environmental science and engineering are key research themes in the Highlands and Islands. The region's geography and marine/oceanographic conditions make it an ideal location to test, demonstrate and deploy marine energy technology. Orkney hosts a world-leading cluster in wave and tidal energy, but research centres and their expertise – as well as wave and tidal arrays – are located throughout the Highlands and Islands, as well as elsewhere in Scotland and the UK.

EMEC

5.2.4 Established in 2003, EMEC was created in response to the House of Commons Science and Technology Committee's recommendation in April 2001 that the UK should position itself to exploit the emerging opportunity in marine renewables technologies. It aimed to do this by establishing a national offshore wave and tidal test centre. It is the world's first and only centre to provide purpose-built testing facilities to developers[152,153], and is the only grid-connected, independently accredited facility for wave and tidal device-testing in the world. More marine energy devices have been tested at EMEC than at any other single location globally, which has firmly established it as a world leader.

EMEC
THE EUROPEAN MARINE ENERGY CENTRE LTD

IS THE WORLD'S ONLY GRID CONNECTED WAVE AND TIDAL TEST SITE

5.2.5 Between 2007 and 2017, EMEC participated in over 30 UK-funded projects worth more than £15m.[154] It has also helped to lever more than €88m in EU funds across 20 projects through ERDF Interreg, Ocean ERA-NET and Horizon 2020, with a total project budget to Scottish companies of almost €24m.[155] Of these, EMEC has led on four projects, including its Energy Technology Verification (ETV) service, the only ETV Verification Body in Scotland.[156] EMEC has delivered a cumulative GVA of £116.3m to the Highlands and Islands and £284.7m to the UK as a whole.

Wave Energy Scotland (WES)

5.2.6 Formed as a subsidiary of HIE at the request of the Scottish Government in 2014, WES was established in response to challenging conditions within the wave market, and to a lack of private investors. It runs the world's largest wave technology development programme. WES is driving the search for innovative solutions to the technical challenges facing the wave energy sector, through its challenge-led innovation funding programmes. Over the last three years WES has funded 77 projects, with 170 organisations and committed £29m in funding. WES is also developing four wave energy convertor technologies, as well as managing programmes to develop power take-off technology, advanced control systems and structural materials. The competitive programmes are open to innovators from across Europe with Scottish companies representing 70%. This underlines the dominance of Scotland in the wave sector and in their innovative approach.

5.2.7 WES acquired the IP for two wave device developers, Pelamis (developers of the world's first offshore wave power converter to successfully generate electricity in 2004) and Aquamarine (wave energy company that developed the Oyster technology, a wave-powered pump that pushes high pressure water to drive an onshore hydro-electric turbine) following both companies being placed in administration. Whilst these two relatively high-profile company failures demonstrated the lack of market readiness for investment in nascent wave energy technology, the retention of the IP within the region ensures that the significant learning from the investments made by these companies has been retained in Scotland and can be used to support the development of new technology.

151 Gateway to Research, 2018; Technopolis analysis
152 http://www.emec.org.uk/about-us/
153 HIE, Steve Westbrook (2016) European Marine Energy Centre Economic Impact Assessment
154 Gateway to Research, 2018; Technopolis analysis
155 EMEC analysis, 2017
156 http://www.emec.org.uk/services/etv/

International Centre for Island Technology (ICIT)

5.2.8 Based in Orkney, Heriot Watt's ICIT offers globally recognised research, teaching and consultancy expertise. Its multi-disciplinary research team focuses on accelerating the development of marine renewable energy. A 2012 study identified impacts of £8.8m GVA and 119 jobs in Orkney as a result of the campus and its spin-outs.[157]

Orkney Research and Innovation Campus (ORIC)

5.2.9 Building on the work of EMEC and ICIT in the area, in 2017 HIE and Orkney Islands Council agreed to provide £6.5m in funding to develop the ORIC in Stromness. This 3.75-acre campus will be based around the Old Stromness primary school and Old Academy building where EMEC, ICIT and other businesses are already located. The campus will seek to attract both academic and commercial organisations looking to carry out research across a number of areas, including marine energy.[158]

University of the Highlands and Islands

5.2.10 UHI's marine environment expertise extends to marine energy. This is primarily through its ERI which undertakes modelling and remote sensing approaches to advance understanding of wave and tidal energy resources, as well as research to understand biological and ecological responses to changes in the physical environment, including those resulting from energy extraction.[159] The ERI also hosts the Centre for Energy and the Environment (CFEE), which was part-funded through ERDF, SFC, and HIE.[160]

5.2.11 UHI's ORCA has been closely involved with several marine renewable energy developments including marine research conducted by SAMS UHI, which examines the impact of renewables on the marine environment. Wider renewables expertise and capability exists within UHI in its Agronomy, Sustainable Energy and Micro-renewables (SEAM) and Greenspace centres.

5.2.12 Building on this expertise UHI, working with partners in Northern Ireland, the Republic of Ireland and Scotland, is taking part in the EU Interreg VA SEUPB Programme funded Bryden Centre. Funded with £9m from the Interreg SEUPB Programme, the Centre supports research in marine and bio-renewable energy. As part of the programme, 20 or more PhD students will enrol at UHI each year to complete projects in marine and bio-renewable energy. These students will undertake collaborative projects with industry to produce industrially relevant research with the potential for commercial exploitation.[161]

Offshore wave power could be used as a power source for fish farms, including in more exposed locations.

[157] Biggar Economics (2012) Heriot-Watt University: Economic Impact Study
[158] http://www.emec.org.uk/orkney-renewables-campus-funding/
[159] http://eri.ac.uk/
[160] https://www.northhighland.uhi.ac.uk/study-at-nhc/international/eri/
[161] https://www.uhi.ac.uk/en/merika/media-centre/news/phd-studentships-with-the-new-bryden-centre/

Assets in the wider area

5.2.13 Wave and tidal energy in the Highlands and Islands benefits from science and innovation assets in other parts of Scotland, and they in turn benefit from their proximity to the assets and activities in the Highlands and Islands.

5.2.14 The FloWave Ocean Energy Research Facility at Edinburgh University undertakes cutting-edge academic research into wave and tidal current interactions. It also provides testing facilities for commercial developers to assist with trialling and de-risking technologies at an early stage, before going offshore.

5.2.15 The ORE Catapult, headquartered in Glasgow with a test site in Levenmouth and bases in Hull and Blyth, aims to support innovation and research development in wave, wind and tidal energy. It specialises in bridging the gap between academia and industry. One of its key roles is to provide testing facilities to de-risk innovation and bring projects, products and services closer to market. It provides the first step in the innovation and commercialisation chain that feeds market testing of wave and tidal energy devices at EMEC in Orkney.

5.2.16 The UK has an established research programme through the ORE SuperGen programme.[162] A strong portfolio of organisations collaborate through these projects including a number of leading academic institutions specialising in tidal stream energy research: the Universities of Edinburgh, Exeter, Manchester, Strathclyde, and Queens University Belfast. These are supported by key research and technical organisations, including EMEC and the ORE Catapult.

Industry R&D and innovation assets

5.2.17 As the wave and tidal energy industry is still at a relatively early stage, many of the key industry players are involved in R&D and innovation through the demonstration, testing and proving of market viability for a range of devices and technologies.A key example of this is Orbital Marine Power (formerly ScotRenewables), a start-up developed by a PhD graduate from Heriot Watt's ICIT. Established in 2002, Orbital Marine Power has secured investment from a variety of sources including Total, Fred Olsen, ABB Technology Ventures and DP Energy, as well as the REIF. Its work has seen the development of an innovative floating platform as well as the 2MW SR2000 turbine. Launched as the world's largest tidal energy converter, the SR2000 had produced over 1300 MWh of energy output by December 2017, and had at times provided up to 25% of the electricity requirements of Orkney.[163,164] It is currently delivering the Flotec project with Horizon 2020 support, which will lower the cost of floating tidal technology.[165]

5.2.18 Meygen's Operation and Maintenance (O&M) facility at Nigg Energy Park[166] is a key component of the project's success. Demonstrating the importance of local ports and infrastructure to wave and tidal capability, the facility on the Cromarty Firth is now an important infrastructure asset for the region. It is owned by Global Energy Group and is a multi-user facility servicing the needs of the wider offshore energy industry.

5.2.19 Orkney is also home to Aquatera and Xodus, research consultancies that provide environmental expertise and operational support for offshore, coastal and land-based activities. Xodus has a wealth of experience in Oil and Gas, which it is able to apply to wave and tidal activity. [167]Aquatera is globally renowned for its wave and tidal expertise, and has worked on in excess of 200 marine energy studies and a number of strategic marine energy planning projects.[168] Additionally the broader marine energy supply chain in the region, e.g. Leask Marine and Green Marine, have developed significant marine operational expertise which is now exported around the world.[169]

5.2.20 The Underwater Centre in Fort William has a worldwide reputation for sub-sea training for commercial divers and remotely operated vehicles (ROV). It has access to a sea-water environment up to a depth of 150m in a sea loch, and maintains several test sites at different depths. While the company is currently in administration, there is strong industry appetite for continuation and enhancement of the testing capability & infrastructure at the facility.[170]

5.2.21 Orkney Islands Council's £8.4m development plan to extend the Hatston Pier to cater for marine energy devices brought in £3.2m in support from ERDF and transformed the pier into Scotland's longest commercial deep-water berth, serving not just marine energy but cruise ships.[171] The former naval base at Lyness on the island of Hoy has been re-developed by the Council and a new pier built in Stromness for the same reason – to service marine energy operations.[172] HIE investment has also helped to create office and workshop units at Hatston to service the marine renewables sector.

162 https://www.supergen-marine.org.uk/
163 http://www.scotrenewables.com/company/history
164 RenewableUK (2017) ocean energy race: The UK's inside track
165 http://www.scotrenewables.com/flotec/
166 http://www.nigg.com/about
167 http://www.xodusgroup.com/
168 https://www.aquatera.co.uk/what-we-do/offshore/sectors/wave-and-tidal-energy
169 www.orkneymarinerenewables.com
170 http://news.hie.co.uk/all-news/vision-for-loch-linnhe-subsea-campus/
169 EMEC (2013) Press release: Pier extended to service marine renewables industry
169 EMEC (2011) EMEC – Lyness first client

5.3: LOCAL SCIENCE AND INNOVATION TALENT

Current workforce

5.3.1 Because of the nature of the industry, it is difficult to estimate the scale of employment through conventional datasets such as BRES. Renewable energy is not adequately captured through Standard Industrial Classification (SIC) Codes, so the scale of employment is frequently underestimated by existing statistics. However, there are some estimates available. RenewableUK estimated that 1,724 people were employed in wave and tidal energy in the UK in 2013.[173] Recent HIE research estimates that in the SIA region, there were around 440 people employed in wave and tidal energy in 2016. Data from consultancy firm Aquatera shows that in 2016[174] there were 220 people employed in wave and tidal energy in Orkney. This represents a nearly ten-fold increase since 2000.

5.3.2 However, there is a high degree of skills in the sector that are transferable with/from other sectors. In Orkney, local supply chain companies have formed from diversification – Green Marine is a vessel operator who diversified from fishing; Leask Marine a marine service and engineering company diversified from diving. Both have worked on a great number of test projects at EMEC and have used their knowledge of the sea to provide invaluable support services to developers through their own bespoke tools and techniques.

5.3.3 In addition, the potential for transferable skills from offshore engineering in the North Sea to renewables is considerable, as the oil and gas sector seek to improve their own efficiencies and sustainability. With pressures on North Sea oil and gas operations, EMEC has seen new business start-ups focusing on helping the oil and gas sector reduce costs by using renewable technologies. East Coast Oil and Gas Engineering (EC-OG) has recently installed their innovative Subsea Power Hub (SPH) at EMEC. This represents an example of cross-over innovation that could not have been foreseen when EMEC was envisaged, but is a perfect illustration of the benefits of an innovation-oriented culture and landscape.

1,724 employed in **UK WAVE AND TIDAL ENERGY**

440 in the **HIGHLANDS AND ISLANDS**

Skills pipeline

5.3.4 Just over 600 students were studying energy-related[175] science, engineering and technology subjects in Scotland in 2016/17. The vast majority (nine in ten) of these students were studying at postgraduate level. The SIA region specialises in undergraduate energy-relevant education, but with limited numbers currently (58 students). The courses are delivered predominantly at NAFC Marine Centre UHI, which specialises in maritime technology related courses, but also at Lews Castle College UHI and Perth College UHI. All 58 students were from Scotland which may indicate that they will remain in Scotland and apply their skills post-studying, but there is no guarantee.

5.3.5 Across Scotland, there were 326 graduates with energy-relevant degrees in 2016/17. These graduates qualified from seven Scottish HE Institutions, the vast majority with a postgraduate qualification (90%), mirroring the current student level of study. In the Highlands and Islands, 32 students graduated in 2016/17, largely from NAFC Marine Centre and all at undergraduate level.

5.4: NATIONAL AND INTERNATIONAL ENGAGEMENT

5.4.1 The Highlands and Islands has taken a lead role in the renewable energy sector, being home to a number of globally significant projects. As such, HIE provides the strategic lead in Scotland in supporting the wave and tidal sector. HIE hosts the HI Energy[176] brand which represents the region's energy sector. HIE has had dedicated staff resource committed to renewables, with a significant focus on marine, for close to 20 years. In this time, it has invested substantially in port and harbour facilities, supply chain development, projects and technology development, as well as in the creation of EMEC and WES.

5.4.2 The range of devices from international companies tested at EMEC is also evidence of the region's expertise and international reputation. Devices from companies based across Europe, such as Norway, Sweden, Spain, the Netherlands, Austria and Germany, as well as from Canada have been tested at the Centre, clearly demonstrating EMEC's globally recognised expertise and available resources. Since its establishment in 2003, EMEC has exported its knowledge to 18 different countries. In 2016 its consultants provided expertise to Belgium, China, Ireland, Peru, Singapore, South Korea, Sweden and the USA. EMEC also runs a group, "International Waters", which co-ordinates all the test sites around the world. This group meets every year.[177]

[173] RenewableUK (2013) Working for a Green Britain & Northern Ireland 2013–23: Employment in the UK Wind & Marine Energy Industries
[174] ekosgen/HIE (2017) Energy-related employment in the Highlands and Islands: Evidence base refresh, 2016
[175] These include the HESA JACS codes for Energy resources; Offshore engineering; Maritime technology.
[176] http://www.hi-energy.org.uk/
[177] http://www.emec.org.uk/press-release-international-waters-meet-at-icoe-2016/

5.4.3 WES has developed a series of performance metrics to assess the maturity of wave and tidal technology. This is in common with work by the US Department of Energy, the EC and the International Energy Agency, who have all now agreed to collaborate in a project led by WES and funded by the EU Ocean ERA-NET project. More widely, the WES model of driving innovation through the use of pre-commercial procurement (PCP) has been recognised internationally as being particularly effective. The EU has announced plans to establish a European version, Wave Energy Europe, and have committed €24m to the project which will start in 2020. WES is engaging with other EU Member states to develop the project.[178]

5.4.4 There are also clear links with the ORE Catapult. Along with CENSIS, it has been funded by HIE, the SFC, SE and Scottish Government to assess whether sensor technology from other industries can be used to detect, monitor and give advance-warning of potential collisions with tidal energy devices, or if a new sensor technology is needed. EMEC has a Memorandum of Understanding with the ORE Catapult and is collaborating with them on a number of projects, such as RiaSOR, a project looking to establish best practice reliability testing for wave and tidal devices.[179] The Bryden Centre Partnership is another example of cross-border collaboration, led by UHI in the SIA region.[180]

5.4.5 Consultancy firm Aquatera has participated in regional, national and international collaboration in relation to the issues associated with marine energy development. It has done this through direct participation in the following fora:

- The EC's Ocean Energy Forum, Orkney Renewable Energy Forum and Scottish Renewables Forum;
- The US Department of Energy's Annex IV working group (part of the International Energy Agency's Ocean Energy Systems Technology Collaboration Programme);
- The Oregon Wave Energy Trust; and
- Various marine energy working groups in Chile.

5.4.6 Aquatera has provided management of the Secretariat function for the UK's Offshore Renewables Joint Industry Programme (ORJIP) for Ocean Energy since its inception in 2015. Aquatera has also undertaken the development of a roadmap for marine energy development in Chile for the British Embassy, and produced an aquatic energy roadmap for Peru.

5.5: DEVELOPMENTS IN THE WIDER FUNDING LANDSCAPE

Current funding for wave and tidal energy

5.5.1 Public sector funding for research, development and innovation has been critical for the development of the wave and tidal sector, particularly in the Highlands and Islands. It has been required to support an embryonic industry develop and prove not only the commercial viability of technology and devices, but also test and demonstrate that the devices can withstand the harsh environment of the seas around the coast of Scotland. Through delivery, the region has been highly successful in realising high impact R&D, despite the high risks and high costs involved.

5.5.2 Between 1997 and 2016, almost £128m in industrial grant funding (excluding academic research) for technology was made to companies developing wave and tidal technology in the UK. When considering equity and loan investments this totals over £270m.[181]

5.5.3 A key tool for supporting the wave and tidal energy sector has been the Scottish Investment Bank's REIF. REIF provided funding to a number of the marine energy devices and projects tested, developed and in operation in the Highlands and Islands, including devices developed by MeyGen, Orbital Marine Power (formerly ScotRenewables), Sustainable Marine Energy, Albatern and Nova Innovation.

5.5.4 The mid-term review of REIF found that the investment has made an important contribution to the renewable sector, and has helped to foster and develop the nascent marine sector in a way no other intervention mechanism could have achieved. With many technology developers finding themselves in the so-called investment "valley of death", i.e. at a stage not yet ready to attract money from private investors or technology firms, REIF monies de-risked investment and allowed projects to progress. REIF has also influenced the approach to investing in renewable energy elsewhere, e.g. the European Investment Bank.[182] A successor fund, the European Energy Investment Fund, has now been established by the Scottish Government and will be delivered by the Scottish Investment Bank. With £20million of funds available to spend by March 2019.

5.5.5 Previously, the WATERS fund, a joint venture between HIE, SE and the Scottish Government, has supported nine companies with £10.8m of funding (total project values of £22m) for the development of new wave and tidal energy devices.[183]

5.5.6 Recognising the challenges facing wave energy in relation to tidal energy technology, WES supports the development of innovative solutions to the technical challenges facing the wave energy sector. To date WES has awarded £29m across 11 countries, including Sweden, Italy and Belgium. The four current WES investment programmes are:

- Power Take-Off;
- Novel Wave Energy Converters;
- Structural Materials and Manufacturing Processes; and
- Control Systems.

5.5.7 The objective for WES is to produce two "Proof of Concept" devices, tested in real sea conditions by 2020. WES is currently only funded until 2020, and further funding will be required to take proof of concept to commercial product. Currently there is no innovation funding available for this stage of development in the UK.

5.5.8 Secure, clean and efficient energy is one of the societal challenges targeted by the current Horizon 2020 Framework. The existing 2018-20 work programme has allocated more than £1.7bn to projects including for ocean-energy technology (i.e. wave and tidal). Part of the programme includes a call for a European pre-commercial procurement programme for wave energy R&D, with an indicative budget of €15-20m.[184]

178 https://setis.ec.europa.eu/system/files/set_plan_ocean_implementation_plan.pdf
179 https://ore.catapult.org.uk/press-releases/hi-tech-collaborative-project-to-cut-costs-and-boost-confidence-in-tidal-energy-projects/
180 https://www.brydencentre.com/news
181 HIE/Caelulum, 2016
182 ekosgen/Scottish Enterprise (2016) Mid-Term Review of the Renewable Energy Investment Fund (REIF)
183 http://news.hie.co.uk/all-news/latest-round-of-waters-funding-announced/
184 European Commission (2017) Horizon 2020 Work Programme 2018-2020: 10. Secure, clean and efficient energy (C(2017)7124)

5.5.9 The Orbital Marine Power (formally ScotRebewables) FloTEC project is one of a number of projects currently funded by Horizon 2020. The project aims to further advance their already low cost floating tidal technology to deliver a 25% lower Levelised Cost of Energy (LCoE) preproduction model. EMEC is a project partner in this and six other Horizon 2020 projects relating to marine energy, including the InToTidal, Ocean 2G and Clean Energy from Ocean Waves (CEFOW) projects.[185]

5.5.10 Funding for renewables and marine energy projects is also available through the Interreg North-West Europe and North Sea Region programmes. EMEC are currently leading the FORESEA project[186], which helps to bring offshore renewable energy technologies to the market by providing free access to North-West Europe's world-leading network of test centres. FORESEA has been supporting developers of offshore renewable energy technologies to test in real sea conditions around North West Europe. Through the project consortium, EMEC is connected to SmartBay in Ireland, SEM-REV in France, and the Dutch Marine Energy Centre.

5.5.11 Aquatera is involved in an Interreg North-West Europe project. The Low Carbon Off-Grid Communities (LOGiC) project aims to develop a standardised model for renewables-based decentral hybrid energy systems (DHES), combining different types of renewables, such as tidal, wind and solar PV with each other as well as with battery storage. This is to overcome the intermittent nature of these energy sources to enable cheaper, cleaner and more reliable electricity for local communities in 'energy remote' areas.[187]

Future funding opportunities

5.5.12 As noted earlier, there are some substantial changes underway in terms of available funding in both the UK and European context. Wave and tidal energy researchers and developers have benefitted significantly from European funding sources, and the possible loss of access to Horizon 2020 is a threat to future funding revenue streams for research and innovation beyond the 2014-2020 programme period. Though the UK Government has committed in principle to matching its Horizon 2020 contribution, UKRI participants in Horizon 2020 are effective in securing a greater share of funding in return; as a result, there is likely to be a substantial funding gap. This is a significant concern.

5.5.13 However, the Industrial Strategy Challenge Fund will target renewable energy systems, and the linking of energy supply, storage and use to develop smart energy systems.[188] Current projects being delivered by organisations in the Highlands and Islands and consortium partners demonstrate that wave and tidal energy technology already forms a key part of this approach.

5.5.14 Future CfD auctions offer potential for the sector, and particularly tidal, if they fairly accommodate emerging technologies. Projects need a mix of tapered support mechanisms, of which CfD is just one. Beyond the capital support requirement for initial R&D, CfD could remove some of the challenges the wave and tidal technologies face in terms of routes to market during the generation phase. At present, wave and tidal energy needs support in this regard, and addressing shortcomings around CfD auctions is one way of achieving this. The marine energy industry is also currently developing proposals for the creation of an Innovation Power Purchase Agreement (IPPA) to support <10MW scale projects. It also calls for ongoing technology development funding support, particular for the wave sector.

5.5.15 More widely, there is potential for wave and tidal energy to provide on-site power to a wide range of sectors with operations in the Highlands and Islands. Local clean energy production will be very valuable across more peripheral areas of Scotland and the UK. The existing regulatory framework can be a barrier to on-site, local energy production and to collaborative R&D and innovation funding opportunities.

> Wave and tidal energy would be an effective and clean power source for marine biotechnology, for example in seaweed processing.

[185] European Commission Cordis database search, 2nd April 2018, at: https://cordis.europa.eu/
[186] http://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/
[187] http://www.nweurope.eu/projects/project-search/low-carbon-off-grid-communities-logic/
[188] https://www.gov.uk/government/collections/industrial-strategy-challenge-fund-joint-research-and-innovation#prospering-from-the-energy-revolution

6: CONCLUSIONS

AMBITIONS AND PROPOSALS: THE HEADLINES

- The MAXiMAR SIA is driven by four hypotheses which have been tested, fine-tuned and confirmed with stakeholders, including industry.
- In preparing the SIA, the consortium has developed its ambitions and priorities for realising the potential of the marine economy and yielding productivity growth.
- Our driver is to create an environment which invests in ideas and commercialises research outcomes to benefit the region, Scotland and the UK.
- Though the sectors will grow at different rates, evidence points to a total value of the marine economy in Scotland of £5bn by 2035. Estimates suggest this is an approximate seven-fold increase on current values.
- To capitalise on the enormous opportunities, it is critical that routes to market support mechanisms are put in place to commercialise marine economy innovation in the Highlands and Islands.
- We aim to build the skills base, regulatory framework, infrastructure and ecosystem to support the sustainable growth of the marine economy
- Partners have identified cross-sectoral examples and opportunities that will exploit synergies and tackle common challenges.
- We have developed a set of four proposals, or targeted opportunities, that will deliver our ambitions and build on the region's capabilities and strengths. They provide the strategic framework for the future of the marine economy and the impacts will be international. They will secure the UK's place at the forefront of the marine economy.
- The marine economy in the SIA region will be developed through a whole-sector approach to science and innovation, skills-planning, funding, supporting access to markets, growth and problem-solving.
- The consortium will work to influence and support a Sector Deal for the marine economy.

6.1: GAP ANALYSIS

6.1.1 The three sectors in the marine economy are at different stages of their development but it is clear that for each there is significant and demonstrable potential for growth and contribution to the circular economy. Based on the estimated current value, which is not easy to define given that the marine economy is not a defined sector in its own right, the marine economy in the Highlands and islands could, with the right investment, grow seven-fold by 2035.

6.1.2 The impact of the marine economy in the Highlands and Islands extends beyond the region. Science and innovation in other parts of Scotland are driven by the assets and activities in the Highlands and Islands. Research in Aberdeen and the Scottish Central Belt influences the marine economy in the Highlands and Islands, and assets in the Highlands and Islands drive operations outside the region as well as locally. It also supports an extensive and diverse supply chain.

6.1.3 If the potential in the Highlands and Islands and for the UK is to be maximised and the economic benefits realised, there are some clear challenges that must be addressed. Failing to address the challenges will inhibit growth and have a negative impact on the economic and social health of the Highlands and Islands. The importance of this cannot be overstated as the Highlands and Islands faces severe population decline making talent retention and attraction a critical issue for the marine economy as well as for the wider regional economy. The potential impact of Brexit on the labour supply compounds this risk.

6.1.4 The region is characterised by dispersed, fragile communities that stand to benefit from a healthy marine economy. The four hypotheses of the MAXiMAR SIA were developed to provide a holistic and systematic framework to understand and address the challenges. They are designed to work together to tackle the common issues faced by aquaculture, marine biotechnology and wave and tidal energy and so leverage the value of the marine economy. The potential and added value will only be realised through a collective response across the combined challenges. They hypotheses are based on:

- Having the mechanisms in place to support the commercialisation of the marine economy science and innovation assets and so realise the economic potential for the region, for Scotland and for the UK.
- Implementing a planning and regulatory framework that supports and encourages innovation and development, balanced with environmental sustainability and the needs of different user groups.
- Identifying opportunities and developing marine economy clusters in science, innovation and operations building on the strong networks and relationships in the region.
- Making sure that the right skills, education and workforce development opportunities, science and infrastructure are in place to fuel marine economy growth.

6.1.5 Figure 6.1 illustrates the current strengths of the marine economy in the Highlands and Islands, the opportunities and potential, the factors that are inhibiting it reaching its potential and the targeted opportunities arising from the SIA.

Figure 6.1: Sector strengths, potential, inhibitors and the opportunities in the Marine Economy

MARINE ECONOMY | POTENTIAL LIES IN NATURAL ASSETS AND RESOURCES HYPOTHESES

SECTOR	CURRENT CAPABILITIES AND STRENGTHS	POTENTIAL	INHIBITORS	CROSS CUTTING OPPORTUNITIES	POTENTIAL IMPACTS
Aquaculture Potential value by 2030: £3.6bn	• Quality product at premium price • An established sector with skills, experience and infrastructure supported by education and innovation • World class R&D supporting the industry • Access to global network of industry R&D	• A growing global market for finfish and shellfish • Higher value jobs and activities in Scotland • Expand production whilst maintaining quality • Develop circular economy activities with marine biotechnology and wave and tidal energy e.g. waste products, local power source • Capture technology to drive increased productivity and cleaner technology	• Protective and unduly conservative planning and regulation regime • Skills pipeline to fuel growth and adapt to new ways of working • Challenges in expanding production in to more exposed sites	O1: Regional cluster model for marine innovation, technology and skills • 1a: Workforce development and enhanced educational provision • 1b: A marine economy innovation infrastructure plan for Scotland • 1c: Science, research and industry: scale and alignment O2: Routes to market O3: Planning and regulation for the marine economy O4: A regional marine economy prospectus	• Innovation and R&D that meets the needs of the marine economy industry • A skilled available workforce • Increased inward investment in the Highlands and Islands • Contribution to improved productivity in Scotland • The value to the UK economy is maximised • Scotland is a global leader in the marine economy and home to world class science and innovation
Wave and Tidal Energy Potential value by 2035 (UK): £800m	• Scotland is the world leader in wave and tidal science and innovation • EMEC is globally renowned test centre • WES is world's largest wave energy technology programme • Locally based skills, innovation and expertise • World's largest tidal stream array project • Access to some of the best wave and tidal resources in the world	• Energy production and supply chain development • Provision of local power sources, e.g. in marine biotechnology and aquaculture • Supply chain opportunities of supplying goods and services (boats, expertise, logistics and components and devices) • Lack of innovation funding to take proven concepts to commercial viability • Capture technology to drive increased productivity and cleaner technology	• Lack of routes to market to capture the value • Competition for sector leadership is growing in other countries		
Marine Biotechnology Potential value by 2030: £600m (Highlands and Islands)	• Supply of a diverse range of high quality raw product • World class science and innovation expertise and facilities • Enterprising SME and multinational businesses	• Biofuel production • Food supply • New materials e.g. for packaging • Application in cosmetics industry • Human health and medicine • Circular economy activities e.g. using waste products to provide protein for aquaculture or bioremediation	• Challenges in commercialising innovation • Scale-up of activities • Protective and out-dated planning and regulation • Uncertain skills base across the supply chain • Early stage sector, public sector led		
CAPTURING THE VALUE	**PLANNING, POLICY AND REGULATORY FRAMEWORKS**	**CROSS-SECTOR CLUSTERING**	**PEOPLE, EDUCATION, SCIENCE AND INFRASTRUCTURE**		

6.2: TARGETED OPPORTUNITIES

6.2.1 The opportunities for the marine economy in the Highlands and Islands have been developed with industry, education, the public sector and other key stakeholders working collaboratively. They address the particular challenges for the marine economy in the region. At this stage, some are more developed than others and so it will be important to take a partnership approach to developing the detail and then planning and implementing them. They are based on identified need, rather than being developed to target particular funding streams, however, they align with regional, Scottish and UK policy objectives and take cognisance of the current and emerging funding opportunities. By driving these forward, the marine economy will contribute to the transformation of food production and clean affordable energy. Marine biotechnology also has a potential role in helping to meet the needs of an ageing population through innovations in human health.

6.2.2 This SIA is about creating an environment where there is increased investment in ideas, in line with the first foundation of productivity set out in the UK Industrial Strategy.[189] It aligns with all five foundations in so much as it focuses on developing people and skills, developing infrastructure to support the growth of the marine economy, and key to it will be supporting commercialisation, the development of new businesses and helping entrepreneurs to take their products to market. Communities in the Highlands and Islands are diverse, and often fragile, experiencing permanent disadvantage because of their geographic remoteness. The marine economy has an important role to play in supporting and sustaining these communities, providing employment, skills development, business and economic benefits.

6.2.3 Overarching the opportunities is the proposition that the marine economy should be developed by taking a whole-sector approach, for example to strategic planning, science and innovation, operations, funding and problem-solving. There is a great deal of intelligence, knowledge and experience in each sector. However, it is largely kept within each sector and in many cases, within individual institutions. Integrating the three sectors and adopting a strategic approach for the marine economy will enable this knowledge to be better shared between industry, academia and the public sector. Importantly, the community will form the fourth element of this quadruple helix so that the marine economy works with communities where possible and appropriate.

6.2.4 In terms of funding, there is scope for businesses and research in the Highlands and Islands to attract greater levels and from more diverse sources. As part of the work flowing from the SIA, there will be a strategic plan for accessing funding for science, innovation and growth of the marine economy. There will also be a commitment to support and influence the development of a Sector Deal for the Marine Economy.

6.2.5 We have developed four Targeted Opportunities; the first has three strands flowing from it.

[189] Industrial Strategy: Building a Britain for the Future, HM Government, 2017, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

1: REGIONAL CLUSTER MODEL FOR MARINE INNOVATION, TECHNOLOGY AND SKILLS	
Strategic case	Industry has expressed a need for access to high quality, state-of-the-art facilities, equipment and wider infrastructure to drive enhanced R&D and aid clustering, close to the marine environment. A number of key locations in the region host research and technology organisations which already support this. These are supported by a wider range of education and innovation assets, many of which are not currently sufficiently resourced to meet industry needs. There is a strong case for a major cluster development incorporating technology and sea-trial testing facilities and industry support mechanisms. It will incorporate enhanced marine training and skills development provision which will scale up training provision in the Highlands and Islands, and will align with other training providers across Scotland. There is an opportunity to develop an innovative partnership model that builds on the combined existing infrastructure to better meet the needs of industry, grow innovation in the sector, extend and expand the skills base, and attract new business to the region. A key element will be a pilot test site to explore the potential for, benefits of, and associated risks of clustering marine economy activity across the sectors, for example, use of drones and robotics in areas that offer different marine characteristics. New approaches would be developed, deployed and monitored, and lessons learnt and applied in the region and further afield. Enhanced infrastructure would include expanded business incubation space. Underpinning the regional cluster model will be three critical strands: • 1a: Workforce development • 1b: Blue economy infrastructure investment plan • 1c: Science, research and industry: scale and alignment
Economic case	The regional cluster model would create the conditions to maximise innovation and support growth of the marine economy. It would facilitate collaboration and cross-sectoral working, provide a route to market for innovation and research, encourage entrepreneurship and business development. It would also add value to the existing innovation-supporting infrastructure. The economic benefits would be additional jobs, enhanced productivity and additional GVA generated from the development and testing of new technologies and processes, new and expanded businesses, and new and/or expanded products and services. It would anchor learning and skills development in the Highlands and Islands.
Financial case	The model and supporting infrastructure will require a capital and revenue funding plan that ensures sustainability. Capital funding estimates range from £100m - £130m, with revenue funding of between £8m - £10m per annum, depending on the agreed programme.
Management case	HIE, working with consortium partners and other contributors will be responsible for developing the wider business case, and managing the workstreams. An expert team will be created to lead this.

1a: Workforce development

There is potential to better exploit and facilitate cross-sectoral working, training and development, as well as workforce movement between sectors. There is also a need to understand current and emerging skills gaps and training requirements across the marine economy. This requires scaling up the provision of education and learning in the Highlands and Islands to anchor skills development in the region, align need with opportunity, and address both replacement and expansion demand in the labour market. This, along with upskilling the existing workforce to keep pace with new processes and developments is a key issue identified by industry and public sector partners, and one that the current skills system is not meeting. For FE and vocational skills, it will capitalise on the activities and partnership working of the network of marine training centres across Scotland. For HE, it will require additional funded student places across different and new disciplines – potentially identifying scope for more than 100+ new HE students per annum. Additional training and education facilities will be required, potentially supported through collaboration with existing colleges and industry. New provision will be required that brings together the synergistic opportunities across the marine spectrum, to encourage innovation in the future workforce.

Developing the cluster model is likely to identify some additional resources to meet identified gaps in provision. SDS and the SFC have a leading role to play in the funding of the skills plan, working in co-operation with existing providers.

A detailed roadmap and implementation plan will outline the requirements and associated costs. The need to ground this activity in the region and attract trainees/students that seek to remain in the region will be crucial. This will be led by HIE and supported by Skills Development Scotland and the Scottish Funding Council.

1b: A marine economy innovation infrastructure plan for Scotland

Mapping the existing infrastructure to better understand current provision, and how it aligns with need will be critical in developing a targeted and proactive plan to ensure appropriate infrastructure is in place to develop and grow the marine economy science and innovation opportunity. This will be integral to the regional cluster model and will be driven by industry needs. It will identify the infrastructure, equipment, facilities, incubation and soft-landing space required across the three sectors, and include costed proposals targeting appropriate funding opportunities. The economic impact of a well-researched innovation infrastructure investment plan will be measured in terms of employment, productivity and GVA over a 30-50 year period, and this planned approach will accelerate realisation of the economic and social benefits generated by the marine economy.

The resources required will be largely capital investment and will link to existing regional strategic infrastructure such as the EMSP and the ORIC. There will be an additional requirement for staff time within the relevant bodies, and scope for consultation with industry. The investment case that will be developed will require significant funds by Government over a 10-20 year period.

The delivery of this strand of the cluster model work will involve the Scottish Government, Marine Scotland, Scottish Enterprise, education and research bodies and industry groups. It will align with other complementary initiatives such as Stirling University's City Region Deal approved funding of £17m bid to develop the Institute of Aquaculture, and the planned Islands Deal and Argyll and Bute Rural Growth Deal.

1c: Science, research and industry: scale and alignment

Marine economy research undertaken in institutions is often not well-aligned with the current and emerging needs of industry. There is a perceived imbalance between science that focuses on environmental factors and that which focuses on technology, process and product development. The current scale of research taking place in the region is also insufficient to meet the needs of the sector and requires to be increased and better aligned. Academic research, located in close proximity to industrial activity is vital and the regional cluster model will be central to delivering this. Two key components are required to ensure proper alignment of the science and research base in the region – ensuring it is industry-driven and ensuring that there is capacity to broaden the research activity. Both have been identified as key to accelerating the use of new technologies across the three sectors.

Realising this will require an investment in the research environment by growing the number of principal investigator and post-doctoral opportunities in the region at the various innovation sites, and providing a collaborative challenge funding programme to encourage industry engagement and ensure focus is on the right industry challenges.

The impacts of new ways of working, events and fora to proactively facilitate better understanding, and funding for joint development of research proposals will be measured in the longer-term in enhanced employment, productivity and GVA. An investment in the tens of millions will be required to achieve the necessary scale and depth of science and innovation research taking place in the region. We will also align with other existing and proposed initiatives such as the recent EOI submitted to the UK ISCF for Fish Health and the MASTS NERC DTP bid, and work with Marine Scotland Science to identifying key priority research themes.

2: ROUTES TO MARKET	
Strategic case	The marine economy in the MAXiMAR SIA region has enormous potential with an international reach. However, each of the three sectors faces challenges in terms of realising the potential and commercialising innovation. The Highlands and Islands has the potential to produce large quantities of wave and tidal energy and contribute significantly to the development and provision of clean energy to UK and international markets. New technology is being developed and tested in the region and there is a need to optimise its value. As such, the region is well-placed to take forward activity to realise this opportunity. However, the dated infrastructure to get the energy to market is inhibiting production, innovation, testing and development. There are four elements to this opportunity: • connecting the production areas to the National Grid; • providing a range of 'routes to market' support mechanism for example through Contracts for Difference, time limited enhanced fee tariffs and/or through the tax system; • bringing activities that need power to the source, rather than relying on the power being routed to the activities; • capturing the potential of hydrogen production from wave and tidal as a power source. • **Marine biotechnology** is the least developed of the three sectors and has enormous largely untapped potential. Despite its assets, the UK trade balance for marine biotechnology is negative and worsening as a result of persistent failure to remove the barriers and challenges to commercialisation of marine biotechnology science and innovation. The Targeted Opportunities in in the SIA will be an important toolkit for addressing some of the barriers i.e. planning and regulation and an innovation cluster. However, specific mechanisms will be established to support marine biology enterprises to develop and take their products to market. It will include specialist scale-up support and support to access financial investment and de-risking strategies. **Aquaculture** is relatively well established as a sector and very well established in the region, with many large vertically integrated producers. However, small scale innovative companies and entrepreneurs in Scotland face structural and geographical barriers to access the Scottish market. They frequently have to take their innovations overseas and sell them into competitor markets. This impacts on the companies and means that the UK and the sector in Scotland is losing the benefits of the innovations and potential gains in efficiency and productivity, and subsequently losing global market share. Increasing the active support for collaboration between the small innovators and the larger companies will raise awareness of the innovative work and opportunities, leading to joint projects. In addition, financial mechanisms to temporarily reduce the cost to larger companies of testing new innovations would help to remove some of the barriers.
Economic case	This opportunity and the objectives and activities within it will increase the economic value of the Scottish marine economy. It will allow more enterprises to commercialise their innovations and increase the number of enterprises active in the market. It will also help to exploit international markets in Asia and North America to be exploited. The economic benefits, measured in employment, productivity and GVA will be generated by the three elements and include both new entrants and supply, as well as increased supply from existing operations.
Financial case	The business case will develop the long-term financial case for investment in infrastructure (particularly for wave and tidal) and implementing routes to market support mechanisms. It will take account of the specific routes to market challenges for each of the three sectors in the marine economy, and in particular locations. It will also look at the long-term potential for innovation to make the sectors economy commercially sustainable.
Management case	Implementing this opportunity will require significant resource and commitment from a range of sources in Highlands and Islands. For wave and tidal it will include UK Government, OFGEM and Scottish Southern Electric. For marine biotechnology and aquaculture, it will involve a range of partners including the Innovation Centres, HIE, and the Scottish Government. This work stream will be led by EMEC, SAIC and IBioIC.

3: REFRESHED PLANNING AND REGULATION FRAMEWORK FOR THE MARINE ECONOMY	
Strategic case	Scotland has developed a highly effective planning and regulation process for marine renewables, which has enabled it to lead the sector and attract international investment. Other aspects of marine planning are less successful in terms of helping to accelerate development and economic value. There is also important learning from other countries on developing and implementing proactive planning and regulation that supports sustainable development. A strategic, refreshed framework for a multi-sector approach to planning and regulation will be key to facilitating innovation, research and development, taking an active management approach, through a process of survey, deploy and monitor, supporting a collaborative approach between regulator(s) and science, innovation and industry, and also the communities within which the resource is located.
Economic case	The economic case is based around the acceleration of decision-making and reduced costs from a refreshed multi-sector regulatory framework agreed to the public and private sector. This would lead to the acceleration of economic benefits generated by the industry, as well as increased productivity through a reduction in unnecessary regulatory costs.
Financial case	The resources required for this work will mainly be staff time within the relevant bodies, including existing regulatory bodies and consultation with industry. More active systems require more resource, but this is necessary to gain traction and trust across the marine system.
Management case	The management of this work will involve the Scottish Government, Marine Scotland, regulators such as Crown Estate Scotland, SEPA, SNH, and education and research bodies and industry groups.

4: A REGIONAL MARINE ECONOMY PROSPECTUS	
Strategic case	The Highlands and Islands has very strong, and in many ways unique marine economy research capabilities, opportunities and assets. It also has a global reputation for some of its activities and products, but crucially there is a lack of informed knowledge and detailed understanding, worldwide, about its marine specialisation. There is also a lack of an accurate understanding about the research and career opportunities offered by the marine economy in the region amongst both local residents and those living, working and studying out with the Highlands and Islands. The prospectus will help the region promote itself globally to a range of audiences. It will also be a tool for individual organisations, including industry partners, to use.
Economic case	The economic case is based around the benefits that will be accrued of attracting new research and innovation, inward investment, new enterprises, business growth and in talent recruitment and retention.
Financial case	The resources required will be staff commitment from the range of organisations who will contribute to developing and promoting the prospectus.
Management case	Developing and managing the prospectus will be led by HIE and Scottish Development International (SDI) but will be developed collectively, with consortium partners.

6.3: MAKING IT HAPPEN

6.3.1 The SIA is not an end in itself. Its real purpose is to plan and inform the delivery of prioritised actions to grow the marine economy. These actions will be based on the evidence set out in the SIA and the targeted opportunities. The quality and depth of the conversation that has taken place over the past 18 months within the consortium has highlighted significant opportunities to maximise the marine economy, through working cross-sectorally, collaboratively, and strategically.

6.3.2 The work has clearly highlighted gaps in infrastructure, education, and scientific capacity, which are holding the region back from realising its full potential. It has also highlighted the need to be able to accurately define the constituent sectors of the marine economy, and capture their individual and combined values. This will allow the consortium to monitor progress in terms of the marine economy achieving its target value of £5bn by 2035.

6.3.3 The consortium members are committed to maintaining this momentum and driving the ambitions and targeted opportunities set out in the SIA. We know that it is the effective leadership of these activities that will be crucial. We recognise that the SIA is only the beginning of the process and we now need well-planned implementation to make sure that the SIA benefits the Highlands and Islands, Scotland and the UK. HIE will play an important part in this, having led the consortium to date, but the collective power of all partners is required along with a reorganisation of the stakeholders into an agreed governance structure.

Governance

6.3.4 The SIA activities will continue to be overseen by the MAXiMAR consortium which currently comprises 11 members. HIE will continue to chair and provide the secretariat for the consortium, and monitor progress against the SIA's ambitions. The cross-sectoral consortium membership will work to ensure that the appropriate stakeholders are engaged and can contribute to the work going forward. This will include continuing to work closely with industry and industry representatives.

6.3.5 The consortium will meet every two months in the first year. We will review the scheduling of meetings at the end of year two and if appropriate, will meet quarterly thereafter. Industry will be represented primarily through the Innovation Centres and HIE, and industry partners will be co-opted to participate in specific themes, activities and work streams. We will establish a cross-sectoral industry innovation group tasked with identifying industry demand to inform technological developments.

Driving progress

6.3.6 Lead individuals and organisations will be identified and tasked with taking forward each of the Targeted Opportunities. The clear allocation of responsibility will contribute to the overarching strategic management and implementation of the SIA and ensure that actions are progressed and reported back to the consortium. We recognise that this may require resourcing to draw in expertise as required. The leads have been identified in table 6.1:

Our first 100 days

6.3.7 Following approval of the SIA by BEIS, we will have a high-profile formal launch in early Autumn to publicise the report and generate wider support for taking forward its actions. We will develop a communications strategy detailing how we will raise awareness and understanding of the marine economy opportunity, and promotion of the region's specialisation. This will include an international dimension and identified opportunities to promote the region's marine specialisations globally.

6.3.8 We will develop a detailed action plan with milestones, responsibilities, timescales and a process to monitor, review and drive progress. This will include reviewing, refreshing and updating the SIA.

6.3.9 As a priority, we will liaise with the developers of the Islands Deal and the Argyll and Bute Rural Growth Deal to ensure that the marine sectoral ambitions are reflected in their portfolio of innovation projects. We will also work closely with University of Stirling to weave its City Deal aquaculture investment into the targeted opportunities.

Closing remarks

6.3.10 The SIA has been an extremely helpful process and has highlighted the opportunities for the marine economy and the challenges that the public sector, industry and academia will work together to address. New relationships have been established and existing partnerships galvanised. Through it, we have a very clear, evidence-based understanding of the marine economy and a definitive and agreed agenda to develop it in cross-sectoral partnership. We will work collectively for the long term to realise the ambitions of the SIA and respond positively to the changing context which we will undoubtedly face. We will advance science and innovation to benefit people in the Highlands and Islands, businesses and the wider economy. However, the reach of the SIA's benefits will go far beyond our geographic boundaries, to Scotland, the UK and internationally.

6.3.11 Developing the SIA has demonstrated our combined ability to think innovatively, challenge assumptions and be confident in the unique opportunity that we have in the Highlands and Islands. We are now ready to realise that opportunity.

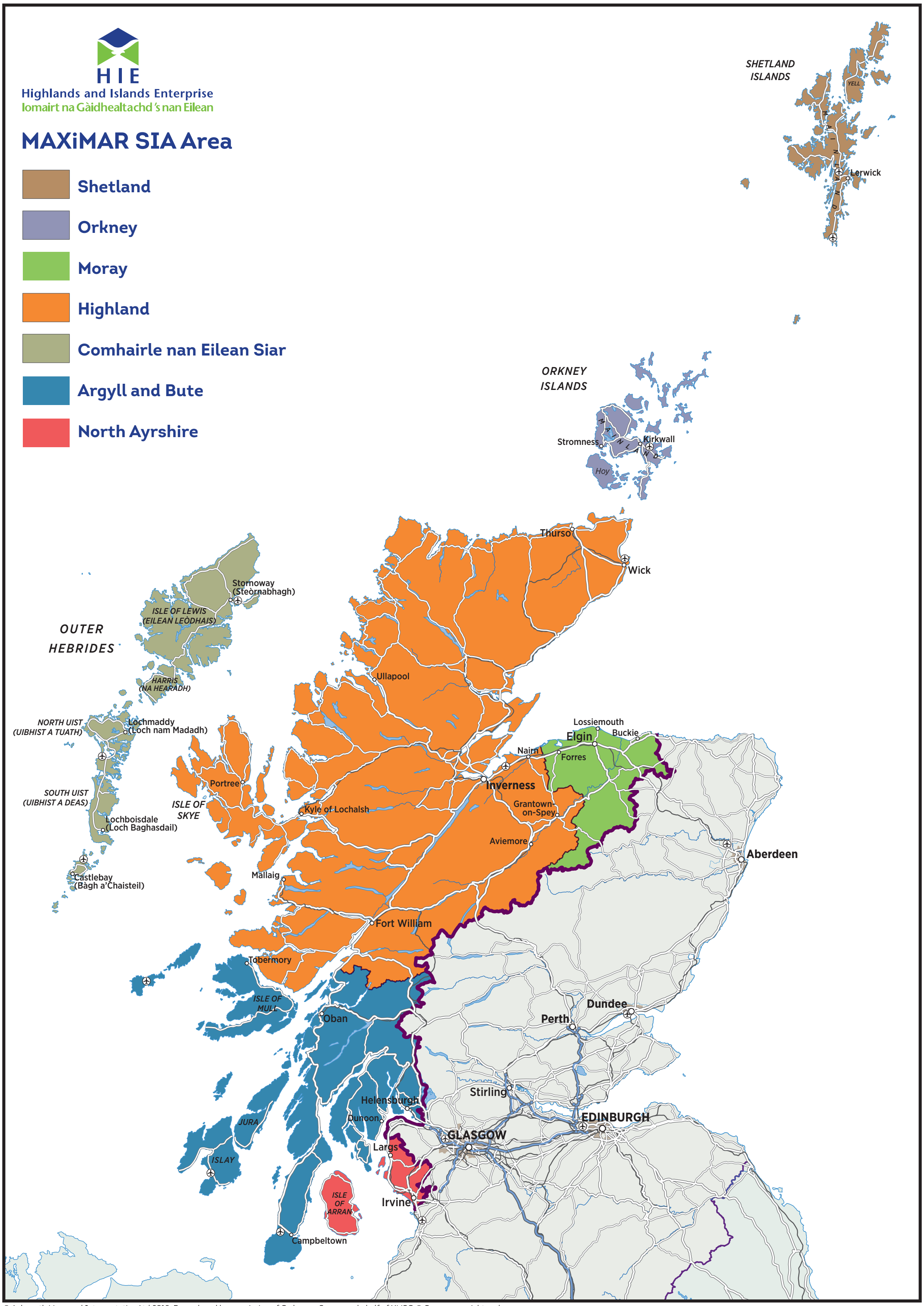
Table 6.1: Targeted Opportunity Leads

	TARGETED OPPORTUNITY	LEAD
1	Regional cluster model for marine innovation, technology and skills	HIE with collaborators
	a. Workforce development	SFC and SDS
	b. Marine economy innovation infrastructure plan	Scottish Government and Marine Scotland
	c. Science, research and industry scale and alignment	Scottish Government, Scottish Universities and Research Pools
2	Routes to market	SAIC, EMEC and IBioIC
3	Regulatory framework	Marine Scotland
4	A regional marine economy prospectus	HIE with SDI and consortium members

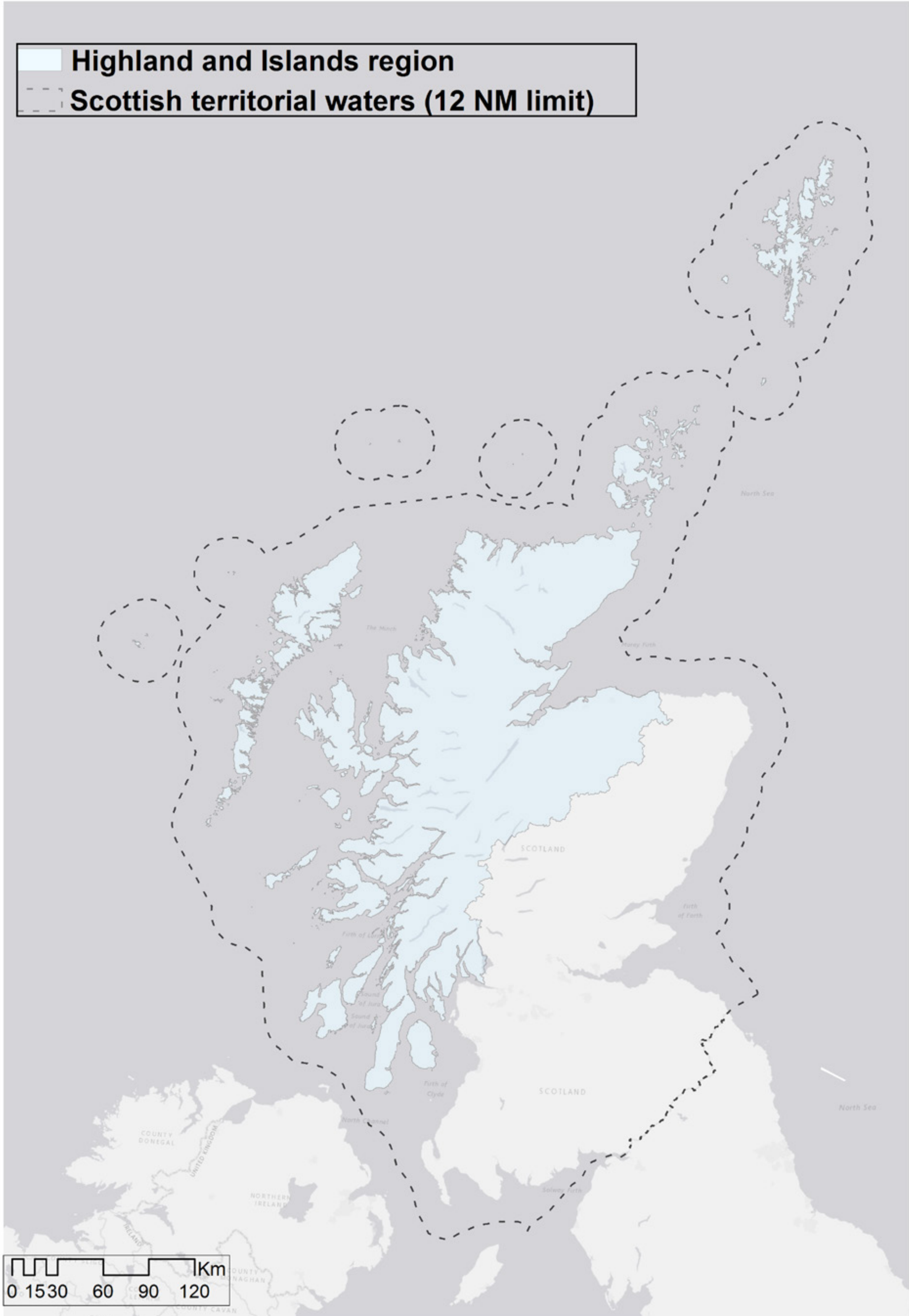
APPENDICES

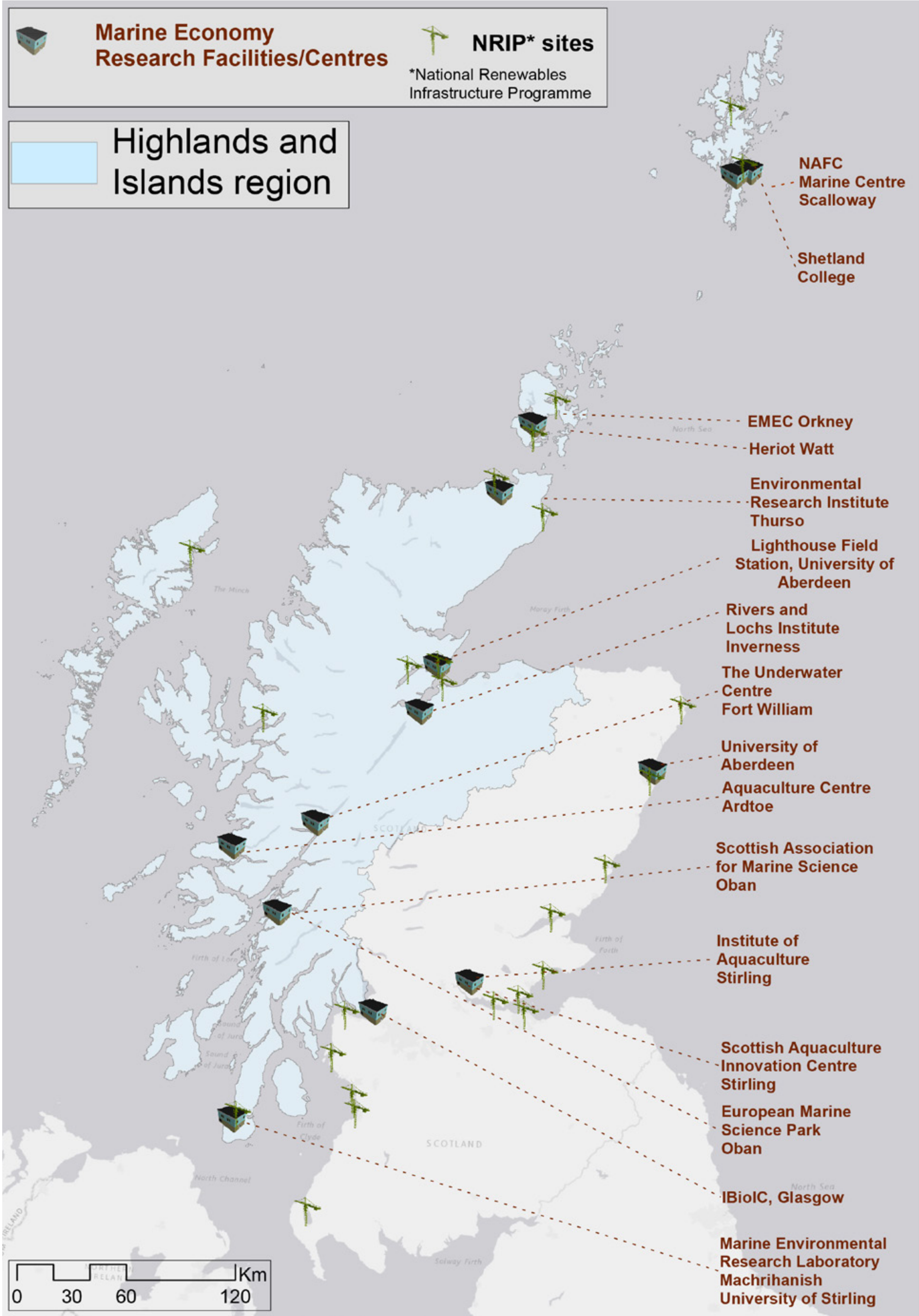
APPENDIX 1: MAPS

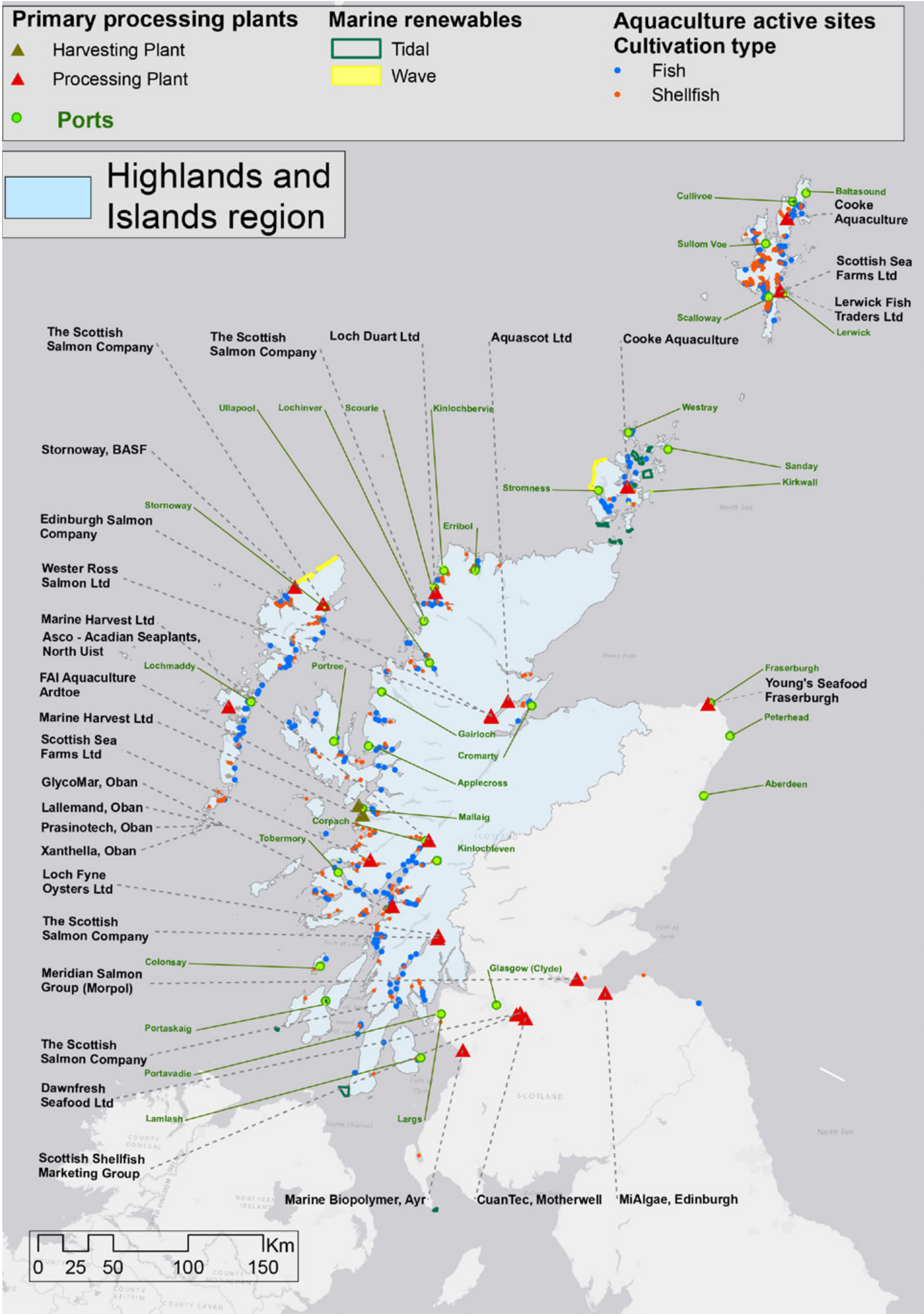
1a: MAXiMAR SIA Area



1b: Scottish Territorial Waters




Marine Economy Research Facilities/Centres
NRIP* sites
*National Renewables Infrastructure Programme
Highlands and Islands region
NAFC Marine Centre Scalloway
Shetland College
EMEC Orkney
Heriot Watt
Environmental Research Institute Thurso
Lighthouse Field Station, University of Aberdeen
Rivers and Lochs Institute Inverness
The Underwater Centre Fort William
University of Aberdeen
Aquaculture Centre Ardtoe
Scottish Association for Marine Science Oban
Institute of Aquaculture Stirling
Scottish Aquaculture Innovation Centre Stirling
European Marine Science Park Oban
IBioIC, Glasgow
Marine Environmental Research Laboratory Machrihanish University of Stirling
Km
0 30 60 120


Primary processing plants
Harvesting Plant
Processing Plant
Ports
Marine renewables
Tidal
Wave
Aquaculture active sites
Cultivation type
Fish
Shellfish
Highlands and Islands region
Cullivoe
Baltasound
Cooke Aquaculture
Sullom Voe
Scottish Sea Farms Ltd
Scalloway
Lerwick Fish Traders Ltd
Lerwick
The Scottish Salmon Company
The Scottish Salmon Company
Loch Duart Ltd
Aquascot Ltd
Cooke Aquaculture
Ullapool
Lochinver
Scourie
Kinlochbervie
Westray
Stornoway, BASF
Sanday
Kirkwall
Stromness
Stornoway
Edinburgh Salmon Company
Erribol
Wester Ross Salmon Ltd
Marine Harvest Ltd
Asco - Acadian Seaplants, North Uist
Lochmaddy
Portree
Fraserburgh
Young's Seafood Fraserburgh
FAI Aquaculture Ardtoe
Peterhead
Marine Harvest Ltd
Gairloch
Scottish Sea Farms Ltd
Cromarty
Applecross
GlycoMar, Oban
Aberdeen
Lallemand, Oban
Mallaig
Prasinotech, Oban
Corpach
Tobermory
Xanthella, Oban
Kinlochleven
Loch Fyne Oysters Ltd
The Scottish Salmon Company
Colonsay
Meridian Salmon Group (Morpol)
Glasgow (Clyde)
Portaskaig
The Scottish Salmon Company
Portavadie
Dawnfresh Seafood Ltd
Lamlash
Largs
Scottish Shellfish Marketing Group
Marine Biopolymer, Ayr
CuanTec, Motherwell
MiAlgae, Edinburgh
Km
0 25 50 100 150

APPENDIX 2: SIA HYPOTHESES

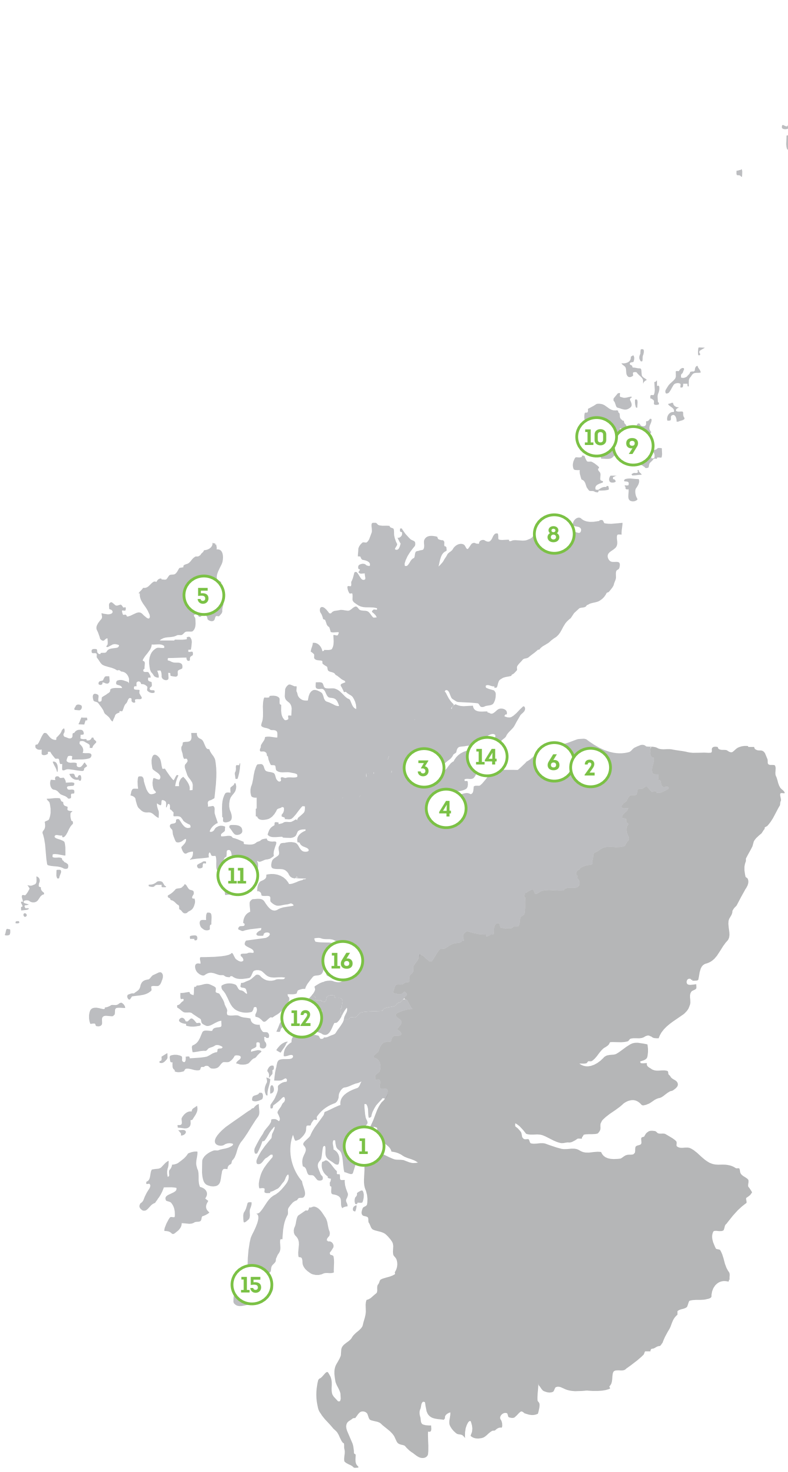
Hypothesis 1: Capturing the value:
The current value of our coastline and marine activities contributes significantly to regional, Scottish and UK economies – singularly (i.e. as three distinct sub-sectors) and as inter-woven/inter-dependent sectors. We hypothesise that if these three sectors are better integrated they have the potential to be a significant engine for economic and social development and will grow and become economically and environmentally sustainable pillars of the Scottish and UK economy over the next 20 years if managed appropriately.

Hypothesis 2: Planning, Policy and Regulatory frameworks:
We acknowledge that Scotland needs a progressive and responsible regulatory environment. We believe we are moving in this direction but more could be done including identification of the barriers and enablers across the three sub-sectors, and learning how government and industry can solve these. Other regions and countries do it differently, and Scotland could learn from comparators in Norway, Denmark, Canada and Portugal, as well as from the Marine Planning Partnership operating in the Shetland Isles. We hypothesise that the development of a flexible, responsive and collaborative regulatory framework in the marine environment will stimulate innovation and economic growth while protecting the natural environment.

Hypothesis 3: Cross-sector clustering:
Creating multi-sector clusters of marine energy, biotech and aquaculture organisations (incorporating industry and academia) will result in significantly increased growth rates for the marine sector. This will unlock significant technological and innovative capacity over the next 20 years and cement these sectors in the UK. To optimise this economic value from our science and innovation base, we need to create the conditions that support clustering in the region, close to the natural resources and production. We hypothesise that this will be enhanced by targeting cross-cutting technologies (e.g. robotics, satellites, sensors and biosensors, fish health and diagnostics, marine biotechnology, marine equipment, gliders, smart electronics, big data) and by providing the facilities for testing, development and validation of new technologies.

Hypothesis 4: People, Education, Science and Infrastructure:
The marine economy of the Highlands and Islands has a long history of innovation in marine industries and is home to a highly skilled workforce. However, growth of these sectors is out pacing the current availability of a skilled workforce and the availability of appropriate training and education within the region. As such growth of these marine sectors is being constrained due to the inherent challenges of a rural economy. We hypothesise that a targeted and multi-faceted strategy of investment in skills, education and innovation is required to overcome these barriers to realise the true value of these marine economies to Scotland and to the UK.

APPENDIX 3: EDUCATIONAL PROVIDERS IN THE HIGHLANDS AND ISLANDS



1. Argyll College UHI
2. Glasgow School of Art
3. Highland Theological College UHI
4. Inverness College UHI & Scotland's Rural College
5. Lews Castle College UHI
6. Moray College UHI
7. NAFC Marine Centre UHI
8. North Highland College UHI
9. Orkney College UHI
10. Heriot-Watt University Orkney Campus ICIT
11. Sabhal Mòr Ostaig UHI
12. Scottish Association for Marine Science UHI
13. Shetland College UHI
14. University of Aberdeen
15. University of Stirling
16. West Highland College UHI

APPENDIX 4: ORGANISATIONS WITHIN THE MARINE ECONOMY SECTORS

MARINE ENERGY

38techinsight
42 Technology Ltd
4c Design Ltd
4C Engineering
Aquatera
Argyll Workboats
Arup
ABB
Andritz Hydro
Atmos Consulting
Aurora Marine Ltd
AWS Ocean Energy Ltd
AJS Design Engineering Ltd
Albatern Ltd
Artemis Intelligent Power Ltd
Atlantis Resources Corp
BiFAB
Bryan J Rendall (Electrical) Ltd
Balmoral Offshore Engineering
Bathwick Electrical Design Ltd
Black and Veatch Ltd
Bluewater Energy Systems
Blue Power Energy Ltd
British Precast Concrete Federation.
Caelulum Ltd
Caldive Ltd
Carbon Trust Advisory Ltd
Cascade Drives AB
CETO Wave Energy UK Ltd
Checkmate Seaenergy Ltd
Cheros Srl
CorPower Ocean AB
Calder Engineering
Corpower Ocean
CD Campbell Marine Contractors
CMI Offshore
Coastal Connection Llp
Contec Design Services Ltd
Cory Brothers Shipping Agency
Crinan Boatyard Ltd
David Kerr Engineering Consultant Ltd
DNV GL UK Ltd
Dr Johannes Spinneken
DuPont Performance Polymers
Delta Marine
DH Marine Ltd
Ecosse Subsea Systems Ltd
Edinburgh Designs Ltd
ÉireComposites Teoranta
European Marine Energy Centre (EMEC)
Enercro Ltd
Energy Technologies Institute
Energy Technology Centre Ltd
Engie Fabricom
Enviro Centre
Exceedence Ltd
EandM Engineering Ltd
Energy of Orkney
Environmental Research Institute
European Marine Science Park
Fathoms Ltd
Fred Olsen
FloWave TT Ltd
Fountain Design Ltd
Ghent University
Green Marine (UK) Ltd
Griffon Hoverwork Ltd
Gael Force Marine
Global Energy Group
Green Marine
Halcrow (now part of CH2M Hill)
Harper Macleod
HRAI Group Ltd
Hugh Simpson Contractors Ltd
Hamnavoe Engineering
Haydale Composite Solutions Ltd
Hebrides Marine Services Ltd
Iberdrola Engineer and Construction
Innosea Ltd
Inverlussa Marine Services
Islay Energy Trust
Joules Energy Efficiency Services Ltd
JGC Engineering and Technical Services Ltd
John Gunn and Sons Ltd
JP Knight Caledonian Ltd
Kishorn Port Limited
Kongsberg Maritime
Kelvin Hydrodynamics Laboratory -
University of Strathclyde
Kingspan Environmental Ltd
Laminaria
Limerick Wave Ltd
LandM Engineering Ltd
Leask Marine
Lerwick Engineering and Fabrication
Lerwick Port Authority
Lochs Diving Services Ltd
Mackellar Subsea Ltd
Marine Design International Ltd
Mocean Energy Ltd
MacLean Electrical
Malakoff Limited
Marine Projects Ltd
MeyGen Ltd (owned by Atlantis Resources
Limited)
Mohn Aqua
Moray First Marine
MRC Energy Ltd (Marine Resource Centre)
Nautricity
NAFC Marine Centre
Natural Power
Nortech Marine
National Composites Centre
NGenTec Ltd
North Electrical Services
North Fish (Shetland) Ltd
North West Marine Services Ltd
Nova Innovations Ltd
Ocean Kinetics
Offshore Marine Electronic/Electrical
Services Ltd
OpenHydro (a DCNS Company)
Optica Marine
Orcades Marine
Orkney College
Oceantec Energías Marinas SL
Offshore Subsea Consultancy Services Ltd
Optimus (Aberdeen) Ltd
Orcades Marine Management
Consultants Ltd
ORE Catapult
Oscilla Power Ltd
Orkney Harbours
Orkney Islands Council
Orkney Renewable Energy Forum
Orkney Sustainable Energy Ltd
Pelagic Innovation Ltd
PolyGen Ltd
Pure Marine Gen Ltd
Precision Aquaculture (Subsea Electronics
Ltd)
Professional Diving Academy
Qinetiq
Queen’s University Belfast
Quoceant Ltd
Renewable Parts Ltd
Rigmar Services
Roving Eye Enterprises
Radius Systems Ltd
Rentajet Group Ltd
Ricardo-AEA
RiserTec Ltd
Romax Technology Ltd
Rototek Ltd
RPS Consulting Engineers
Scuola Superiore di Studi Universitari
e di Perfezionamento Sant’ Anna
Sea Power Ltd
Supply Design Ltd
Sustainable Marine Energy
SAMS (Scottish Association for Marine
Science)
Scotmarine
Orbital Marine Power (formally
ScotRenewables (Tidal Power) Ltd)
Scrabster Harbour Trust
Seafari Marine Services
Siemans
Scottish and Southern Electricity
Seatricity
Sgurr Energy
Shearwater Marine Services Ltd
StormCats Ltd
Stornoway Port Authority
Streamline Shipping
Subsea 7
Subsea Dynamics
SULA Diving
Technology from Ideas Ltd
Tecnalia Research and Innovation
Tension Technology International Ltd
The Concrete Centre
Tocardo
Total
Torrance Partnership
Trident Energy Ltd
Umbra Cuscinetti S.p.A.
Underwater Centre
Varrich Engineering Design
Voestrom Ltd
Wave Venture
Wello Oy
Wick Harbour Authority
Xodus (Aurora) Group
Zyba Ltd

AQUACULTURE

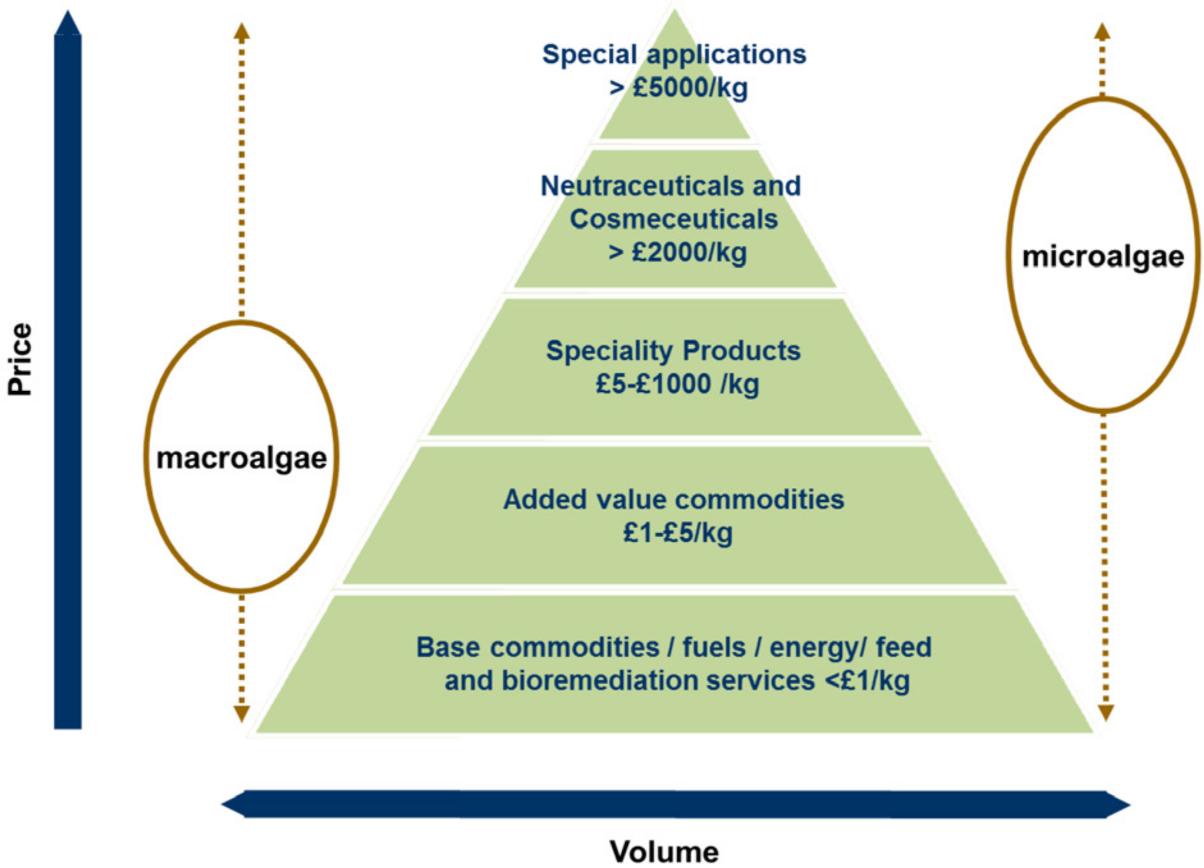
4c+
A and C Tait
Ace Aquatec
AKVA group Scotland Ltd
Alimentos Ventures GmbH
Altech
Aquagen
Aqualife
Aquamoor
Aquapharma
Aquascot
Association of Scottish Shellfish Growers
Aurora Marine Limited
Balta Islands Seafare Ltd.
Benchmark holdings
Bioemitters
Biomar
Blueshell Mussels Ltd
C and A Thomason Limited
Calysta
Cargill
Cooke Aquaculture Scotland
Coop
Cryogenetics
Cuantec
Dawnfresh
Europharma
Farne Salmon and Trout ltd
Ferguson Shipping (Kishorn Port) Limited
Ferguson Transport (Spean Bridge) Limited
Fish Vet Group
FishFrom
Fusion Marine Ltd
Gael Force Marine Equipment Ltd
Genetics
Grieg Seafood Hjaltland (UK) Ltd Hendrix
Hatch Blue Ltd
HIPRA
Hookmarine
Hygiene Teknikk Limited
IFFO
Inverlussa Marine Services
Johnson Marine Ltd
Kames fish farming
Landcatch
Loch Duart Ltd
Loch Fyne Oysters HQ
Loch Laxford Shellfish Ltd
Lochnell Native Oysters Limited
M-Dive
Macduff Shipyards Limited
Malakoff Limited
Marine Harvest (Scotland) Limited Marine
Sense
Marks and Spencer
Morrisons
Mohn Aqua (UK) Ltd
Neemco limted
Neogen Europe
Net Services
Nevis Marine Ltd
Niri Scotland Ltd
Norfab equipment
Nutraid
Ocean Tool Aquaculture Ltd
Orkney Fish
Otter Ferry Seafish Ltd
Parmaq
Primerdesign
Pulcea
Sainsbury's
Scot-Hatch Ltd
Scottish Sea Farms Ltd
Shetland Mussels Ltd
Simply Blue
Skretting
Solvay
SSQC Ltd
Sterner
Tactical Wireless Ltd
Tesco
The Centre for Aquaculture Technologies The
Scottish Salmon Company Limited Traigh
Mhor Oysters
Tritech
Vaki
Vard Aqua (Storvik Limited)
W & J Knox
Waitrose
Wester Ross Fisheries Ltd
Xanthella
Xelect
Xyrex Ltd
Youngs seafood ltd

MARINE BIOTECHNOLOGY

Algae Biomass Organisation
Ardtoe marine lab
BASF
Blue Sky Bio
Bryoactives
Du Pont
FAI Aquaculture
FMC Biopolymer Glycomar
GSK
Hebridean Seaweed
Hebridean Spa
Lallemand/Aquapharm
MiAlgae
Marine Biopolymers
Mara
Mars
NCIMB
Prasinatech
Scottish Bioenergy
SRSL
Uist Asco
Xanthella

APPENDIX 5: CAPACITY AND PRICING OF PRODUCTS FROM MICRO- AND MACROALGAE[190]

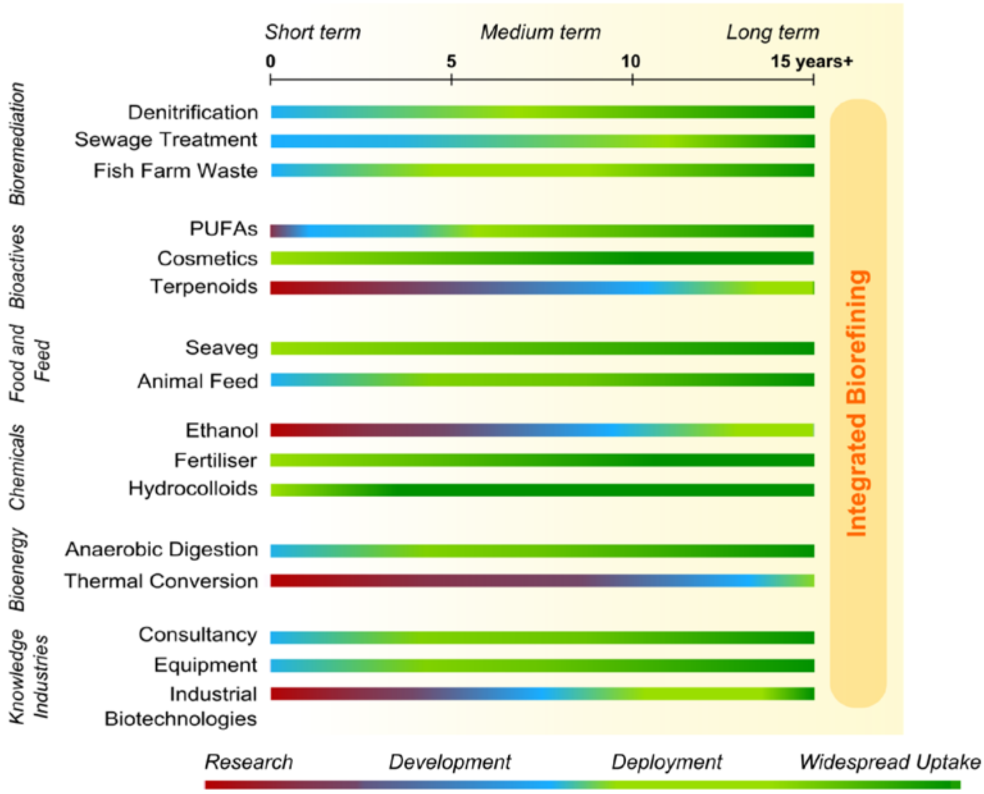
The figure below demonstrates the current capacity and pricing of products from microalgae and macroalgae. It shows that there is a general relationship between volume and value in macroalgae and microalgae products – segmented by use and value ranges.



[190]Adapt (2013) A UK Roadmap for Algal Technologies

APPENDIX 6: ALGAL TECHNOLOGY ROADMAP

The following chart outlines the principal opportunities for marine biotechnology. Different applications of marine biotech are developing at different speeds, depending on volume, production and technological development. Integrated biorefining is recognised as an opportunity to derive consecutive tiers of value from waste products from the production process. For example, a high value extract from one process may leave a large amount of biomass that may be realised in a secondary process.

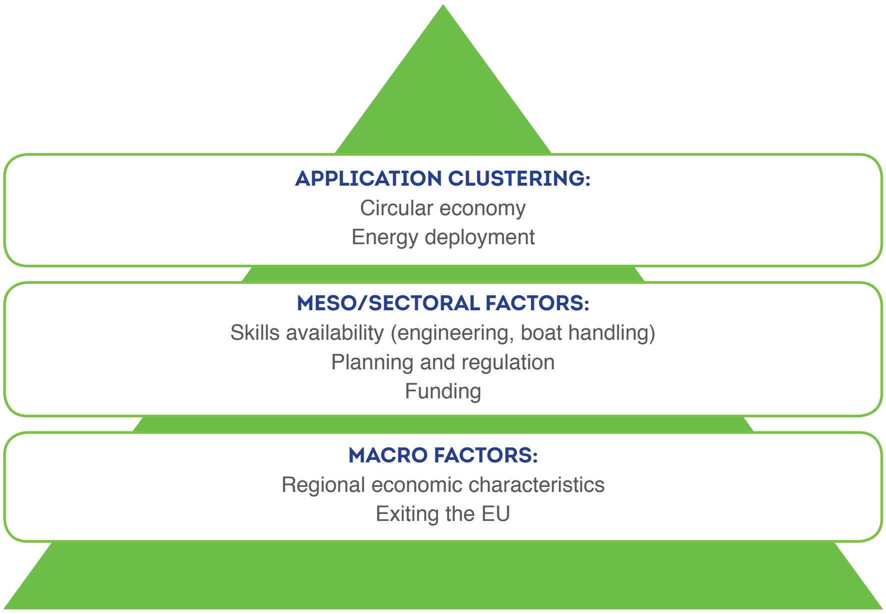


Source: Adapt/Innovate UK, NERC (2013)[191]

[191] P. 5, https://connect.innovateuk.org/documents/3312976/3726818/AB_SIG+Roadmap.pdf

APPENDIX 7: CLUSTERING LEVELS

As outlined in the following diagram, clustering within the marine economy can take place at different levels – at the 'base' level of macro factors; at a meso- or industry level or at a specific application level.



THE CASE FOR DEEPER INTEGRATION OF THE MARINE ECONOMY IS ALREADY MADE IN ORKNEY – A CLUSTERED APPROACH TO DIFFERENT ACTIVITIES IS THE NORM IN THE UTILISATION OF NATURAL / SPATIAL CAPITAL, PHYSICAL INFRASTRUCTURE, SKILLS, PLANNING AND FUNDING.	
The opportunities set out in the SIA are already underway in Orkney. A new Research and Innovation Campus (ORIC) for energy and low carbon programmes has been announced in March 2018. HIE is investing £4.65m in the campus project, including £1.48m of ERDF money. Orkney Islands Council is investing £2m, including £0.5m of Scottish Government Regeneration Funding, in addition to transferring ownership of the Old Academy and former Stromness primary school to the partnership. The Old Academy is already home to the EMEC, Heriot Watt University's ICIT, environmental consultants Aquatera and number of other businesses. With considerable community involvement in many marine and wider renewable energy matters, together, there is a clear 'quadruple helix' (public, private, academic and community collaborative working) of integration across sectors and underlying capacity.	

AQUATERA TESTIMONIAL	An Orkney-based environmental consultancy, cites the innovation capacity ingredients in Orkney as translatable to the rest of the Highlands and Islands, namely:
	
	• **Willing and able supply chain:** with high degrees of experience, collaborative teams and a cost effective and cost-conscious workforce. (This includes a shared understanding of requirements that can be gained through forums such as the Orkney Renewable Energy Forum in Orkney, www.oref.co.uk)
	• **University capacity:** R&D, training, associated colleges all prime pump expertise within local industry
	• **Can-do attitude:** already proven innovation capacity
	• **Wealth Distribution:** estimated 2,000 households in Orkney with a direct link with and benefit from renewables.
	• **World leading facilities:**
	  ◦ EMEC and ICIT (Orkney)
	  ◦ Academic and infrastructure assets across Highlands and Islands all feeding into development projects in Orkney: ERI, UHI; Ardersier, Nigg, Kishorn; Lyness, Lerwick, Scrabster, Invergordon

AMONG THE AREAS ORKNEY HAS DEMONSTRATED AN INTEGRATED APPROACH TO THE MARINE ECONOMY:	
PLANNING	Orkney already has a marine innovation site trialling wave and tidal devices, and understands the issues posed by consenting a site involving novel uses with potentially unknown effects, and balancing a range of marine activities. The MSP work in Orkney has been developed to include novel and emerging marine renewable energy alongside other marine sectors.
GOVERNANCE	The Islands (Scotland) Bill going through the Scottish Parliament will support Orkney's regional powers in determining their marine sector strategy. The island areas have particular regulatory systems that have informed the Bill
INTEGRATED SUPPLY CHAIN	Orkney's geography means that its supply chain functions will overlap across sub-sectors: • **Logistics:** For example, Northwards is a logistics company providing services to aquaculture (feed and equipment transport) and the renewables sector. • **Skills:** In addition to common, marine-specific jobs, engineering skills can span land and marine uses. For example, Merriman's engineering provides services to the aquaculture sector, renewables, ferries, lighthouse maintenance and so on. The contention is that this integration of services de-risks supply for each sector as they fluctuate, retaining skills, and providing a higher level of skills than siloed engineering in other areas of the UK, e.g. in the Central Belt. Leask Marine is involved in innovation through collaborative working with clients – such activity is valuable for different sectors but can be missed because it is not explicitly research focused. Orkney College UHI is working with industry to develop its marine courses, and the Nautical College offers private courses across marine industries.
USE OF MARINE ASSETS	Marine assets (e.g. harbours with specific capacities) can be in limited supply in Orkney, and the wave and tidal / renewables boom has sought to set this infrastructure in place. This has brought benefits to other marine sectors, for example cruise ship access to Hatston port (developed under the National Renewables Infrastructure Plan[192]), and can allow aquaculture to make use of existing other assets (e.g. other harbours, crane facilities, etc.) that are not used in wave and tidal. Capacity is put to full use. Elsewhere in Orkney, one aquaculture company, used a quarry site on Sanday that had previously been used to construct turbines, on the basis that assembly was demonstrated as possible even on a more remote island. This brought jobs and income to remote communities but was also the commercially rational decision to be near the natural resource.

192 http://www.hie.co.uk/growth-sectors/energy/n-rip.html

8B: MARINE BIOPROCESSING CENTRE

HIE HAS PROPOSED THE FORMATION OF A MARINE BIOPROCESSING CENTRE (MBC) IN THE HIGHLANDS AND ISLANDS TO SUPPORT THE FURTHER DEVELOPMENT OF THE MARINE BIOTECHNOLOGY SECTOR IN THE REGION.

The proposed MBC will build on the strengths and opportunities set out in the SIA. It would provide the equipment and facilities to allow the already existing marine biotechnology cluster to increase the scale of its activities and reduce the risk associated with commercialisation. In providing the equipment needed for scale-up and commercialisation, the facility will ensure that this economic activity is retained in the Highlands and Islands and benefits Scotland and the UK more widely. In the absence of this sort of facility, companies in the Highlands and Islands have had to outsource meaning that the associated income has been lost to the region.

The primary objective of the MBC is to provide the facilities needed to address major challenges around bridging the gap between research development and commercialisation and upscaling projects. In developing the proposal, HIE commissioned research on the strategy development and potential economic impact of the facility. This research has shown that the MBC would make an important contribution in addressing the challenges and realising the significant potential of marine biotechnology.

The economic impact assessment found that in year three the MBC would provide total (direct, indirect and induced) impacts of 12.5 FTEs and £597,600 income in the Highlands and Islands. In addition, the support that the MBC would provide to the marine biotechnology sector will bring wider impacts and it is estimated that in the first six years, five new companies will be established, creating 36 new jobs and safeguarding a further 24.

The MBC will be based on the extensive existing natural resources, cluster of marine biotechnology companies and academic strengths in the Highlands and Islands. SAMS UHI in particular is recognised as a world leading institution in the field. As well as supporting marine biotechnology, the MBC will provide significant benefits for the wider marine economy given the extensive links between the subsectors. The development of marine biotechnology could have benefits in areas such as aquaculture feed. It is also likely that there will be significant crossover with aquaculture in the research undertaken in the MBC.

The proposed MBC is a prime example of collaborative working between the public, private and academic sectors in the Highlands and Islands. Support from the public sector will provide a facility to promote the development of the private sector. It will draw extensively on academic equipment and research capability which will boost activity and commercial income for UHI. It is proposed that, if the MBC is located alongside SAMS UHI at the European Marine Science Park (EMSP), it would have access to extensive knowledge and facilities including SAMS UHI's seaweed hatchery and Culture Collection for Algae and Protozoa.

THE RIPPLE EFFECT: EXTENDING INNOVATION RELATIONSHIPS IN SCOTTISH AQUACULTURE

Over 2016-2017, SAIC supported a project to develop new diagnostic techniques for assessing fish health – techniques it believed could generate savings worth millions of pounds to the industry in Scotland. The project is an example of drawing in new researchers and ways of thinking into aquaculture. It demonstrates how SAIC is connecting the dots in aquaculture innovation by signposting companies to other forms of innovation support.

Involved in the project were trout producer Kames Fish Farming, salmon producer Marine Harvest, Randox Food Diagnostics and Europharma, and Dr Brian Quinn, Reader in ecotoxicology at the University of the West of Scotland. Dr Quinn had previously undertaken industry-focussed research, but had not worked on aquaculture projects. His involvement in the project stemmed from his attending SAIC events. He said:

“I went to SAIC workshops on gill health and rapid diagnostics, and I think the approach is excellent. It’s really useful that industry and academics are all in the same room.”

Hearing from producers about their challenges, and connected by SAIC to Kames and Marine Harvest, he set about developing a project to re-purpose diagnostic technologies used for humans, and used them to test biomarker responses in salmon and rainbow trout. The tests initially focussed on the impact of sea lice treatments, but the project partners hoped they would form the basis for processes that could scan for a wide range of health issues in fish.

This, in turn, could create a method of assessing fish health with earlier and more specific diagnoses. Current practice can cause significant losses for farmers due to the effects of illnesses on the fish before diagnosis and treatment; a cost that could be halved with diagnostic technology, with a potential saving of £75,000 per growth cycle in lab costs alone.

Positive outcomes

Building on the successful development of techniques and data gathered in this project, and the strong industry-academic relationship from the first project, Dr Quinn took advice from SAIC about possible next steps. As a result, he submitted a Knowledge Transfer Partnership (KTP) proposal with Marine Harvest in late 2017 to establish in-house analytical clinical chemistry capability to assess fish health and the impact and early detection of disease in salmon.

As a result of the three-year project, a KTP associate has been embedded into Marine Harvest, developing their in-house clinical chemistry capability. The techniques and data developed in the initial SAIC-supported project have now formed an integral part of Marine Harvest’s new fish health monitoring programme.

The project has also resulted in SAIC funding being awarded in March 2018 to a follow-on innovation project: Investigation into the causes of and possible solutions to failed rainbow trout in aquaculture.

Highlands and Islands Enterprise (HIE) – LEAD Partner - is a Scottish Government funded Enterprise agency responsible for generating economic growth across the region. HIE's own sector teams in Energy, Life Sciences and Food and Drink, and its close relationships with account managed businesses ensures it will place business needs and opportunities at centre stage. Working with the SDI team, it helps companies reach international markets and ensure businesses are globally competitive. HIE has an annual budget of circa £100m. WES is a subsidiary of HIE. It's funding the development of innovative technologies to produce efficient and reliable components and subsystems which will form the basis of the cost-effective generation of wave energy in Scotland. To date WES has awarded £11.8M to 39 projects involving 80 separate organisations in 5 different countries.

Lead representative: Carroll Buxton, Director of Regional Development

The University of the Highlands and Islands (UHI) is the United Kingdom's leading integrated university encompassing both FE and HE. UHI is made up of 13 Academic Partners, including SAMS, the ERI and the NAFC Marine Centre which are all specialist marine research institutes. SAMS UHI is Scotland's largest and oldest independent marine science organisation, dedicated to delivering marine science for a healthy and sustainable marine environment through research, education and engagement with society. Based on the Scottish west coast, SAMS UHI research strengths include experts in marine renewables, aquaculture, marine biotechnology and marine policy. The NAFC Marine Centre delivers training and education, research and development, and provides consultancy and advisory services for maritime industries. The ERI based in Thurso is also a major contributor to research in renewable energy and the environment.

Lead representative: Nick Owens. SAMS Director and CEO

Scottish Aquaculture Innovation Centre (SAIC) is one of eight Innovation Centres established by the SFC in partnership with both of Scotland's enterprise agencies (HIE and SE). SAIC's primary purpose is to bring together industry and academia to provide innovative solutions to industry-defined problems and to support growth, sustainability and profitability of the Scottish aquaculture industry. SAIC's activities are aligned with the aquaculture industry's ambitions to grow UK wide GVA from £1.8bn to £3.6bn by 2030. It specialises in bringing world class academic, scientific and engineering knowledge to industry projects, working with a wide range of companies from large multinationals to local and regional SME.

Lead representative: Heather Jones, CEO

European Marine Energy Centre (EMEC) is an innovation catalyst established in 2003, the world's leading demonstration centre for wave and tidal energy technologies. It provides developers of both wave and tidal energy technologies with purpose-built, accredited, multi-berth, open-sea testing facilities for wave and tidal energy converters. With 14 grid-connected test berths, there have been more marine energy converters deployed at EMEC than any other single site in the world, with developers attracted from around the globe to prove what is achievable in some of the harshest marine environments. EMEC provides independently-verified performance assessments and a wide range of consultancy and research service. EMEC is at the forefront in the development of international standards for marine energy, and is forging alliances with other countries, exporting its knowledge around the world to stimulate the development of a global marine renewables industry. EMEC has generated £284.7m GVA for the UK economy.

Lead representative: Neil Kermode, MD

Industrial Biotechnology Innovation Centre (IBioIC) is also part of the Scottish Innovation Centre Programme. IBioIC are specialists in the industrial biotechnology sector, with the knowledge and technical expertise to help stimulate the growth and success of biotechnology industry within Scotland by enhancing connections between industry, academia and government. Their main purpose is to accelerate and de-risk the development of commercially viable, sustainable solutions for high-value manufacturing in chemistry and life science sectors. IBioIC target is to generate £1 to £1.5bn of GVA contribution annually to the Scottish economy, with a growth of revenue from todays estimated value of £190M, to between £2 and £3bn by 2030.

Lead representative: Roger Kilburn, CEO

Marine Scotland Science (MSS), the scientific Division of Marine Scotland, plays an integral part in supporting the Scottish Government's vision of marine and coastal environments which are clean, healthy, safe, productive, and biologically diverse and are managed to meet the long-term needs of both nature and people. Their purpose is to provide expert scientific, economic and technical advice and services on issues relating to marine and freshwater fisheries, aquaculture, marine renewable energy, and to provide evidence to support the policies and regulatory activities of the Scottish Government through a programme of monitoring and research and to perform regulatory and enforcement activities. Marine Scotland is responsible for the Scottish National Marine Plan in support of sustainable use of our seas.

Lead representative: Dr Ian Davies, Head of Marine laboratories

National Oceanography Centre (NOC) The National Oceanography Centre is the UK's leading Institute for sea level science, coastal and deep-ocean research and one of the top five in the world. NOC is wholly owned by the NERC and receive national capability funding to support and underpin marine Science within the UK and through international programmes. The NOC has two sites, Southampton and Liverpool, and employs around 650 staff. A truly multi-disciplined centre, its research encompasses Marine Geoscience, Marine Physics and Ocean Climate, Marine Systems Modelling, Ocean Biogeochemistry and Ecosystems, and Ocean Technology and Engineering. It is home to the nation's marine data assets; the British Oceanographic Data Centre, the British Ocean Sediment Core Research Facility, the National Marine Equipment Pool, Europe's largest fleet of autonomous and robotic vehicles, and manages two state of the art research ships. In 2015 the Marine Robotics Innovation Centre was opened at its Southampton site.

Lead representative: Professor Angela Hatton, Director of Science and Technology

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

Lead representative: Tim Hurst, CEO

Heriot Watt University (HWU) was established in 1821 as the world's first mechanics institute. It went through a number of subsequent name changes and then in 1966, achieved university status and was named Heriot-Watt University. The university is the eighth oldest HE institution in the UK. The university has five campuses located in Edinburgh, the Scottish Borders, Dubai, Malaysia and Orkney. The university is divided into six schools including: energy, geoscience, infrastructure and society; engineering and physical sciences; social sciences; mathematical and computer sciences and textiles and design. It has key strengths related to the Blue Economy with its Orkney Campus co-located with EMEC and industry stakeholders, focussing on marine environmental interactions.

Lead representative: Dr Gillian Murray, Deputy Principal (Enterprise & Business)

Marine Alliance for Science and Technology for Scotland (MASTS) is a Scottish research pool established in 2014 comprising a consortium of 15 Universities and key associated agencies related to marine science. It was set up to advance marine science and technology in Scotland and elsewhere, and provides a key resource to undertake, enable and promote marine research, communication and education across Scotland.

Lead representative: Professor David Paterson, Executive Director

The University of Stirling was the first genuinely new University in Scotland for over 400 years when it was founded by Royal Charter in 1967. We retain our pioneering spirit and a passion for excellence in all we do. Our magnificent 330-acre campus in the City of Stirling is home to our five Faculties, Graduate School and Innovation Park. We also own and operate two major aquatic research stations at Buckieburn, just outside Stirling, and Machrihanish in Kintyre. Since 1971, our Institute of Aquaculture has been a leading international centre for research and education, and is now the largest of its kind in the world. We proudly bring together excellent researchers from a variety of disciplines in order to meet the wide range of challenges Scotland and the world faces as aquaculture grows to meet global demand. We work in close and direct partnership with businesses throughout the aquaculture production sector.

Lead representative: John Rogers, Director of Research and Innovation Services

GLOSSARY OF ABBREVIATIONS

AILG	Aquaculture Industry Leadership Group
AMETS	Atlantic Marine Energy Test Site
BBSRC	Biotechnology and Biological Sciences Research Council
BERD	Business Enterprise Research and Development
Bn	Billion
BRES	Business Register and Employment Survey
C2C	Current to Current
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBBC	China Britain Business Council
CEFOW	Clean Energy from Ocean Waves
CENSIS	Innovation Centre for Sensor and Imaging Systems
CfD	Contracts for Difference
CFEE	Centre for Energy and the Environment
CoHI	Convention of the Highlands and Islands
DECC	Department of Energy and Climate Change
DHES	Decentral Hybrid Energy Systems
DZR	Deposition Zone of Regulation
EAA	Ecosystem Approach to Aquaculture
EC	European Commission
EC-OG	East Coast Oil and Gas Engineering
EMEC	European Marine Energy Centre
EMFF	European Maritime and Fisheries Fund
EMSP	European Marine Science Park
EOI	Expression of Interest
ERDF	European Regional Development Fund
ERI	Environmental Research Institution, UHI
ESIF	European Structural Investment Fund
ETV	Energy Technology Verification
EU	European Union
FE	Further Education
FTEs	Full-Time Equivalent
GDP	Gross Domestic Product
GVA	Gross Value Added
HAB	Harmful Algal Bloom
HE	Higher Education
HIE	Highlands and Islands Enterprise
HND	Higher National Diploma
IBioIC	Industrial Biotechnology Innovation Centre
ICIT	International Centre for Island Technology
IP	Intellectual Property
IPPA	Innovation Power Purchase Agreement
LCoE	Lower Levelised Cost of Energy
LOGIC	Low Carbon Off-Grid Communities Project
LQs	Location Quotients
M	Million
MA	Modern Apprenticeship
MASTS	Marine Alliance for Science and Technology for Scotland
MAXiMAR	Maximising the Marine Economy
MCT	Marine Current Turbines
MEPB	Marine Energy Programme Board
MERL	Marine Environmental Research Laboratory
MGR	Marine Genetic Resource
MSP	Marine Spatial Planning
MSS	Marine Scotland Science
MUSES	Multi-Use in European Seas
NAFC	North Atlantic Fisheries College
NERC	Natural Environment Research Council
NMP	National Marine Plan
NVQ	National Vocational Qualification
O&M	Operation and Maintenance
OPEX	Operating Expenses
ORCA	Orkney Research Centre for Archaeology
ORE	Offshore Renewable Energy
ORIC	Orkney Research and Innovation Campus
ORJIP	Offshore Renewables Joint Industry Programme
PCP	Pre-commercial procurement
PIAs	Priority Innovation Areas
PTEC	Perpetuus Tidal Energy Centre
PV	Photovoltaics
R&D	Research and Development
RAE	Research Assessment Exercise
RAS	Recirculation Aquaculture Systems
REF	Research Excellence Framework
REIF	Renewable Energy Investment Fund
RLI	Rivers and Lochs Institute
ROV	Remotely Operated Vehicles
SAIC	Scottish Aquaculture Innovation Centre
SAMS	Scottish Association for Marine Science
SDI	Scottish Development International
SDS	Skills Development Scotland
SE	Scottish Enterprise
SEAI	Sustainable Energy Authority of Ireland
SEAM	Agronomy, Sustainable Energy and Micro-renewables centre
SEPA	Scottish Environment Protection Agency
SFC	Scottish Funding Council
SIA	Science and Innovation Audit
SIC	Standard Industrial Classification
SMAS	Scottish Manufacturing Advisory Services
SMEs	Small and Medium Enterprises
SNH	Scottish Natural Heritage
SoXSA	Scottish Centre of Excellence in Satellite Applications
SPH	Subsea Power Hub
SRUC	Scotland's Rural University College
SSIA	Scottish Seaweed Industry Association
SSMG	Scottish Shellfish Marketing Group
TAMU-CC	Texas A&M University Corpus Christi
TRLs	Technology Readiness Levels
UHI	University of the Highlands and Islands
UKRI	UK Research and Innovation
UN	United Nations
WATERS	Wave and Tidal Energy: R&D Support
WES	Wave Energy Scotland

EMEC
THE EUROPEAN MARINE ENERGY CENTRE LTD

wave energy
SCOTLAND

University of the
Highlands and Islands
Oilthigh na Gàidhealtachd
agus nan Eilean

IBioIC

HERIOT
WATT
UNIVERSITY
UK | DUBAI | MALAYSIA

SAMS

Scottish Government
Riaghaltas na h-Alba
gov.scot
marine scotland

MARINE ALLIANCE SCIENCE TECHNOLOGY SCOTLAND

Scottish
Aquaculture
Innovation
Centre

National
Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

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