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AQUACULTURE AND FLOATING OFFSHORE WIND

Potential Synergies

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HIE
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Iomairt na Gàidhealtachd 's nan Eilean

CONTENTS

1 INTRODUCTION

OVERVIEW AND BACKGROUND

1.1 With a coastline of almost 10,000km in Mainland Scotland, of which 62% is in the Highlands and Islands region (almost one third of the UK's total coastline), the marine economy, and the opportunities it represents are vital for Scotland. It makes a significant contribution to the national economy and helps to support fragile, rural, and remote communities, particularly in the Highlands and Islands. Reflecting its importance, there is a broadly supportive policy environment for its sustainable development and alongside this, the Scottish Government is committed to becoming a net zero country by 2045.

1.2 Recognising the potential of aquaculture and floating offshore wind energy, HIE commissioned ekosgen to undertake exploratory research to identify potential synergies between aquaculture and floating offshore wind sectors in Scotland, with a view to understanding the nature of the support framework required to help realise opportunities and unlock new growth, as well as associated policy implications for the public sector. Funding for the project was provided by Scottish Enterprise (SE).

1.3 The Scottish aquaculture industry has set the ambitious goal of doubling its value by 2030[1] but if this is to be realised, then new locations will have to be developed. These are likely to be further offshore, in deeper waters and in more energetic and hostile conditions. This move further offshore will require new technologies, new equipment, and new ways of working. Alongside this, Floating Offshore Wind (FOW) is an emerging industry in the renewable energy sector and Scotland is currently a leader in the development and deployment of FOW.

1.4 There is a clear policy rationale at Scottish and UK levels for exploring potential collaborations and synergies between aquaculture and floating wind energy. The Scottish Energy Strategy highlights the connections between the energy system and all parts of the economy, and its importance for sustainable, inclusive growth[2]. Scotland's National Marine Plan[3] aims to enable the sustainable development and use of marine areas so benefiting the marine environment and promoting existing and emerging industry. Part of that sustainability must be around energy use. In the same vein, Crown Estate Scotland's Corporate Plan (2020-23) has the strategic objective of supporting the sustainable expansion of Scotland's Marine Economy. It outlines a growth agenda across offshore renewables, aquaculture and coastal infrastructure and so is also very closely aligned with this study.

1.5 At UK level, as part of the Industrial Strategy, the *Clean Growth* grand challenge aims to maximise the accrual of benefits for UK industry of the global shift to clean growth. The thematic priorities of the Industrial Strategy Challenge Fund include *Transforming food production* and *Prospering from the energy revolution* – all relevant to aquaculture and offshore wind.

AIMS AND OBJECTIVES

1.6 The aim of this study is to explore the potential synergies between aquaculture and floating offshore wind with a view to maximising innovation and sustainable economic growth of these two industries in Scotland, and specifically the Highlands and Islands, including the supply chains. For the purposes of this study, we are considering aquaculture in its broadest sense – incorporating finfish, shellfish, and seaweed or macroalgae production. By understanding the policy and regulatory frameworks for each sector, and the drivers of each industry, the research aims to provide evidence and

[1] https://www.scottishaquaculture.com/media/1174/scottish-aquaculture-a-view-towards-2030.pdf
[2] https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/pages/2/
[3] https://www.gov.scot/publications/scotlands-national-marine-plan/

proposals on how the two might collaborate to overcome challenges and create opportunities that will benefit the industries and Scotland more widely.

1.7 The specific research objectives are to:

- Provide an overview of current and projected activity in aquaculture and FOW sectors in Scotland;
- Highlight opportunities and barriers to growth for each sector;
- Describe the regulatory regimes that apply to each sector;
- Consider potential synergies between the sectors, and identify cross-sectoral opportunities;
- Consider actions and activities required to capitalise on these opportunities and support sustainable growth;
- Assess potential displacement issues and highlight additional synergies with floating wind farms developments in sectors other than aquaculture (e.g. marine biotechnology, marine transport, sea fisheries, marine tourism);
- Provide an overview of a future policy and regulatory framework which would facilitate synergistic and sustainable growth of these sectors;
- Provide case study examples and/or learning from similar cross-sectoral activity (either between aquaculture and floating offshore wind, or other cross-sectoral activity with similar challenges).

RESEARCH APPROACH

1.8 The research methodology comprised two principal strands – desk research and a programme of consultations with experts drawn from research, academia, industry, and public sector agencies. A list of organisations consulted with is provided at Appendix 1.

1.9 A structured and carefully planned approach to the desk research was undertaken to ensure it was carried out consistently and comprehensively. This included the preparation of a research framework built around the research objectives to structure the desk-based research. Relevant source materials were identified through web-based and other searches, and through working with HIE, partners and consultees to provide access to additional insight, reports, and research not in the public domain.

1.10 In the primary research and consultations, a semi-structured topic guide was used flexibly to reflect the role, area of expertise, and organisation of the consultee.

REPORT STRUCTURE

1.11 The remainder of the report is structured as follows:

- Chapter 2 explores major industry trends across aquaculture and floating offshore wind;
- Chapter 3 examines the aquaculture industry in Scotland, and the barriers and challenges it faces;
- Chapter 4 examines floating offshore wind in Scotland;
- Chapter 5 details the policy and regulation landscape;
- Chapter 6 examines the innovation drivers in each sector;
- Chapter 7 examines the opportunity for synergy identified in the research;

- Chapter 6 considers how the synergies can be realised; and
- Chapter 8 provides the study conclusions and considerations for future actions.

2 INDUSTRY TRENDS

INTRODUCTION

2.1 The chapter sets out the broad global landscape for both aquaculture and floating offshore wind and the key drivers of change.

GLOBAL INDUSTRY TRENDS

Aquaculture

2.2 Global aquaculture production, including seaweed cultivation, has grown steadily over the last decade or so. Total production of aquatic animals has increased at an annual rate of 5.3% to 82.1 million tonnes in 2018, whilst algae production (including seaweed) has seen higher growth rates of around 20% per year, reaching 32.4 million tonnes in 2018.[4] Aquaculture production for aquatic animals and algae is dominated by Asia, and particularly China – China produces more than half of the world's aquaculture output. It is also the most diverse in terms of finfish and shellfish production.[5] Other Asian producers, including Vietnam, are also increasingly diversifying their species output.[6]

2.3 For farmed aquatic animals specifically, Asia has held an 89% share in global production over the last two decades or so. Among major producing countries, China, India, Indonesia, Vietnam, Bangladesh, Egypt, Norway, and Chile, have consolidated their share in regional or world production to varying degree over the past two decades.[7]

2.4 There has been growth in aquaculture markets outside of Europe. Africa, the Americas, and Asia as production regions have all seen their share of the global aquaculture market increase. Though China dominates production, its aquaculture market share (58%; -7 percentage points (pp) 2000-18) has decreased in contrast to other Asian producers including India (9%; +3pp), Indonesia (7%; +4pp), Vietnam (5%; +3pp) and Bangladesh (3%; +1pp). Chile has seen an increase in its market share of almost one third over the 2000-18 period, whilst Norway, in contrast to the rest of Europe, has seen an increase in its market share of around 0.5pp to around 2%.[8]

[4] http://www.fao.org/state-of-fisheries-aquaculture

[5] https://www.fao.org/fishery/facp/chn/en

[6] https://www.aquafisheriesexpo.com/vietnam/en-us/news-updates/vietnam-aquaculture-overview

[7] Ibid.

[8] UN FAO (2020) The State of World Fisheries and Aquaculture: Sustainability in Action, p.33

Table 2.1: Aquaculture production by global regions, and by selected major producers 2000-2018 (thousand tonnes; percentage of world total)

Global region/ selected country		2000	2005	2010	2015	2018
Global Region						
Africa	000 Tonnes	399.6	646.4	1,285.80	1,777.60	2,195.90
	% world total	*1.23%*	*1.46%*	*2.23%*	*2.44%*	*2.67%*
Americas	000 Tonnes	1,423.40	2,176.90	2,514.60	3,274.70	3,799.20
	% world total	*4.39%*	*4.91%*	*4.35%*	*4.50%*	*4.63%*
Asia	000 Tonnes	28,420.60	39,185.90	51,228.80	64,591.80	72,812.20
	% world total	*87.67%*	*88.46%*	*88.72%*	*88.76%*	*88.69%*
Europe	000 Tonnes	2,052.60	2,137.30	2,527.00	2,948.60	3,082.60
	% world total	*6.33%*	*4.82%*	*4.38%*	*4.05%*	*3.75%*
Oceania	000 Tonnes	121.5	151.5	187.8	178.5	205.3
	% world total	*0.37%*	*0.34%*	*0.33%*	*0.25%*	*0.25%*
Country						
China	000 Tonnes	21,522.10	28,120.70	35,513.40	43,748.20	47,559.10
	% world total	*66.39%*	*63.48%*	*61.50%*	*60.12%*	*57.93%*
India	000 Tonnes	1,942.50	2,967.40	3,785.80	5,260.00	7,066.00
	% world total	*5.99%*	*6.70%*	*6.56%*	*7.23%*	*8.61%*
Indonesia	000 Tonnes	788.5	1,197.10	2,304.80	4,342.50	5,426.90
	% world total	*2.43%*	*2.70%*	*3.99%*	*5.97%*	*6.61%*
Vietnam	000 Tonnes	498.5	1,437.30	2,683.10	3,462.40	4,134.00
	% world total	*1.54%*	*3.24%*	*4.65%*	*4.76%*	*5.04%*
Bangladesh	000 Tonnes	657.1	882.1	1,308.50	2,060.40	2,405.40
	% world total	*2.03%*	*1.99%*	*2.27%*	*2.83%*	*2.93%*
Norway	000 Tonnes	491.3	661.9	1,019.80	1,380.80	1,354.90
	% world total	*1.52%*	*1.49%*	*1.77%*	*1.90%*	*1.65%*
Chile	000 Tonnes	391.6	723.9	701.1	1,045.80	1,266.10
	% world total	*1.21%*	*1.63%*	*1.21%*	*1.44%*	*1.54%*
World	000 Tonnes	32,417.70	44,298.00	57,743.90	72,771.30	82,095.10

Source: UN FAO (2020)

2.5 There is evidence of growth in Aquaculture in Scotland (for example, Salmon production increased by 32% to around 204,000 tonnes between 2010 and 2019, trout increased by 44% to 7,400 tonnes over the same period). Whilst Scotland is also competitive in terms of the value of its product, attracting premium process, volume growth is not sufficient to be competitive globally in terms of market share (e.g. Scotland's aquaculture production is around 10% of Norway's, based on comparisons between UN FAO data set out in Table 2.1, and Marine Scotland production survey data).

2.6 A significant challenge facing Scottish and indeed wider UK aquaculture sector is that of market share. Evidence indicates that despite increasing output, Scotland's global market share is decreasing – in comparison to competitor markets, growth in Scottish aquaculture is modest, and considerably weaker. For example, the rate of production growth for salmon in Scotland has been lower than competitor countries and has resulted in a reduction in global market share in competition from countries such as Norway and Chile.[9,10] The latter has seen an 80% growth in production volume between 2010 and 2018.

[9] Food and Drink Scotland (2017) Aquaculture Growth to 2030: A strategic plan for farming Scotland's seas

[10] EY (2019) The Norwegian Aquaculture Analysis 2018

2.7 Norway accounts for over half the Atlantic salmon produced globally[11], and exports approximately 95% of its total production (1.16m tonnes).[12],[13] Many of Norway's top aquaculture companies such as Mowi and SalMar, (who part-own Scottish Sea Farms, and as of June 2021 Grieg Seafood[14]), both suppliers, and AKVA Group, a supply chain business, either operate in Scotland, or own Scottish companies. The Norwegian aquaculture sector has realised significant growth in recent years. Its business base has decreased by over 25% in the period 2009-18, but the evidence indicates that there has been consolidation in the industry, similar to the consolidation that has taken place in the Scottish finfish aquaculture sector. Over the same period, employment in Norwegian aquaculture has grown by 68% to over 8,500, and total sales have grown from around £2.29bn (Kr 22.4bn) in 2009 to £6.25bn (Kr 67.8bn) in 2018, an increase of over 272%.[15] In comparison, over the same period the value of production in Chile has increased by around 150% to almost $10.5 million – though it is worth noting that the volume of production has increased by 46% to just under 1.29 million tonnes.[16]

Drivers of change in global aquaculture

2.8 There is an increased demand globally for protein, of which fish and seafood is a key component. This is being driven by global population growth and rising affluence in developing countries. Rising incomes in developing countries have led to increased demand for high quality protein, primarily from meat and fish. There is also a perception in developed countries that seafood is a healthy protein option and a desirable element of the diet. As a result, seafood has become one of the largest traded food commodities in the world.

2.9 A key element of meeting this demand is increasing sustainable production through aquaculture, and the industry has subsequently been one of the fastest growing food production sectors in the past couple of decades.[17] The growth aspirations of the Scottish aquaculture sector, and indeed elsewhere in the UK and globally, reflect this increasing demand.

2.10 Allied to this is the need to ensure future food security. There is widespread recognition of the role that increasing aquaculture production can play in meeting this food provision requirement[18]. The UN FAO considers that aquaculture has expanded fish availability to regions and countries with otherwise limited or no access to the farmed species, often at more affordable prices, leading to improved nutrition and food security.[19]

2.11 Global aquaculture production continues to expand, but there is increasingly limited access to viable inshore and near-shore sites. As such, there is a move towards more exposed locations. Facilities such as SalMar's Ocean Farm 1 (sited off the coast of Trondheim) are being deployed to test the viability of offshore production.[20]

2.12 Environmental considerations are also driving change in aquaculture. Disease management and mitigating the environmental impact of waste from fish farms is a key focus of innovation amongst aquaculture companies and research institutions such as the Sustainable Aquaculture Innovation Centre (SAIC; previously the Scottish Aquaculture Innovation Centre).

[11] Ibid., p.22

[12] EY (2018) The Norwegian Aquaculture Analysis 2017

[13] Eurofish International Organisation (2019) at: https://www.eurofish.dk/norway

[14] https://www.shetlandtimes.co.uk/2021/06/29/greig-seafood-sells-shetland-operations-in-164m-deal

[15] Directorate of Fisheries, Norway (2019) Statistics for Aquaculture, at: https://www.fiskeridir.no/English/Aquaculture/Statistics/Total

[16] http://www.fao.org/fishery/statistics/global-aquaculture-production/en

[17] UN FAO (2020) The State of World Fisheries and Aquaculture: Sustainability in Action

[18] ekosgen and Imani Development, for HIE (2018) MAXiMAR: Maximising the Marine Economy in the Highlands and Islands

[19] UN FAO (2020) The State of World Fisheries and Aquaculture: Sustainability in Action

[20] https://www.fishfarmingexpert.com/article/world-s-first-offshore-fish-farm-arrives-in-norway/

2.13 It is worth noting that there are other industry responses to the demand for increased production. These include overcoming health challenges (a particular focus of SAIC), increasing the onshore phase of production through Recirculation Aquaculture Systems (RAS), and deploying enclosed cages in coastal waters. However, these are targeted at current modes of production, rather than necessarily representing a change in approach, although it's likely that truly offshore cage sites would be stocked with salmon smolts much larger than has been standard practice for inshore cage sites. These are already being produced using RAS installations in Scotland and Norway to increase productivity of inshore cage systems.

2.14 Trends in aquaculture in Scotland, and offshore aquaculture developments are explored in more detail in Chapter 3.

Floating offshore wind

2.15 By the end of 2020, there was an estimated 31.9GW installed offshore wind capacity[21], of which around 3% is installed in Scotland.[22] Whilst offshore wind is a comparatively mature sub-sector, other components of the offshore renewables sector are nascent. Though there have been some recent success stories in terms of deployment, the growth of wave and tidal energy remains uncertain. Floating offshore wind (FOW) is another relatively recent development in terms of marine renewable energy generation and is arguably approaching commercial maturity.[23] By the end of 2020, there was approximately 80MW of floating offshore wind generating capacity installed globally: c.75% of this is installed in Europe (59MW), with the remainder in Asia.[24] Of the European installed capacity, much of this is accounted for by the Hywind Scotland project, with a capacity of 30MW.

2.16 A number of different designs for are being deployed in a range of scenarios:

- The spar buoy design, as developed by Equinor[25] and used in its Hywind floating platform;
- A semi-submersible platform design that relies on buoyancy for stability, as used by developers such as Principle Power[26] and Hexicon[27];
- A concrete-constructed barge with integrated damping pool to maintain stability, developed by Ideol[28]; and
- Stiesdal Offshore Technologies' *TetraSpar* tension-leg platform.

2.17 The deployment of FOW installations is growing. Equinor's Hywind Scotland project off the coast of Aberdeenshire near Peterhead (discussed further in Chapter 4) is currently the only commercial-scale facility with a substantial operational track record. Equinor is also developing the Hywind Tampen windfarm[29] off the coast of Norway, to power the Snorre and Gullfaks oil and gas platforms and will be the first array to do so. It will have 11 turbines with a total generating capacity of 88MW. The Tampen project will be a test bed for further development of floating wind, exploring the use of new and larger turbines, installations methods, simplified moorings, concrete substructures and integration between gas and wind power generation systems.

[21] https://www.rystadenergy.com/newsevents/news/press-releases/global-installed-offshore-wind-capacity-to-see-37pct-growth-in-2021-fueled-by-china/

[22] https://www.scottishrenewables.com/our-industry/statistics

[23] https://www.greentechmedia.com/articles/read/so-what-exactly-floating-offshore-wind

[24] , at: https://www.energy.gov/sites/default/files/2021-08/Offshore%20Wind%20Market%20Report%202021%20Edition_Final.pdf

[25] https://www.equinor.com/en/what-we-do/floating-wind.html

[26] https://www.principlepowerinc.com/

[27] https://www.hexicon.eu/

[28] https://www.bw-ideol.com/en

[29] https://www.equinor.com/en/what-we-do/hywind-tampen.html

2.18 A second FOW array in Scotland, the Kincardine Offshore Floating Wind Farm[30], has recently been built 15 km off the coast of Aberdeen, with a generating capacity of 50 MW. It entered operation in late September 2021.[31] Much of the fabrication for the project is being undertaken in Spain.[32]

2.19 Elsewhere in the world, FOW projects are being delivered in France (e.g. the EFGL project[33]), Japan (Hibiki[34]) and Portugal (WindFloat Atlantic[35]).

Drivers of change for floating offshore wind

2.20 Decarbonisation of the energy generation industry is arguably the primary driver for growth and development of FOW. As countries, industries and specific businesses pursue net zero ambitions, securing renewable energy generation is critical. Even for continuing carbon-based fuel operations such as oil and gas, which will still be required during the energy transition, there is a push to ensure that emissions for extraction are as low as possible.[36]

2.21 Hydrogen is growing in importance in terms of future energy mix. Hydrogen production is also driving the need for higher volumes of renewable generation. Given that many potential FOW sites are at distances that are not viable for cable connection to national grids, hydrogen production and storage is one option for such sites.

2.22 Another driver for the exploration of FOW is the constraint on the size of available piled offshore wind sites. In the UK alone, suitable piled offshore wind sites are constrained to a capacity of around 47 GW in UK waters. Pursuing FOW opens up a much wider range of sites for marine energy generation.

2.23 Cost reduction is also an important consideration for the FOW industry in the short term. FOW is not currently cost-competitive relative to piled offshore wind since the proven, mature technology used in piled offshore wind is cheaper to deploy. However, FOW projects are helping to bring costs down. For example, Equinor has already seen a reduction in capex costs per megawatt of 70% between its initial Norway demonstrator and its Hywind Scotland array and expects a further 40% drop between Hywind Scotland and Hywind Tampen.[37] Industry ambitions for cost are around €40-60 per mWh by 2030, from around €200 in 2018.[38] A recent report published by the ORE Catapult identifies a number of pathways to subsidy-free generation for the FOW industry. The report also states that there is expectation that cost reduction in UK FOW will happen much faster than for piled offshore wind.[39]

[30] https://pilot-renewables.com/

[31] https://www.offshorewind.biz/2021/09/21/worlds-largest-floating-wind-farm-starts-operating-statkraft-buys-entire-output/

[32] https://www.grupocobra.com/en/proyecto/kincardine-offshore-floating-wind-farm/

[33] https://mhivestasoffshore.com/eoliennes-flottantes-du-golfe-du-lion-efgl-selects-v164-10-0-mw-turbines-from-mhi-vestas-offshore-wind/

[34] https://www.bw-ideol.com/en/ideols-floating-wind-turbine-japan-officially-inaugurated-after-months-sea

[35] https://www.edp.com/en/innovation/windfloat

[36] https://www.gov.scot/publications/annual-energy-statement-2020/

[37] https://www.equinor.com/en/news/20210323-hywind-scotland-uk-best-performing-offshore-wind-farm.html

[38] https://www.greentechmedia.com/articles/read/floating-wind-is-cutting-costs-faster-than-regular-offshore-wind

[39] https://ore.catapult.org.uk/wp-content/uploads/2021/01/FOW-Cost-Reduction-Pathways-to-Subsidy-Free-report-.pdf

3 AQUACULTURE IN SCOTLAND

INTRODUCTION

3.1 This chapter examines, in greater detail, the aquaculture industry in Scotland and the current trends in its development. It also explores the major constraints and challenges to growth that aquaculture faces, as well as the drivers of innovation for the sector.

3.2 Following on from this, the opportunity for offshore aquaculture in Scotland and current developments, both in Scotland and elsewhere is explored. Challenges and constraints to offshore development in aquaculture are also set out.

INDUSTRY STRUCTURE

Finfish and shellfish aquaculture

3.3 Aquaculture is a key food and drink industry for Scotland. It operates in a global market, particularly in terms of its salmon production. The Highlands and Islands is the largest aquaculture production region in the UK. Its coastline with many sheltered lochs is ideally suited to aquaculture production which, coupled with best-practice production processes and high provenance and traceability, helps Scotland command a high premium for its aquaculture produce and is a key area of competitive advantage.[40]

3.4 The industry directly employs over 2,400 workers, mainly in Salmon production. This is a 25% increase on 2010 employment levels. Conversely, the industry has seen a decrease in the number of businesses over this period. For finfish and salmon in particular, this is at least partly due to consolidation within the sector.[41]

Figure 3.1: Employment and business structure in Scottish aquaculture, 2019

Species	Employment	Companies
Salmon	1,932	23
Rainbow Trout	144	22
Other species	53	13
Shellfish	277	129
TOTAL	**2,406**	**187**

Source: Marine Scotland Scottish Fish Farm and Shellfish Production Surveys 2019 (2020)
Employment rather than FTEs presented due to data collection methods

3.5 The aquaculture industry in Scotland has seen considerable growth in recent years. For example, production in salmon increased 32% to 203,881 tonnes in 2019 over 2010 production volumes. In salmon production terms, Norway and Chile are the top two producers globally, whilst Scotland is ranked third – although there are considerable gaps between harvest volumes.[42] Rainbow trout and other finfish saw similar increases. Whilst mussel production has seen a small decrease over this period, production of other species (e.g. oyster, scallops) has increased considerably (c.31% combined).

3.6 Scottish aquaculture accounts for most of the wider UK aquaculture sector. Aquaculture in Scotland, and finfish aquaculture in particular, is a relatively mature sector in comparison to FOW. It is also highly vertically integrated, with production companies owning considerable proportions of the value chain besides production (e.g. processing). It is characterised by a small number of global finfish producers (mainly salmon, with some trout production) typically located in the Highlands and Islands

[40] ekosgen and Imani Development, for HIE (2018) MAXiMAR: Maximising the Marine Economy in the Highlands and Islands

[41] Marine Scotland Science (2020) Scottish Fish Farm Production Survey 2019; Scottish Shellfish Production Surveys 2019

[42] For example, see: https://www.sciencedirect.com/science/article/pii/S0044848619300638; https://mowi.com/it/wp-content/uploads/sites/16/2020/06/Mowi-Salmon-Farming-Industry-Handbook-2020.pdf

region, and a larger business base of smaller shellfish producers, again predominantly located in the Highlands and Islands.

3.7 Aquaculture, including the supply chain in Scotland contributes over £1.8bn annually to Scotland's economy and 8,800 jobs[43], including upstream businesses supplying farms with inputs (e.g. feed, engineering and equipment, veterinary services,) and downstream process and handling businesses (e.g. seafood processing, retail, food service). It also supports a wider, and more geographically dispersed supply chain including processing, distribution, feed supply, workboat services, manufacturing and servicing of equipment, scientific services, and exporting. The industry is of particular significance to the economic growth in rural, coastal and island communities where it can act as an anchor industry providing year-round, well-paid jobs and contributing to the viability and prosperity the areas where commercial activity takes place.

3.8 Aquaculture businesses are key investors in local skills and infrastructure in rural areas, supporting community resilience beyond its economic impact.[44] For example, Mowi Scotland frequently contribute resources to strengthen the communities in which they operate, as part of the company's corporate social responsibility and social licence to operate in the area. Staff contribute to local communities, businesses, and services through volunteering (e.g. to the fire service, or coastguard), and the company's corporate social responsibility activity extends to sponsorship of local sports teams, community events, donations to schools, and the establishment of community funds. Mowi have recently built affordable housing on Rum and Muck and have reached an agreement to support the development of affordable housing on Colonsay, along with Argyll and Bute Council, Highlands and Islands Enterprise, the Communities Housing Trust, and Colonsay Community Development Company.[45]

3.9 The industry ambition is to raise aquaculture's economic value in terms of turnover to £1.1bn across Scotland by 2030, with an increase in tonnage potentially increasing jobs in the sector to 6,000 (with wider UK economy value of £3.6 billion and 18,000 jobs, including those in the supply chain).[46] This would require a year-on-year growth of 5%. Based on historic Marine Scotland data, growth in turnover would be sufficient to meet the value target. However, the employment growth rate that would be required is insufficient to meet growth targets for aquaculture in Scotland by 2030. Further, industry ambition is to double output to somewhere in the range of 300,000 to 400,000 tonnes per annum for finfish production, with a median production figure of 350,000 tonnes. Recent research has indicated that dependent factors that would facilitate this 100% increase in production by 2030, along with challenges that would need to be overcome, suggest that a 50% increase in production might be more likely. [47,48]

Seaweed cultivation and harvesting

3.10 Seaweed harvesting is very much a nascent sector, therefore estimates around the scale and economic value of the sector are limited. It was previously estimated by Viking Fish Farms in 2012 that the UK macroalgae industry has an economic value of £1-1.3m.[49] There were 27 seaweed related business in UK in 2016, with 16 using UK-harvested seaweed and 11 using seaweed harvested elsewhere[50]. Many of the 16 businesses using UK-harvested seaweed are based in and harvest their seaweed in the Highlands and Islands. At Scotland-level, although a significant resource, seaweed is

[43] Imani Development, Westbrook Associates for HIE and Marine Scotland (2017) *The Value of Aquaculture to Scotland*

[44] Marine Scotland (2017) The Value of Aquaculture in Scotland (Fact sheet 40)

[45] https://mowiscotland.co.uk/2021/03/12/creating-affordable-housing-for-island-communities/

[46] Food and Drink Scotland (2017) Aquaculture Growth to 2030: A strategic plan for farming Scotland's seas

[47] Imani Development, Westbrook Associates for HIE and Marine Scotland (2017) *The Value of Aquaculture to Scotland*

[48] ekosgen, for Marine Scotland (2020) Supporting the Economic, Social and Environmental Sustainability of the UK's Marine Sectors

[49] Cefas (2016) Seaweed in the UK and abroad – status, products, limitations, gaps and Cefas role

[50] https://www.frontiersin.org/articles/10.3389/fmars.2019.00107/full

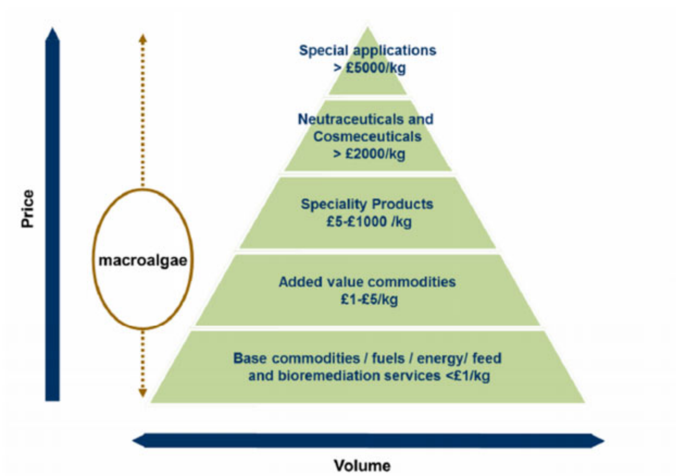
being harvested at a small scale at present. As a result, there is a lack of data available on the value of seaweed harvesting to Scotland.

3.11 Marine Scotland is currently considering the need for further regulation of policy for wild seaweed harvesting following on from the publication of its Wild Seaweed Harvesting Strategic Environmental Assessment (SEA)[51].

3.12 There is also an opportunity around the cultivation (or farming) of seaweed, as opposed to harvesting. Seaweed cultivation, as opposed to wild harvest, in Scotland (and the UK) is currently at a pre-commercial stage, with a number of pilot farms having been established. In Scotland, as at October 2020 there were three 'live' lease option agreements that have been granted by Crown Estate Scotland.[52] SAMS are currently investigating the potential of this in Scotland, and are operating a pilot farm; such farms are also operated (or have been operated) elsewhere in the UK by Queen's University Belfast in Northern Ireland, and Swansea University in Wales.[53] One small commercial farm is run by New Wave Foods (trading as SHØRE) in Caithness.[54] Farming would help negate some of the environmental consequences of harvesting, as outlined in the next section, particularly wild seaweed's natural barrier against coastal erosion and flooding and its role as shelter/food for the marine ecosystem.

3.13 The value, and hence productivity, associated with seaweed production (both harvested and cultivated) varies depending on the type of products being produced, as shown at Figure 4.11, with the estimated return for biomass estimated at <£1/kg compared with >£5,000/kg for certain special applications.

Figure 4.11: Pricing of products from macroalgae and current capacity for macroalgae production in the UK



Source: Cefas, (2016) Seaweed in the UK and abroad – status, products, limitations, gaps and Cefas role

3.14 Estimated timescales also vary extensively depending on product type.[55] Some applications, such as cosmetics, fertiliser, sea vegetables and hydrocolloids are already well established with further future growth anticipated. In the longer term, the application of seaweed in industrial biotechnologies,

[51] https://www.gov.scot/publications/wild-seaweed-harvesting-strategic-environmental-assessment-environmental-report/
[52] https://www.crownestatescotland.com/news/ref-148-seaweed-cultivation
[53] https://www.frontiersin.org/articles/10.3389/fmars.2019.00107/full
[54] https://shoreseaweed.com/about-shore/
[55] Adapt/Innovate UK, NERC (2013)

thermal conversion, ethanol and terpenoids are still at the research stage, with deployment 10 to 15 years away.

3.15 At a regional level, Marine Biopolymers Ltd has estimated that its plans for kelp harvesting off the west coast of Scotland have a potential value of £300m.[56] Research commissioned by HIE has underlined that whilst Scottish seaweed harvesting in itself may be of a relatively low value, it could enable a very high value (in the range of £100-£500m after ten years) manufacturing and pharmaceutical industry.[57]

3.16 There is considerable potential for growth in Scotland, as well as development of the sector's exploitation and use of seaweed. With smaller scale harvesting ongoing at present in Scotland, there is an ambition throughout the sector to develop large-scale wild seaweed harvesting, particularly around the nation's coasts[58].

INDUSTRY CONSTRAINTS AND CHALLENGES

3.17 As noted in Chapter 2, there is an increasing global demand for protein being driven by population growth and affluence as a result of economic development. The quality and provenance of Scottish aquaculture means that it is well-positioned to take advantage of this demand. However, there are a number of inter-related challenges and market failures that constrain the sector and sub-sectors within it. These prevent aquaculture realising the growth opportunities and currently mean that Scotland cannot adequately respond to market demand.

Environment and the marine space

3.18 Available space, or lack of it, is a key sectoral growth constraint for aquaculture[59,60,61], and the achievement of industry ambitions to double in size by 2030. There is increasingly limited availability of inshore sites for aquaculture development, and competition for marine space with other uses. This is further compounded by perceptions of aquaculture in some quarters – the sector is viewed by some more negatively relative to other marine uses considered to be less intrusive with less of an environmental impact. This pressure on current marine space highlights the need for productivity improvements and for alternative locations to facilitate expansion. Currently most production sites are in near-shore or inshore waters, but availability of new inshore sites is constrained.

3.19 Leases for new sites are awarded and managed by Crown Estate Scotland, whilst licences are issued by Marine Scotland. Aquaculture production is regulated by Marine Scotland, SEPA and Food Standards Scotland[62]. Access to new sites in other locations is arguably limited[63], either by management systems for other types of use, or environmental designations, such as Marine Protected Areas (MPAs). These environmental issues have been considered by a Scottish Parliamentary inquiry that reviewed the impacts of salmon farming, which highlighted the need for better data, monitoring and

[56] https://www.bbc.co.uk/news/uk-scotland-46252427

[57] HIE (2018) Wild Seaweed Harvesting as a diversification opportunity for fishermen

[58] http://marine.gov.scot/information/strategic-environmental-assessment-sea-wild-seaweed-harvesting

[59] Marine Scotland Science (2012) Scottish Marine and Freshwater Science Volume 3 Number 6: Development of a GIS based Aquaculture Decision Support Tool (ADST) to determine the potential benthic impacts associated with the expansion of salmon farming in Scottish sea lochs

[60] For example: Sanchez-Jerez, P. et al. (2016) Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. Aquaculture Environment Interactions, 8, pp.41-54

[61] Hofherr, J., Natale, F. & Trujillo, P. (2015) Is lack of space a limiting factor for the development of aquaculture in EU coastal areas? Ocean & Coastal Management, 116, pp.27-36

[62] https://www.gov.scot/policies/aquaculture/fish-farm-consents/

[63] e.g.: https://www.msp-platform.eu/projects/aquaspace-ecosystem-approach-making-space-sustainable-aquaculture

research, greater management and mitigation of environmental impacts from aquaculture, and an ecosystems-based approach to planning and development.[64]

3.20 Climate change is impacting on Scotland's aquaculture sector and will continue to do so in future. Notable effects include changing physical and chemical characteristics in coastal waters, as well as potential water quality degradation as a result of temperature increases. Currents and meteorological conditions are also being disrupted. [65] Degradation in water quality and other environmental challenges will impact on the quality of produce, which in turn poses a threat to the position of the product as a high quality one that attracts a premium price. This is a critical consideration in a sector where premium quality and provenance are key competitive advantages for Scotland. Higher sea water temperatures could in the medium to long term offer opportunities to farm new species[66], but they may also lead to the emergence of new diseases and increase the prevalence of existing parasites and pathogens. Warmer waters may be contributing to increasing occurrence of harmful algal bloom events, which can cause mass finfish mortalities or disrupt harvesting or shellfish.[67] Additionally, the speed at which climate change will impact on sea conditions means that there is a likelihood of more frequent storm activity in the investment time frames of 25-30 years, which needs accurate modelling to better inform business cases. At this point, modelling can effectively be done 'on paper', considering wave forces, structural requirements, economics, and so on. However, there will ultimately be a need for field trials, and to take risks with demonstrator sites and equipment.

3.21 Fish health and welfare is a priority for farmers. The finfish industry in Scotland is facing issues of sea lice, amoebic gill disease and other pathogens, and climate change will most likely exacerbate these.[68] Issues of fish health impact on business profitability, security and consistency of supply, and adversely impact industry reputation.

3.22 There are a number of environmental challenges impacting on the growth of the seaweed harvesting and marine biotech sector, as outlined in Marine Scotland's 2016 Wild Seaweed Harvesting SEA, including:

- Threat to habitat and/or shelter for plants and animals (as well as a loss of direct and indirect food sources), which would impact on the immediate ecosystem;
- Loss of nursery grounds for juvenile invertebrates and fish, with consequences for commercial fish stocks;
- Potential for increases in coastal erosion or flooding due a lack of seaweed protection;
- Loss of carbon stores and sinks provides by some species; and
- Loss or damage to cultural heritage assets and reduction in resource available to crofters.

3.23 Mitigation measures have been identified, in particular to protect areas of the Scottish coast especially sensitive to harvesting and where industrial scale harvesting may be restricted or unacceptable. This includes exposed coastal areas prone to erosion and where kelps help dissipate wave energy, and areas where beach cast seaweed is used by crofters.

[64] https://www.parliament.scot/parliamentarybusiness/CurrentCommittees/107588.aspx

[65] See for example: IPCC (2014) Fifth Assessment Report, at: https://www.ipcc.ch/assessment-report/ar5/; also Cheng, L. et al. (2020) Record-Setting Ocean Warmth Continued in 2019, Advances in Atmospheric Sciences, Vol. 37, pp.137-142

[66] Callaway, R. et al. (2012) Climate change and marine aquaculture in the UK. Aquatic Conservation: Marine and Freshwater Ecosystems 22, pp.389-421

[67] ekosgen and Imani Development, for HIE (2018) MAXiMAR: Maximising the Marine Economy in the Highlands and Islands

[68] Government Office for Science (2018) Foresight: Future of the Sea

Engineering, equipment, and technology

3.24 As a high proportion of finfish aquaculture in Scotland is owned by a small number of international companies, science and research often happens outside of the UK and innovations and solutions are imported from, for example, Norway and Canada. Whilst some indigenous companies such as Gael Force Group[69] are innovating in aquaculture engineering, building on their barge building and pen production expertise, there is a challenge in high-value R&D and innovation taking place outside of Scotland and indeed the UK. Thus, there is a deficit of domestic technological capital for aquaculture.[70] The recent sale of Grieg Seafoods from its Norwegian parent company to Scottish Sea Farms[71] (itself jointly owned by Norwegian Firms SalMar and Lerøy Seafood Group) highlights the potential risk of the domestic technological capital deficit.

3.25 The drive towards offshore sites means that existing production equipment will not be viable as it cannot withstand the more extreme marine conditions in genuine offshore sites, though it is understood that the current generation of HDPE cages have proven acceptable to major operators thus far in developing more exposed coastal sites. The forces involved, and the high costs in overcoming those offshore forces represents a massive risk to investment, where inshore or onshore sites with known marine and meteorological conditions continue to have a substantial competitive advantage over potential offshore locations. For example, costing for cage failure at a rate of 1 in 10 years may be inadequate and may actually need to be costed at double the rate, i.e. at 1 in 5 years. In the current context, there are clear competitive advantages in the cost of production in inshore waters versus offshore.

3.26 The cost of developing new systems and equipment, and demonstrating market viability are therefore high, and potentially prohibitive for some operators. This is a barrier to first mover investment amongst some aquaculture companies.

Access to finance

3.27 Across many marine sectors and uses, access to finance is a key challenge that can constrain growth of businesses and sectors. Businesses can find it difficult to secure investment, for example to buy and upgrade equipment, and invest in new technologies, staff development and training. The outcome is that they are not as efficient and productive as they could be and so risk losing competitive advantage. If there is a critical mass of underinvestment in a sector, then there is likely to be a loss of market share and a loss of global competitiveness.

3.28 A key issue is that the return on investment is often realised in the longer term and is perceived as riskier than banks allow for. There is also a lack of understanding of marine sectors such as aquaculture on the part of lenders, for example how assets are viewed and how that relates to risk assessment.

3.29 Where a Scottish aquaculture operation is part of a much larger international company, the UK-based operation can access finance from the parent company or group and can access non-UK sources (i.e. internal financing). This happens most frequently in larger finfish (salmon) production companies in Scotland, but Scottish-based operations must then demonstrate competitiveness within an international portfolio of production. However, these types of financing options are not available to smaller finfish and shellfish producers.

3.30 The equipment required for aquaculture production is often highly specialist and expensive, and this is often not reflected in resale value, particularly in a sector typified by a small number of large enterprises, and a large base of micro-businesses. This can deter potential investors from investing in

[69] https://www.gaelforcegroup.com/

[70] ekosgen, for Marine Scotland (2020) Supporting the Economic, Social and Environmental Sustainability of the UK's Marine Sectors

[71] https://www.shetlandtimes.co.uk/2021/06/29/greig-seafood-sells-shetland-operations-in-164m-deal

production companies and equipment supply chain companies. Industry equipment is not mortgageable. Banks often demand personal guarantees to secure investment which can be a barrier for business owners. Only a small number, such as Clydesdale Bank and Triodos, have any appetite to invest in aquaculture companies. Thus, few companies seek investment from UK financial institutions. In contrast, in Norway commercial-owned banks such Arctic Securities[72], and the government-owned Export Finance Norway (Eksfin)[73], offer long-term financing and guarantees to support Norwegian production and exports – with the latter including state-backed risk relief.

3.31 An additional challenge is the current funding environment. Whilst organisations such as SAIC are still funding academic R&D and innovation in aquaculture, there has been a fundamental change in the funding landscape as a result of Brexit. Post Brexit, there is uncertainty on replacement funds to the European Marine and Fisheries Fund (EMFF), ongoing access to Horizon Europe or Interreg programmes as a third-party country, and the extent to which the Shared Prosperity Fund will support aquaculture and other marine sectors.

Social licence

3.32 Aquaculture's social licence[74] for current and expanding production is under threat from a vociferous environmental interest. In recent years, aquaculture has received well publicised negative media coverage, primarily related to fish health[75] and environmental impacts including responses to predation.[76] This has served to undermine how the industry is perceived by the public, and undoubtedly also negatively impacts on how the industry is viewed by some as a career option.

3.33 However, there are some good examples of co-investment and co-operation between the aquaculture industry and host communities in terms of housing, and other infrastructure and services including digital connectivity. For example, the development of the Scottish Salmon Producers' Organisation (SSPO) Community Charter[77] shows how the process of community engagement should work and where benefits can be seen for both communities and farming companies. The Charter demonstrates the recognition by industry of the need for aquaculture sites and their staff to be more sensitive to the local community in which they are based.

OFFSHORE DEVELOPMENT IN SCOTTISH AQUACULTURE

Opportunity and current activity in Scotland

There is significant opportunity to develop infrastructure in offshore aquaculture but also a need for Scotland to enhance its competitiveness. The advantage of the Scottish coastline which is well-suited to existing inshore aquaculture production diminishes as countries pursue offshore production to increase volume.[78] However there is some activity in Scotland to explore and develop offshore aquaculture opportunities.

3.34 SAMS are currently delivering the OffAqua project[79], in partnership with Stirling University's Institute of Aquaculture. The aim of the project is to evaluate the environmental conditions required for the development of offshore aquaculture, including evaluating physical/hydrodynamic conditions, improve modelling for offshore locations, and to undertake risk analysis of equipment failure in more exposed locations.

72 https://www.arctic.com/secno/en/department/corporate-finance/aquaculture
73 https://www.eksfin.no/en/industries/fisheries-and-aquaculture/
74 The level of acceptance or approval by local communities and stakeholders of businesses and their operations
75 https://www.theguardian.com/business/2018/oct/29/campaigners-call-for-temporary-ban-on-new-scottish-fish-farms
76 https://www.scotsman.com/news/environment/fish-farms-kill-more-seals-as-industry-tries-to-save-salmon-1-4593698
77 http://scottishsalmon.co.uk/wp-content/uploads/2016/09/community_charter_2016_digital.pdf
78 UK Government (2017) Future of the Sea: Trends in Aquaculture
79 https://www.sams.ac.uk/science/projects/off-aqua/

3.35 There is speculation the existing farms will trial Scotland's first open ocean salmon farm with a view to expanding their production capacity. It is anticipated the farm will be similar in design to SalMar's Ocean Farm 1 (Norway – see 3.46 below), making use of sector-leading Norwegian aquaculture and offshore technology, as is usually the case. This model is expected to cost around £60 million. Ocean Farm 1 showed strong initial results holding up to 1.25 million fish, with high survival rates, high quality fish and consistently low lice levels. However, the extent to which this is viable in Scotland depends on the regulatory environment, reaching agreement with SEPA on stock levels, and assessments of the marine environment. [80]

3.36 A high-energy site has been tested by Cooke Aquaculture off the island of Westray in Orkney (Skelwick Skerry). The site has a mooring grid and four flotation cages of 130m circumference, fabricated with flexible, high density polyethylene providing a cage volume of over 28,000m^3. Part-funded by the European Marine and Fisheries Fund (EMFF), its first harvest was May 2019. There are plans to increase capacity and directly employ up to 16 staff. Technologies more suited to this high-risk and changeable environment are being examined to simplify processes. [81]

Offshore aquaculture developments elsewhere

3.37 SalMar was awarded a license by the Norwegian government for aquaculture development to spur new technology concepts. These innovation licences are free and are aimed at addressing aquaculture's spatial and environmental challenges.[82] As a result, it developed a full-scale offshore fish farming pilot facility established in 2017 called Ocean Farm 1. [83] The farm is 68m in height, 110m in diameter and 250,000m^3 in volume. It is based in Frohavet in the west of Norway near Trondheim. The structure was built in China based on Norwegian technology. The farm is designed to test out the biological and technological aspects of offshore fish farming, with a view to addressing sustainable growth issues in the aquaculture industry. Ocean Farm 1 has an interdisciplinary partnership across aquaculture, offshore and research and is a pilot facility for testing, learning, research, and development.[84]

3.38 Open Blue produces deep water open ocean raised fish with low environmental impact. Working with aquaculture engineering company Innovasea, they have deployed robust pens and equipment to create the world's largest open ocean aquaculture production site off the coast of Panama, farming cobia. The site must contend with a high energy environment with strong currents and waves consistently above 1.5m high, located more than 11km offshore. This environment is not suited for traditional aquaculture equipment. The farm has been designed and built with submersible sea station pens (22 pens, 14,500m^3 capacity), an integrated feeding system serving 12 pens from a single point, and copper alloy mesh netting to prevent predator attacks and reduce stress on fish stocks. Up to 1,200 tons of fish are harvested annually with equipment expected to last 10-20 years for pens and 2-5 years for nets.[85] Other designs, such as that developed by Impact9, are submersible and use elastic properties of its components to give it unique compliance to waves – making it suitable for the relatively shallow waters around the British Isles.[86,87]

3.39 The Wier and Wind project[88] aims for large-scale cultivation of 'Wier' Dutch seaweed, over a three-year period (July 2019-2022). The project, which is part-funded through the Interreg Vlaanderen Nederland cross-border programme, aims to determine whether seaweed could be grown on a large scale in the areas between the wind farm's turbines. Previous test projects have grown smaller amounts

[80] https://thefishsite.com/articles/scotland-set-for-first-open-ocean-farm
[81] https://cookeaquaculturescotland.com/skelwick-skerry-site-receives-full-planning-permission/
[82] https://www.norwayexports.no/news/new-development-licenses-spur-ocean-farming/
[83] https://www.salmar.no/en/offshore-fish-farming-a-new-era/
[84] https://www.fishfarmingexpert.com/article/world-s-first-offshore-fish-farm-arrives-in-norway/
[85] https://www.innovasea.com/case-study/open-blue-largest-open-ocean-fish-farm/
[8686] https://www.fishfarmingexpert.com/article/taking-the-plunge-a-submersible-cage-for-scotland/
[87] https://www.impact-9.com/
[88] https://www.power-technology.com/features/offshore-wind-farm-seaweed-wier-north-sea-farmers-aquaculture-farming/

of seaweed closer to shore, but this project aims to cultivate an area of up to 20,000m^2 in unsheltered waters. Offshore wind already relies on maritime industry operations for power development. Belgium Norther wind farm have plans to use offshore wind turbines in aquaculture to automate the growth and harvest of seaweed, developing a system for use at other wind farms to scale up multi-use aquaculture. The wind farm is 23km off the Belgian coast near Zeebruge, has been operational since 2009 and now has 44 wind turbines generating 370MW, controlled by renewable energy power producers: Belgian Elicio, Dutch Eneco and Diamon Generating.[89]

3.40 Offshore Shellfish based in Brixham in Devon, England have developed an offshore rope-cultured mussel farm across three sites in Lyme Bay, at distances between three and six miles offshore. It will cover a total area of 15.4 square km and produce around 10,000 tonnes per year once fully developed. A system of floats and rope 'droppers', on which the mussels are grown, are attached to a 250m long mooring line anchored to the seabed. Working in conjunction with Plymouth University, Offshore Shellfish is the first mussel farm in Europe to obtain Best Aquaculture Practice (BAP) certification[90]. The BAP certification programme assesses the sustainability of every step of the production chain, examining environmental responsibility, animal health and welfare, food safety and social accountability.[91]

3.41 The Native Oyster Restoration Alliance (NORA)[92] is a collaboration of projects across Europe seeking to re-establish populations of native oysters in the seas around Europe. Whilst many projects are delivered in coastal waters (e.g.), some are located offshore. One such project is the Rich North Sea Oyster Pilot, which aims to kick-start a population of native flat oysters within Blauwwind's Borssele III & IV offshore wind farms, situated about 55 km from the port of Vlissingen in the Netherlands.[93] As well as growing luxury seafood produce, oyster reefs are good for other species and so increase biodiversity. There is also a degree of carbon capture in oyster shells.[94] Additionally, within Scotland, the Dornoch Environmental Enhancement Project (DEEP) is part of the UK and Ireland Native Oyster Network, and is seeking to re-establish a native oyster colony in the Dornoch Firth using wild oysters from Loch Ryan.[95]

Challenges and constraints to offshore development

3.42 The primary constraint to development of offshore aquaculture is scale of forces that are present in high-energy offshore environments. Conventional inshore aquaculture production structures will not withstand oceanographic and meteorological conditions in offshore locations.

3.43 Structures for offshore aquaculture developments require different cage designs as they must withstand harsher weather conditions, and the distance from the shore means more complex logistics chains and maintenance systems. So far, it is understood that submersible cages are considered more resistant to wave action but there is a need for maritime data across a suitable time-series period to develop and deploy the appropriate technology – this typically would require at least a year of site monitoring.

3.44 If sea cages are designed to be optimised for specific offshore locations, that should reduce failure and maintenance/replacement costs and any uncertainty in use and longevity.[96] However, the environment and conditions in these more exposed sites may drive up production costs and will certainly mean that processes and equipment will need to be significantly adapted to cope with the conditions in

[89] https://www.power-technology.com/features/offshore-wind-farm-seaweed-wier-north-sea-farmers-aquaculture-farming/

[90] https://offshoreshellfish.com/

[91] https://www.bapcertification.org/

[92] https://noraeurope.eu/

[93] https://noraeurope.eu/the-netherlands-joint-project-blauwwind-and-the-rich-north-sea-oyster-pilot/

[94] https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.2017.0891

[95] https://nativeoysternetwork.org/portfolio/deep/

[96] (2020) Innovation Examples. Available at: https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/case-study-examples_en.pdf

such high-energy, dynamic and often extreme environments: for example, being able to withstand wave movement, deeper water and wind. There is therefore an assumption that there would have to be a clear advantage to the cost of production realised through access to increased biomass in any one site. This would be necessary to offset investment costs and identified risks.

3.45 Alongside cost, there are a number of other considerations and challenges. For example, the further that aquaculture sites are located offshore, the closer they will be to areas where wild fisheries vessels are operating and there are concerns about the implications of interaction of farmed and wild fish and possible transfer of disease and pathogens in these deeper waters.

3.46 An additional challenge is that of fish husbandry, which becomes more complex in offshore sites. This is particularly the case with salmon kept in submerged cages, where salmon need access to the surface to rebalance their swim bladders. More generally, the practicalities of fish husbandry become challenging in offshore locations. At current inshore production sites, it is routine for cages and fish stock to be checked manually at least once per day.

3.47 It was also noted through consultations that emerging findings from the OffAqua project suggested that offshore conditions may present additional welfare issues for salmon. An aim of the project is to evaluate the effects of more energetic offshore environments on salmon health, welfare, and general performance. Findings indicate that salmon growth rates may be lower, primarily because of energy expenditure in a more extreme environment.

3.48 Though it is anticipated that offshore aquaculture has the potential for mitigating the observed environmental impacts of inshore sites, there is no real data to support this at present. The greater distance from shore, sea depth and fast currents associate with offshore sites can work to minimise pollution, disease occurrence, and area use conflicts.[97]

3.49 Since offshore sites tend to be less susceptible to nutrient enrichment due to increased water flow and depth, offshore locations should sustainably support a higher density of production than sheltered nearshore locations, particularly if conservative stocking densities are used. However, there is considerable uncertainty regarding pollutants in an open ocean environment.[98]

[97] Froelich, H.E. et al (2017) Offshore Aquaculture: I Know It When I See It, Front. Mar. Sci., 22 May 2017 | https://doi.org/10.3389/fmars.2017.00154

[98] Gentry, R.R. et al (2016) Offshore Aquaculture: Spatial planning principles for sustainable development. Ecology and Evolution Volume 7, Issue 2 p. 733-743

4 FLOATING OFFSHORE WIND

INTRODUCTION

4.1 This section examines floating offshore wind energy in Scotland and the projected activity in this emerging renewable energy industry. It reflects its relatively nascent status, albeit one that has made very good progress in recent years, offering as it does a very valuable and potentially transformative opportunity for energy and for Scotland.

4.2 Winds are stronger and more consistent further out to sea and almost 80% of the world's offshore wind potential is in these deeper waters, in excess of 60m. However, much offshore wind development to date has been in shallower inshore waters, using bottom-fixed turbines. Fixed-bed turbines are best suited to waters less than 60m deep. Deeper waters present significantly greater engineering challenges, and therefore costs. However, there are potentially fewer constraints in deeper waters beyond territorial boundaries – for example due to fewer competing environmental, commercial, and heritage interests, or reduced noise and visual impacts.[99] Removing water depth constraints by deploying floating wind farms substantially increases the ability to harness more of the available offshore wind power.

INDUSTRY STRUCTURE AND TRENDS

4.3 Scotland is a centre for offshore wind generation with 14 offshore wind farms around the coastline, 12 of which consist of fixed-bottom turbines. There is clear alignment between existing expertise and knowledge in oil and gas technology and the needs of FOW which is a strength that must be capitalised on both in terms of industry knowledge, and the skills and knowledge of the workforce. More widely, there is a strong and developing ecosystem for FOW for example the Offshore Renewable Energy Coalition (OREC)[100], the Deep Wind Supply Chain Cluster, the offshore wind representative body which has over 630 members[101] and the Carbon Trust's Floating Wind Joint Industry Project[102] which is a collaborative initiative focusing R&D to address challenges and explore opportunities for the deployment of large-scale commercial floating wind farms.

4.4 Added to this, the ORE Catapult is aiming to establish a Floating Offshore Wind Centre of Excellence (FOW CoE) as an internationally recognised initiative to reduce the cost of energy from floating wind. Its aim is to accelerate the build-out of floating farms, create opportunities for the UK supply chain, and drive innovations in manufacturing, installation, and O&M.

4.5 Offshore wind is uniquely placed to tackle both climate change and deliver transformational economic and social impact across Scotland, enabling a green recovery and being the primary contributor in achieving Scottish Government's net zero and energy transition targets. Offshore wind has the potential to create high value jobs, a significant proportion which are likely to be in remote, rural/coastal communities. The recent ScotWind leasing round, which saw 74 bids across all 15 areas of seabed available for development[103], is likely to see the world's first large scale (≤500MW) floating projects. Most projects put forward are in deeper waters and floating solutions are very well suited to these locations. Global competition is strong and concerted collaborative effort is needed to give supply chain confidence to invest in high value opportunities.

[99] Scottish Government/Marine Scotland (2018) Sectoral Marine Plan for Offshore Wind Encompassing Deep Water Options | Strategic Environmental Assessment Screening and Scoping Report, June 2018

[100] http://www.oceanrenewable.com/about-orec/

[101] https://www.offshorewindscotland.org.uk/deepwind-cluster/

[102] https://www.carbontrust.com/our-projects/floating-wind-joint-industry-project

[103] https://www.crownestatescotland.com/news/scotwind-secures-major-interest-in-scotlands-offshore-wind-potential

4.6 The Innovation and Targeted Oil and Gas (INTOG) leasing round allows developers to apply for the rights to build offshore wind farms to provide low carbon electricity to power oil and gas installations and help to decarbonise the sector. Given the location of oil and gas installations, floating offshore wind will be key so INTOG is an important opportunity to further develop FOW in Scotland. INTOG also aims to enable small scale (less than 100MW) innovation projects, including alternative outputs such as hydrogen.

4.7 There is, however, a growing focus on floating turbines and there are now two in Scottish waters - Hywind Scotland pilot, and Kincardine Offshore Wind Farm (manufactured in Spain and currently under construction off the coast of Aberdeen). The FOW industry is characterised by a mixture of large players and smaller, fleeter developers, in some cases with proprietary technology they are building into projects. Every development, installation and operation involves a wide range of specialist partners contractors, illustrating the value and extent of the international supply chain.

4.8 Demonstrating Scotland's leading position, Equinor's Hywind Scotland pilot park is the world's first floating offshore wind farm with the first turbine being installed in 2009. Lying 25km off the east coast of Scotland near Peterhead, it comprises five 6MW turbines covering approximately 4km^2 and has been producing energy since October 2017. The water depth is between 95m and 129m with an average wind speed of around 10m per second.

4.9 Data gathered through Hywind is being harvested and shared across the industry to help understanding of how the technology can be optimised and to identify areas where efficiencies can be made. It has already achieved substantial cost reductions compared with the sister project – Hywind Demo in Norway. Equinor is currently building what will be the largest FOW Farm in the world, Hywind Tampen. It will be located in the Norwegian North Sea, approximately 140km off the coast in water that is near depths of 260-300m, representing a move to deeper and more remote waters. It will be used to power oil and gas platforms with installation due for completion in 2022.

4.10 The Kincardine Floating Offshore Wind Farm is in the final stages of installation and will be the world's biggest FOW farm (at the time of commissioning). Developed by Kincardine Offshore Wind (KOW) it is expected to reach full capacity in 2021 (previously estimated to be 2020) and will generate enough electricity to power around 55,000 households in Scotland. It is located approximately 15km off the south east coast of Kincardineshire in water depths of 80m to 90m. It is spread over 110km^2 and the turbines have the greatest capacity of any floating turbines currently in use (9.5MW each).

4.11 The next generation of wind turbines are being designed to float further out to sea and the industry expects this to be an increasingly efficient way to generate electricity in the high-wind environment further offshore. The reduced competition in terms of environmental or commercial interests and lower scope for conflict between marine uses means that there is considerable opportunity to service a higher proportion of the UK's future decarbonised electricity requirements.

4.12 Many of the potential markets for FOW lie in countries with limited shallow-water sites making fixed-bed turbine unsuitable. Examples include USA and Japan, large population centres with significant energy demand. FOW technology has enormous potential in these markets and developing the technologies and manufacturing capacity offers a huge export opportunity for Scotland and the UK.

4.13 FOW may also, in the longer term be a lower-cost alternative to bottom-fixed foundations, given the potential for standardisation of foundation designs and the use of low-cost, readily available installation vessels. FOW means less lengthy installation as there is no need for large foundations to be built and there are environmental benefits as there is less disruption and invasive activity on the seabed during construction and ongoing operation.

INDUSTRY CONSTRAINTS AND CHALLENGES

4.14 Whilst Scotland has many strengths and assets that make it ideally placed for FOW, there are a number of challenges that could inhibit FOW development and deployment in Scotland. It is important that these are recognised by all stakeholder and that steps are taken to address them.

Port Infrastructure

4.15 Limited availability of suitable port infrastructure in Scotland is a risk to the industry and the value chain. There are currently only a small number of ports in Scotland with the required depths and quay lengths for turbine. This is compounded by limited quayside areas and adjacent sites for laydown space capable of heavy load bearing. Some recent developments have begun to address this issue for example the South and East Quay developments at Nigg Energy Park at the Port of Cromarty Firth. This is the largest port in the Highlands and Islands and one of the deepest, most sheltered in the country. It is a leading hub for offshore renewable energy projects and is Scotland's busiest cruise port. The most recent infrastructure expansion at the port provides a 218m quayside and nine acres of adjacent laydown area. It is close to renewable energy developments and so is well placed for the next round of Scottish offshore wind projects (ScotWind).

4.16 There are a growing number of other deep water port developments currently taking place in the Highlands and Islands that may be suitable to service offshore aquaculture and FOW when they come online: this includes Kishorn and Stornoway's deep water port development, Phase 4 of development at Invergordon, Dales Voe ultra deep-water quay, Ardersier and the Scapa Deep project in Orkney.

4.17 Despite these examples, current and future needs from the range of potential users and uses will not be adequately met by existing port infrastructure. An additional consideration is the marine interface at the ports and the extent to which they can accommodate the size and shape of loads for FOW and other sectors. An example of the impact is that sub-structures are being be built in other countries and towed directly to the site, bypassing Scotland. This is the case with the Kincardine Offshore Floating Wind Farm for which manufacturing took place in Spain, assembly was carried out in Holland and was then transported directly to the wind farm site for installation. This is a notably unsustainable solution put demonstrates the challenge.

4.18 The evidence clearly shows that additional port upgrades and supporting infrastructure will be required to support scaling up of FOW in Scotland and retain key value add activities such as manufacture and component assembly, for example as set out in the Scottish Offshore Wind Energy Council's Strategic Infrastructure Assessment report published in August 2021.[104] The report details requirements across fabrication, assembly, component manufacturing and maintenance. HIE and partners are aware of the need to invest in and develop ports and harbours to meet the needs of a range of sectors and activities such as oil and gas decommissioning, larger ships in cruise tourism, and marine energy. Demonstrating this, since 2010, a total of £270.8m has been invested in port infrastructure in the Highlands and Islands by HIE, other public sector funding and private finance. There is also an on-going programme of planned investment in ports and harbours in the Highlands and Islands and it is important these take in to account the requirements of FOW and bottom-fixed wind farms. These developments should be future proofed as far as possible, as the technology is developing in terms of blade size and design, sub-structures, and anticipated developments to achieve efficiencies in installation and maintenance.[105] However, through consultations it was highlighted that for spar designs there are limited places (if any) in Scotland that could accommodate these with current designs and assembly methodologies. That said, there is awareness amongst developers who understand that they need to modify their designs or choose designs at concept select stage that can be accommodated at the ports within the country where the project will be built from. For Scotland this means shallower draft designs. Furthermore, to boost local content, many developers are opting for 'industrialised' designs

[104] https://www.offshorewindscotland.org.uk/media/1573/strategic-investment-assessment-report-august-2021.pdf

[105] https://prod-drupal-files.storage.googleapis.com/documents/resource/public/FWJIP_Phase_2_Summary_Report_0.pdf

where consideration is given to in-country manufacturing capability. The advantage for technology providers and project developers is that they can modify their approach to meet local content requirements wherever they go in the world. The upside for Scotland is that floating offers genuine opportunity for high levels of local content.

4.19 Investment in port upgrades will be substantial and should be de-risked as much as possible – through a visible project pipeline, public sector support, and by meeting the needs of multi-sectors, for example, other renewable energy industries, oil and gas decommissioning and in the context of this study, aquaculture and FOW.

Grid connections and energy transmission

4.20 The existing grid and network infrastructure can make it challenging to move the power from where it is generated to where it is consumed. Grid upgrades would be costly but if Scotland is to realise the value of FOW, this is essential. There is, of course, potential for off-grid applications for FOW and offshore wind in general but if it is to maximise its impact and its contribution to net zero, then the grid infrastructure constraints will need to be overcome.

4.21 Energy transmission is also a challenge. The practicalities of getting energy off-site by electric cables for at least some potential sites is not viable, purely from a distance point of view. For example, in Shetland, one site in the ScotWind licensing round approximately 12 miles to the East of Shetland on the 100m contour has the capacity to develop a FOW generation site in the region of 2-3 GW. Whilst getting energy off-site by electric cables is not currently feasible due to the size and cost of cables required, there is ongoing work exploring the potential for export Liquid Organic Hydrogen Carrier (LOHC) vessels.[106] Additionally, the ORION Clean Energy Project[107] in Shetland is exploring opportunities for the decarbonisation of Oil and Gas extraction, as well as green hydrogen production and export. Green hydrogen offers one potential solution for energy capture, storage, and transportation, negating the need for significant expenditure on an export cable, and associated grid upgrade. That said, hydrogen capture and storage is still very much a nascent sector.

Finance, de-risking and risk management

4.22 Scotland's early FOW projects benefited from the Renewable Obligation Scotland Order[108] (ROSO) which was a subsidy mechanism for renewable energy generation capacity and helped to de-risk it. It closed to new entrants in 2017 and the Contracts for Difference (CfD) scheme is now the UK Government's main mechanism for supporting low-carbon electricity generation.

4.23 The discontinuation of ROSO is felt to have been detrimental to the prospect for and of future projects in Scotland and a threat to our global competitive advantage. CfD auctions work to bring prices down by reducing revenue risk allowing project developers to proceed with a capital-intensive project with a long-term, low-risk return. FOW is in its early stages of development and the CfD mechanism currently favours the more mature and affordable types of energy production and so works against a number of emerging technologies such as FOW. However, it is worth noting that fixed bottom wind demonstrated a significant cost reduction trajectory, particularly over the last five years, and is expected to realise further cost reductions.[109,110] With the right support regime it is anticipated that FOW can also follow a similar cost reduction pathway.

[106] https://www.maritime-executive.com/article/liquid-organic-hydrogen-could-facilitate-hydrogen-as-propulsion-fuel

[107] https://www.orioncleanenergy.com/

[108] https://www.gov.scot/policies/renewable-and-low-carbon-energy/renewables-obligation/

[109] Wiser, R. et al. (2021) Expert elicitation survey predicts 37% to 49% declines in wind energy costs by 2050, Nature Energy 6(5), pp.555–565

[110] https://ore.catapult.org.uk/wp-content/uploads/2021/01/FOW-Cost-Reduction-Pathways-to-Subsidy-Free-report-.pdf

4.24 The government wants to bring forward 1GW of floating wind by 2030 but to date it has been strict on conditions for floating CfDs[111]. FOW may be required to meet tougher standards than the bottom-fixed wind industry in order to win a CfD. And in the upcoming CfD auction scheduled for December 2021[112], fixed offshore wind will have a dedicated subsidy 'pot' whilst FOW will have access to 'pot 2' which is for less established technologies.

4.25 There is also a view that CfD is more aligned to suit generation in larger population centre densities and so arguably is less beneficial to energy generation located in Scotland. All of this contributes to the drivers to push down FOW costs. This challenge has been compounded by competition from bottom-fixed offshore wind which is more established and is currently cheaper.

4.26 Whilst costs are reducing and efficiencies are being realised, as a less established technology FOW will require more demonstration projects and development to help with cost reductions. More investment and capacity is needed to help prove its feasibility and to share the risk across a wider range of stakeholders.

4.27 Risk is a major challenge for FOW. In offshore wind generally, contracting of work packages typically sees main (Tier 1) contractors taking on larger work packages with second or third level sub-contractors handling smaller packages. Main contractors often push risk down the supply chain – that is, the larger companies offset the risk by putting sub-contractors in a position to assume this liability. However, appetite for risk is typically lower further down the supply chain, and acts as a barrier to new sector entrants, in turn stifling competitiveness. For example, it is understood that supply chain companies traditionally involved in Oil and Gas would like to get involved in FOW, but don't want to take on the scale of risk involved, since the liability is being pushed down to Scottish supply chain companies rather than being assumed by the larger developers.

DEVELOPMENT OF FLOATING OFFSHORE WIND IN SCOTLAND

4.28 The evidence clearly shows that Scotland is amongst the world leaders in FOW, and it is vital that we retain our first mover advantage so that the opportunities are capitalised on for the industry and the supply chain. There is a global market for FOW technologies, equipment, knowledge and skills and Scotland is currently very well placed to achieve significant market share. Generating export earnings from expertise in areas such as subsea engineering, environmental planning, consenting and project management will support international development and boost Scotland's economy.

4.29 It is broadly accepted that FOW presents a huge economic opportunity for the countries and businesses that position themselves correctly. Crown Estate Scotland's Macroeconomic Benefits of Floating Offshore Wind report[113] suggests that the UK floating offshore wind market has potential to support 17,000 jobs and £33.6 billion of Gross Value Added (GVA), with particular potential for deployment in Scotland's 462,000 km^2 of waters, much of which are more than 60m in depth. Globally, the market is set to grow to at least 4 GW of capacity by 2030 and 55 GW by 2050, offering an export opportunity to Scotland's supply chain which is estimated at around £550 million per annum by 2050. The expertise gained in the oil and gas sector means Scotland is well placed to capitalise on this opportunity as we transition to a net zero economy.

4.30 The economic benefits of this technology will arise from achieving and retaining early mover advantage. This means that the Scottish supply chain must be prepared, with the capability and capacity required to deliver floating offshore wind at commercial scale. This links to the need for a visible and credible development and deployment pipeline.

[111] https://www.newpower.info/2021/01/floating-wind-faces-tough-cfd-hurdle-is-uk-ambition-high-enough/

[112] https://www.gov.uk/government/collections/contracts-for-difference-cfd-allocation-round-4

[113] https://ore.catapult.org.uk/?industryreports=macroeconomic-benefits-of-floating-offshore-wind-in-the-uk

4.31 The Oil and Gas UK's Roadmap 2035[114] is aimed at decarbonising offshore production of oil and gas in the UK sector and so is an opportunity to grow FOW capacity and develop the supply chain to build and service it. Recognising and in response to the net zero agenda, some of the large carbon energy producers are beginning to pivot their resources to develop capabilities in renewables including fixed-bed and FOW. In the transition to clean energy there will still be a need for oil and gas and so these companies are also examining ways of developing remaining reserves as cleanly as possible, for example powering them using renewable energy. The Scottish Government has stated that some fields can only be developed if extraction operations are net zero.

4.32 To stay at the forefront of FOW developments and to drive cost reductions in deployments, the Scottish Government supports the Floating Wind Joint Industry Project (FWJIP), a collaborative R&D initiative between the Carbon Trust and 15 international offshore wind developers. Its aim is to investigate the challenges and opportunities of developing commercial-scale floating wind farms and ultimately reach cost parity with other low carbon energy sources. It does this by running innovation competitions to support the development of viable technologies with the potential to meet some of these needs. As an example, the Scottish Government provided £1m towards the Floating Wind Technology Acceleration Competition which was a competition to overcome key commercial barriers facing floating wind. As a further demonstration of the widespread interest in this field, the DeepWind Cluster[115] is a Scottish offshore wind representative body specialising in fixed and FOW in deeper waters. With almost 600 members representing industry, academia, and the public sector its aim is to support members, and so Scotland, to benefit from the opportunities in fixed-bed and FOW in the UK and internationally.

4.33 There is a strong body of opinion that FOW should be further and specifically supported by the Scottish and UK Governments and relevant agencies to grow rapidly. This should include provision of early support for technology, innovations, deployment, testing and implementation. This is proposed as a separate technology fund, specifically for FOW targeted at driving long term cost reduction so that we can generate renewable energy for domestic use but also for exporting products, services and innovations and expertise.

4.34 FOW development in Scotland must be strategic, collaborative and have a long term, shared vision. To stimulate and encourage the supply chain in the UK, there must be visibility of the future project pipeline, so opportunities and high added value is captured in the UK. Project visibility will assist the supply chain to invest in new facilities to support the construction and maintenance of FOW and de-risk investment. It will also stimulate research and development activities as well as the skills system to ensure the skills are available and talent is developed. The impact of there being high visibility of a future project pipeline cannot be understated.

[114] https://oilandgasuk.co.uk/roadmap-2035/

[115] https://www.offshorewindscotland.org.uk/deepwind-cluster/

5 POLICY AND REGULATION

INTRODUCTION

5.1 Aquaculture and offshore renewables both have separate policy and regulatory frameworks. Whilst there is some overlap between the two, there is also some clear distinction. This section examines the current policy and regulatory landscape in Scotland with regard to aquaculture and floating offshore wind. It also provides an overview of some regulatory considerations for co-located development.

CURRENT POLICY AND REGULATORY LANDSCAPE IN SCOTLAND

5.2 The broader policy context for aquaculture and FOW development is one of transition to a net zero carbon economy, and recovery from the COVID-19 pandemic. *Protecting Scotland, Renewing Scotland: The Government's Programme for Scotland 2020-2021* sets out the commitment to develop a Blue Economy Action Plan which will comprise a programme of collaborative projects across the public sector, science, marine industries, and the marine environmental sector. It also stated the Scottish Governments objective of ensuring the economic recovery from the socio-economic shock of COVID-19 must be a green recovery to meet the statutory commitment to be a net zero society by 2045.[116] Additionally, the update to Scotland's 2018-2032 Climate Change Plan[117] sets out the Scottish Government's pathway to achieving the ambitious targets set by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019.

5.3 Within this broad direction of travel towards net zero and increased sustainability, there are a range of policy and legislative requirements that must be satisfied by developments in either, or both, aquaculture and FOW. These are set out below.

Aquaculture

5.4 The principal challenge to aquaculture development is whether potential sites are logistically and operationally feasible to support growth of finfish, shellfish, or seaweed. If a suitable location is found, then the planning and consenting process can often be slow, expensive and complex to navigate. The outcomes are dependent on decisions by local Councils, and are often difficult to predict as they take into account a wide range of factors. This is particularly difficult and off-putting for small producers and is a deterrent to market entry.

5.5 Competition for space with other sectors and development within Marine Protected Areas (MPAs)[118] can also be obstacles to achieving consent.

5.6 The planning system in Scotland comprises a highly complex set of legislation, guidance and advice that cascades from the Scottish Government down to the statutory planning authorities. At the Scottish Government level, the National Planning Framework 3[119] sets out the statutory strategy for Scotland's long-term spatial development. The Scottish Planning Policy sets out policy on nationally important land use and requires the planning system to support sustainable growth in finfish and shellfish sectors, as well as committing to maintaining the presumption against further marine finfish farm development on the north and east coasts of Scotland. Scotland's National Marine Plan[120] sets out objectives and marine planning policies for aquaculture, including requirement for regional marine plans to consider potential for sustainable growth of aquaculture in their region. The Scottish Government's

[116] https://www.gov.scot/publications/protecting-scotland-renewing-scotland-governments-programme-scotland-2020-2021/

[117] https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/3/

[118] https://www.gov.scot/policies/marine-environment/marine-protected-areas/

[119] Scottish Government, NPF 3, June 2014

[120] Adopted in March 2015.

Seaweed Cultivation Policy Statement covers policies for seaweed cultivation either grown on its own or as part of an Integrated Multi-Trophic Aquaculture (IMTA) system.

5.7 Required consents, licences and assessment for fish, shellfish and seaweed aquaculture developments are summarised in Table 5.1. It should be noted that there are seaward limits for the terrestrial planning legislation. Terrestrial planning authorities (strategic and local planning authorities and national park authorities) are responsible for all terrestrial planning matters down to Mean Low Water Springs and for marine fish farming (finfish and shellfish) where planning consent is required out to 12 nautical miles. In the intertidal zone, between low- and high-water springs, terrestrial planning authority overlaps with Marine Scotland's responsibilities for the marine area. Meanwhile, marine planning within Scottish marine planning regions extends from Mean High Water Springs out to 12 nautical miles. Between 12 nautical miles and 200 nautical miles is the UK marine area.

Table 5.1: Required consents, licences and assessments for fish & shellfish aquaculture and seaweed cultivation developments[121]

Application	Authorising regulator	Legislation	Fish	Shellfish	Seaweed
Planning Permission	Local Authority	Town and Country Planning (Scotland) Act 1997	✓	✓	
Environmental Impact Assessment (if necessary)	Local Authority	The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011	✓	✓	
Marine Licence	Marine Scotland Licensing Operations Team	Marine Scotland Act 2010	✓	✓	✓
Seabed Lease	Crown Estate Scotland	The Crown Estate Act 1961	✓	✓	✓
Authorisation to operate an Aquaculture Production Business	Marine Scotland Science Fish Health Inspectorate	The Aquatic Animal Health (Scotland) Regulations 2009	✓	✓	
Controlled Activity Regulations (CAR) licence	Scottish Environment Protection Agency	The Water Environment (Controlled Activities) (Scotland) Regulations 2011	✓		
Habitats Regulations Appraisal (if necessary)	All of the above	The Conservation (Natural Habitats, &c.) Regulations 1994 and its amendments	✓	✓	✓
Works Licence	Marine Scotland MMO	The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 The Marine Works (Environmental Impact Assessment) (Amendment) Regulations 2017	✓	✓	✓

5.8 Growth in the salmon sector will require robust evidence to demonstrate that the scale of future developments will not significantly impact, disturb, or degrade the marine environment. Whilst it is anticipated that offshore production will serve to mitigate the impacts observed at inshore sites, this will still need to be demonstrated through deploy and monitor approaches.

Floating offshore wind

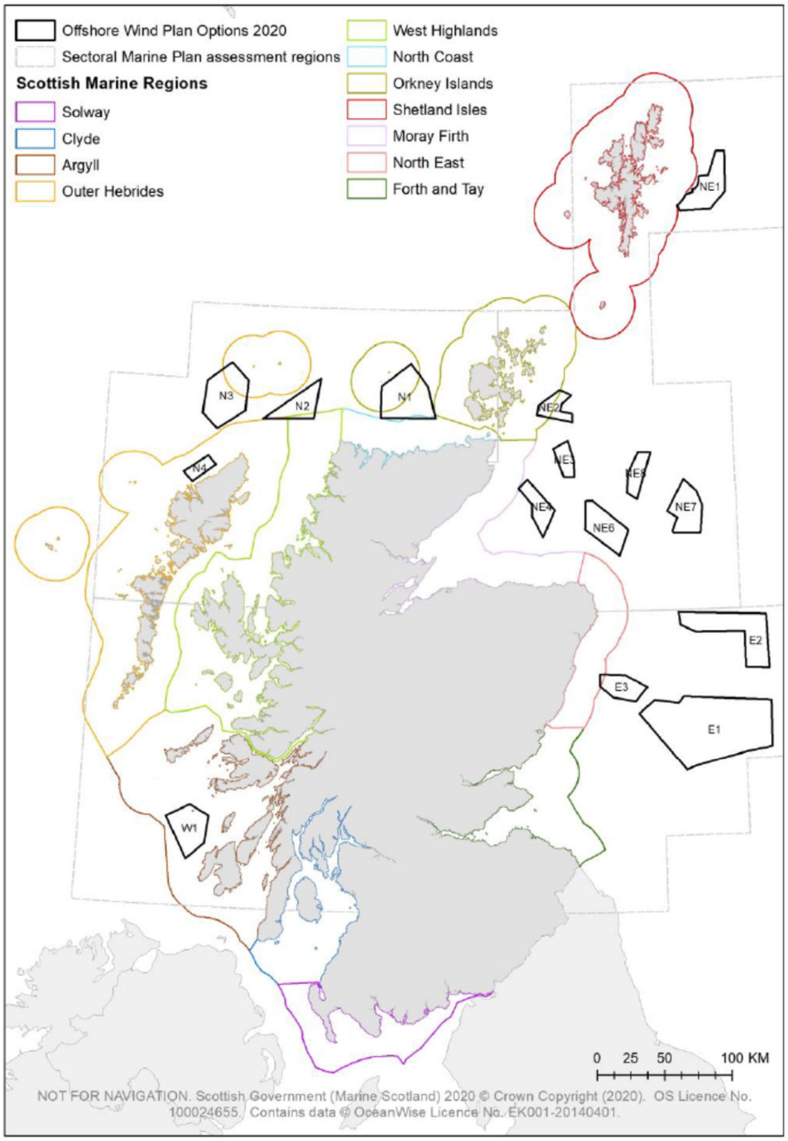
5.9 A set of regulations govern the development of offshore renewable energy developments. The National Planning Framework identifies the importance of Scotland's marine space in contributing to

[121] Adapted from: Nimmo, F, McLaren, K, Miller, J and Cappell, R. (2016). Independent Review of the Consenting Regime for Scottish Aquaculture.

achieving the transition to a low carbon economy. Scotland's National Marine Plan[122] sets out objectives and marine planning policies for the development of test/demonstrator and commercial scale offshore wind and marine renewable energy developments.

5.10 In addition to the National Marine Plan, the 2020 Sectoral Plan for Offshore Wind Energy[123] sets out the options for future development of commercial-scale offshore wind energy in Scotland, including deep water wind technologies. It covers both Scottish inshore and offshore waters. The Sectoral Plan also contains provision for future rounds of ScotWind that may target the decarbonisation of the oil and gas sector in Scotland. Figure 5.1 sets out the zone options for leasing in the current ScotWind round.

Figure 5.1: Offshore wind plan options for ScotWind leasing round



Source: Scottish Government (2020) Sectoral Plan for Offshore Wind Energy

5.11 Table 5.2 summarises the consents, licences and assessments required for the development of marine renewable energy installations, including FOW.

[122] Adopted in March 2015.

[123] https://www.gov.scot/publications/sectoral-marine-plan-offshore-wind-energy/

Table 5.2: Required consents, licences, and assessments for marine renewable development

Application	Authorising regulator	Legislation
Planning Permission	Local Authority	Town and Country Planning (Scotland) Act 1997 (under 50 MW only)
Electricity Generation (construction)	Scottish Ministers	Electricity Act 1989
Environmental Impact Assessment	Marine Scotland	The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, and their amendments
Marine Licence	Marine Scotland Licensing Operations Team	Marine Scotland Act 2010
Seabed Lease	Crown Estate Scotland	The Crown Estate Act 1961
Habitats Regulations Appraisal (if necessary)	All of the above	The Conservation (Natural Habitats, &c.) Regulations 1994 and its amendments
Works Licence	Marine Scotland MMO	The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017 The Marine Works (Environmental Impact Assessment) (Amendment) Regulations 2017

CO-LOCATED DEVELOPMENT

5.12 Though the scope of this research considers synergies across the breadth of development for offshore aquaculture and FOW, specific consideration needs to be given to the regulatory impact of co-located or integrated developments. This is defined as the two industries operating side by side or in integrated sites. For example, General Policy 4 (GEN4 Co-existence) [124] of the National Marine Plan sets out the presumption that:

> *"Proposals which enable coexistence with other development sectors and activities within the Scottish marine area are encouraged in planning and decision-making processes, when consistent with policies and objectives of [the] Plan."*

5.13 The National Marine Plan states that the principle of co-existence "applies to a wide range of scenarios, including using existing infrastructure as a basis for a new activity, or taking advantage of opportunities now and in the future as technology advances, or for inshore activities to locate further offshore in tandem with other industries." However, this does not necessarily mean that co-located or integrated development is encouraged, nor does it preclude the requirement for sustainability appraisals or environmental impact assessments. Furthermore, consideration should be given to cumulative impacts on the environment, and on the range of other potential users, and other marine users who could be indirectly impacted.[125]

5.14 The role of local planning authorities currently only extends to 3 nautical miles. It is understood that between 3 and 12 nautical miles from shore, a co-located development of aquaculture and FOW would need to satisfy both sets of regulatory requirements, i.e. for both aquaculture and FOW – so would require two separate environmental impact assessments, for example, as well as being cognisant of environmental designations such as Marine Protected Areas (MPAs). Outside of the 12 nautical mile limit, only one set of consenting, licensing and assessment would be required (under Section 36 of the Electricity Act 1989, Marine Scotland Act 2010, and The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (and amendments). However, it was identified through consultation that some inconsistencies and ambiguity exist in the regulations that apply to both aquaculture and FOW in terms of the jurisdictions that apply at various nautical distance limits, which may add to the complexities of consenting, licensing, and assessment requirements.

[124] Scottish Government/Marine Scotland (2015) Scotland's National Marine Plan: A Single Framework for Managing Our Seas, p.17

[125] Ibid.

6 INNOVATION DRIVERS

6.1 In Aquaculture and FOW, innovation is key to addressing challenges and constraints to growth, developing technologies, processes, and products, achieving efficiencies, and ensuring competitive advantage. This chapter describes the drivers for research and innovation for each of these.

AQUACULTURE: INNOVATION DRIVERS

6.2 Key aspirations of the industry in Scotland are to retain the reputation for premium products with high welfare and environmental standards and go through transformational growth in volume beyond what current barriers allow but which are within the natural capacity of the oceans.[126] Despite the production growth evident in Scotland, the industry is unable to fully meet domestic or global demand. Given the challenges associated with production volumes and significant growth demands, there is a risk of Scotland losing status as a significant supplier versus competition from Norway or Chile for example.

6.3 The most pressing challenge facing salmon farming is that of improving fish health and environmental sustainability. The Sustainable Aquaculture Innovation Centre (SAIC) funds Scottish research activities, catalysing and co-funding innovation across three priority innovation areas: finfish health and welfare; unlocking sector capacity and shellfish and other non-finfish species[127]. This is in addition to research being conducted by salmon producers in Scotland and overseas. As Scottish salmon is a premium product with global appeal, management of disease (both within sea farms and potential transmission to wild fish) and biosecurity, livestock welfare and environmental stewardship are critical. However, managing biological threats with chemicals damages the environment and undermines social licence, and adds to production costs, while reputational harm is caused by perceived risks of adverse environmental impacts. The use of wrasse as cleaner fish and physical as distinct from chemical treatments have long been the focus of research for SAIC (e.g. a recently completed project looked at the potential to scale up the production of Ballan wrasse for deployment at production sites).[128] Current SAIC projects in fish health welfare[129] include the development of a real-time plankton and algae monitoring system, research into spatial and temporal drivers of gill pathology and research into ultrasound-based technology for salmon delousing.

6.4 There is also a recognition that new production and business models must be developed, given the constraints in and limited availability of inshore and near-shore sites.[130] In response to the lack of inshore sites, the sector is increasingly looking to more exposed locations further offshore. This is a result of the competition for space, frequent negative public perception, and quality of (and impact on) the inshore marine environment. Onshore recirculation aquaculture systems (RAS) and floating closed system aquaculture (CSA) are alternative options. However, the technology is still at a very early stage and the high cost of plant and equipment and a lack of proven commercial viability together impacts on the adoption of RAS as a mainstream means of aquaculture production.[131] Whilst increased use of RAS in the earlier stages of growth is being adopted by different companies (salmon smolt production and marine species hatcheries e.g. halibut production[132]), major RAS investments look to be closer to key markets (i.e. centres of population) to offset higher production costs.

[126] Aquaculture Innovation Centre (2017) Scottish aquaculture: a view towards 2030

[127] https://www.sustainableaquaculture.com/projects/

[128] https://www.sustainableaquaculture.com/projects/finfish-health-welfare/details/scaling-up-the-use-of-cleaner-fish/

[129] https://www.sustainableaquaculture.com/projects/finfish-health-welfare/

[130] Food and Drink Scotland (2016) Aquaculture Growth to 2030: A strategic plan for farming Scotland's seas

[131] It is worth noting that the very large RAS projects being delivered in USA, China, etc. have attracted major investment from financial institutions and venture capitalists

[132] https://www.gighahalibut.co.uk/tag/otter-ferry-seafish/

6.5 Offshore aquaculture has the potential to enhance the sustainability, productivity, and expansion of the sector. Offshore locations provide more space and the environment to accommodate larger production facilities, along with the potential to improve farmed fish health and welfare. Fish farms' separation could be greater, and the deeper waters and stronger currents disperse organisms, contaminants, dissolved and particulate wastes more quickly.[133,134]

6.6 Previous research has identified that potential areas of innovation to exploit offshore aquaculture opportunities could include more robust versions of inshore technologies and development of novel systems that can be submerged to reduce the impact of wind/waves of offshore areas. Advancements in aquaculture technology could allow for utilisation of greater sea depths for production, increased use of autonomous systems, and development of free-floating/propelled offshore installations. Successful development of technology to exploit offshore opportunities could enable relatively small areas to be utilised to substantially increase overall production.[135]

FLOATING OFFSHORE WIND: INNOVATION DRIVERS

6.7 The desk research and consultations clearly identified that the over-riding driver for innovation and development is reducing costs to make FOW viable and competitive with other types of renewable energy. This will require substantial investment and co-operation within industry and with the public sector, research organisations and academics.

6.8 The ORE Catapult produced a report[136] examining cost reduction pathways for floating offshore wind which states that rapid deployment of FOW in the UK will be key to reducing costs and maximising GVA. Recognising the importance of reducing costs, the ORE Catapult established the Floating Offshore Wind Centre of Excellence[137] (FOW CoE). The CoE is a collaborative programme with industry, academic and stakeholder partners and is tasked with developing an initiative to reduce the cost of energy from floating wind, accelerate the expansion of FOW farms, create opportunities for the UK supply chain, and drive innovations in manufacturing, installation and operations and maintenance.

6.9 The areas where the most substantial impacts can be made in terms of reducing costs and so are a focus of research and innovation are:

- Sub-structure manufacture
- Mooring line design and installation
- Array cables
- Minor repairs and preventative maintenance
- Development costs
- Targeted port investment

6.10 To date, FOW substructures have tended to be bespoke with a variety of designs being deployed and tested. By better understanding what works and adopting a more streamlined approach to design, the industry will achieve efficiencies and cost reductions. Added to this, advances in manufacture and assembly facilities and processes, including advanced manufacturing and robotic welding could also have a significant impact on costs.

[133] https://gtr.ukri.org/projects?ref=BB%2FS004246%2F1

[134] SAIC/Houston, S. (2019) Blueprint for aquaculture in Scotland, Food Science and Technology, 33(3), pp.58-61; at: https://doi.org/10.1002/fsat.3303_15.x

[135] Kapetsky, M.J. et al., (2013) A Global Assessment of Offshore Mariculture Potential from a Spatial Perspective

[136] FOW-Cost-Reduction-Pathways-to-Subsidy-Free-report-.pdf (catapult.org.uk)

[137] https://ore.catapult.org.uk/what-we-do/innovation/fowcoe/

6.11 Improvements in the design of mooring lines and installation, along with standardisation of components, use of novel materials (such as synthetic rope) and optimisation of array layouts all have the potential to reduce costs. More integrated design of the interface between anchors, mooring system and substructure would deliver additional benefits, speed up installation and make major repair operations more cost effective.

6.12 FOW is expected to benefit from similar innovations as bottom-fixed farms in terms of minor repairs and preventative maintenance for example through drones, increased automation, and under water autonomous vehicles (UAVs). These technologies are potentially particularly valuable to FOW given that the farms tend to be in less accessible environments and a greater distance from shore.

6.13 There is also a need for adaptions to be made to positioning systems for crew transport vehicles (CTVs), service operations vessels (SOVs) and helicopters to take account of the motion of floating wind turbines.

6.14 There is scope for the costs of front-end engineering design to rapidly decrease as development models are improved and design processes are streamlined and standardised. Examples provided by the ORE Catapult include development costs, such as stakeholder engagement, surveying, and the consent process. These have high fixed costs which, through economies of scale, will reduce with more and larger projects.

6.15 Another area where innovation could reduce costs is in the design of cable connection systems aimed at reducing the time required to connect and disconnect cables. Cable design can also be improved to withstand the different loadings dynamic cables are under in site conditions at FOW sites. Innovation is also required to develop higher voltage array cables to enable FOW farms to use higher rated turbines and increase the number of turbines attached to array strings, which ultimately connect to the export cable. This will require innovation in both static and dynamic cable design to take account of the heave, sway, and surge movements.

6.16 A potential solution, or part of the solution to the cable connection issue is the development of the hydrogen economy. In Scotland there is significant research and testing focused on developing hydrogen technology. This is an important strand of activity that will allow the country to harness and maximise the value of our marine energy capabilities, including FOW. The combination of expertise, natural assets and policy support means that Scotland can position itself as a key player in the production and export of green hydrogen.[138] It must be viewed as an enabler for the development of FOW as it provides an alternative, off-grid route to market.

6.17 As discussed in Chapter 4, there is a need to innovate and invest in ports and port infrastructure to better serve the FOW industry, as well as other marine sub-sectors. Investment in ports, adjacent sites, and where necessary transport links, will have a significant impact on costs and efficiencies for FOW as well as bed-fixed and other industries including aquaculture. There is also a drive for innovations in turbine and sub-structure design so that it can be accommodated by the port infrastructure and manufacturing capability in the specific country from which it will be built and deployed. This will mean not only innovations in design and adaptability, but innovations in manufacturing processes to respond to local circumstances and capabilities.

[138] https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/10/offshore-wind-policy-statement/documents/offshore-wind-policy-statement/offshore-wind-policy-statement/govscot%3Adocument/offshore-wind-policy-statement.pdf?forceDownload=true

7 OPPORTUNITIES FOR SYNERGY

INTRODUCTION

7.1 Both the aquaculture and FOW industries have demonstrable opportunities for growth in terms of value, impact, innovation, and development. They have extremely valuable contributions to make to global issues, specifically food security, the growing demand for protein and the climate emergency. They are at different stages, but they are facing many common challenges and constraints to realising their future potential.

7.2 The two industries operate in international marketplaces, they capitalise on Scotland's natural assets and capital in the quality and characteristics of the marine environment. In aquaculture this flows through to premium quality produce that attracts relatively high prices. In the case of Scottish FOW, the value of electricity will be determined by bids into future UK Government auctions for renewables (the Contract for Difference (CfD)) and influenced by its availability and whether it is dispatchable to the national grid.

7.3 It is unlikely that energy generated through Scottish FOW will be considered premium in the marketplace as it is a very different offer to food and drink.

7.4 They both require sustained and substantial investment and there are challenges that must be addressed if Scotland is to remain at the forefront of innovation and sector development across aquaculture and FOW, and not be left behind competitor markets. There is also an opportunity for Scotland to lead the way and innovate in terms of investing in areas of synergy and achieving cross-industry collaboration and strategic planning and investment.

7.5 In this section, we examine the areas of potential synergy identified in the research, considering it in terms of pre-production, operation, and the development of the supply chain. The chapter starts by discussing the benefits of exploiting these opportunities for aquaculture and FOW to work together.

7.6 Both industries are regulated by similar bodies, albeit in quite different structures.

POTENTIAL BENEFITS OF COALESCING THE SYNERGIES

7.7 There are a range of benefits that could be achieved by taking a strategic approach to harnessing areas of potential synergy between aquaculture and FOW.

7.8 Despite the extent of Scotland's coastal waters, there are pressures from the wide range of users and uses, for example marine tourism, sports and leisure, fisheries, marine transport, renewable energy, aquaculture and oil and gas. If Scotland can optimise the use of the marine space sustainably and achieve more by using it innovatively and collaboratively, then the benefits will likely be accrued for all users.

7.9 Linked to this, if the marine space is used more efficiently, and the environmental impact is monitored, managed, and potentially lessened, then there will be a benefit in terms of social licence and support from the range of stakeholders including communities and marine user groups.

7.10 FOW and aquaculture are both facing technical challenges that could inhibit progress. There is a need for innovation, research and development in both industries, particularly as aquaculture seeks to move further offshore. Both industries have already 'borrowed' and built on technologies from other sectors such as oil and gas, and bottom-fixed offshore wind. Chapters 3 and 4 demonstrate that there are common challenges and so likely to be common or at least very similar solutions, for example in moorings and anchorage that can withstand the high energy conditions in offshore waters.

7.11 By sharing some costs to research the challenges and find solutions, and if there is genuine knowledge sharing and collaboration, then there will be efficiencies and benefits for aquaculture and FOW. Solutions may also have wider applications in the blue economy and more widely - therefore distributing the benefits and extending their reach. Collaboration will help to de-risk investment in innovation for individual organisations and shared solutions for example in technology and equipment will mean that the solutions have a bigger potential market, may achieve economies of scale, and so reduce manufacturing costs, and be more attractive to the supply chain.

7.12 With the publication of the Climate Emergency Skills Action Plan[139], and other skills research and planning documents, there is a clear need for the development of 'green skills' across the economy, including in energy and food and drink. In FOW and aquaculture (particularly as it moves further offshore), there are and will be shared skills that will be required in the workforce as well as upskilling or reskilling of people in the existing workforce. Part of this will be driven by the technology and equipment that will be used, and also the need to undertake tasks in higher velocity environments.

7.13 Synergies in equipment and in the types of skills that will be required means that a more strategic approach can be taken within the skills system to ensure that the right skills are available and are transferable. A more strategic approach offers cost-efficiencies and increases attractiveness to training providers. Increased skills transferability is likely to enhance the attractiveness of the aquaculture and FOW sectors and roles within them, potentially helping to attract and retain talent in the areas and regions with aquaculture and FOW industries.

7.14 Investment is required to fund research, testing and deployment and bring costs down across a range of areas, both for FOW to make it competitive, and for aquaculture in more 'expensive' locations. This includes investment in supporting infrastructure such as transport, distribution routes and ports. Collaboration, and a wider application and use across these and potentially more sectors, will help strengthen the business case for this investment.

7.15 Scotland has a global reputation in aquaculture and is at the forefront of FOW innovation and deployment. Achieving and demonstrating synergies across the two, and more widely into other marine sectors, will help create an exemplar of processes, collaboration, and new ways of working to achieve national and industry objectives. This will enhance our already strong reputation in these fields and create an opportunity to export the approach to other countries and related industries. This will deliver economic as well as strategic added value. It will help to attract skills, talent and contribute to an entrepreneurial and solution-focused ecosystem.

7.16 Collaboration and a strategic approach to identifying and tackling growth inhibitors will lend weight through a combined voice to raise and discuss issues with policymakers and work towards solutions. By demonstrating the impacts of addressing barriers to growth across two industries, the incentive to removing them should, logically, be increased.

POTENTIAL SYNERGIES: PRE-PRODUCTION

Innovation and R&D

7.17 As discussed, R&D and innovation is required to expand the deployment and bring down the costs of FOW. R&D and innovation is also necessary if aquaculture is going to be established in more exposed and deeper environments. Given that these are shared issues, there is potential for shared research to address the challenges and develop cost-effective solutions. This would focus on areas such as equipment and on-site infrastructure, development of maintenance and operation processes, application of digital technology and automation, and data collection systems. From an engineering

[139] https://www.skillsdevelopmentscotland.co.uk/media/47336/climate-emergency-skills-action-plan-2020-2025.pdf

point of view, there is significant knowledge and expertise in offshore wind (fixed-bed and FOW) that could have an application in aquaculture.

7.18 Currently research is largely being undertaken in industry silos examining either aquaculture or FOW. There are a small number of exceptions for example Aqua Wind Tower as discussed in Chapter 3 which is considering both FOW and aquaculture although it is currently being driven by an energy company. There is very little evidence of the knowledge being shared in a formal way, although this may be happening informally and at enterprise rather than industry level.

7.19 Regular access to offshore sites for research will potentially benefit aquaculture, FOW and other marine industries. If there is shared access to support vessels, then the window of opportunity for research will be enhanced and research activity could be planned around regular operations and maintenance trips.

Feasibility, surveying, and environmental impact

7.20 Assessing the feasibility and surveying sites is time-consuming and expensive, especially in deeper and exposed waters. Surveying the seabed is required for siting equipment such as moorings and cables, and there is also a need to survey conditions in terms of swell, current, motion and wind. If two operations are to be co-located or sited in adjacent marine spaces, then there are potential synergies and resource efficiencies in undertaking this survey, feasibility, and planning in partnership. There will also be potential efficiencies in undertaking a joint environmental impact assessment for a site and its proposed activities.

Access to finance

7.21 As discussed in Chapter 3, access to finance for innovation, testing and expansion is an issue that has faced aquaculture businesses in Scotland for a number of years. It is perceived to be an inhibitor to growth and prevents some high value activities from being undertaken. FOW also requires finance to drive growth in Scottish waters and access to this can be challenging given that it is an emerging technology with limited routes to market to date.

7.22 The current post-Brexit funding environment is unclear, and whilst there are a range of potential funding sources that could be explored (e.g. through Innovate UK, Levelling Up Fund), some are place-specific, or more aligned to one industry than the other. Marine Scotland, along with counterparts from the other devolved administrations and Defra, are currently making the case for ongoing support for marine sectors, but delays to the launch of the Shared Prosperity Fund mean that there remains uncertainty regarding the extent of public sector support for innovation in aquaculture and marine renewables.

7.23 Demonstrating a collaborative approach to how funding will be used across the two industries may offer a greater return on investment for funders than industry-specific propositions and bids. It could also deliver greater benefits to each sector and the enterprises within them with less spend or financial risk.

Social licence and stakeholder engagement

7.24 Salmon producers in Scotland have increasingly recognised the importance of social license and have been working to achieve it. This experience of what works, and what is less effective could be shared with FOW operators, and other blue economy industries. The process of achieving the necessary licences, permissions and social licence is critical. It can be time-consuming, lengthy and resource intensive. It requires detailed consultation and communication with a range of stakeholder groups including communities and interest groups. If it is not carried out in a planned, sensitive, and careful way, it can cause delays in project realisation, and in the worst case, result in a project not going ahead.

7.25 There are therefore potential synergies in this important area of pre-installation development and the opportunity to demonstrate the value of co-location in offshore sites in terms of the economic and social benefits, as well as benefits in terms of minimising and managing environmental impacts.

7.26 Co-location, further out to sea may help achieve social licence as it is less visible, it will 'de-clutter' marine space and waste from fish farms (if it is finfish) will be more quickly widely dispersed.

POTENTIAL SYNERGIES: OPERATIONS AND SUPPLY CHAIN

7.27 There are a number of synergies between aquaculture and floating offshore wind than can be exploited to benefit both industries.

7.28 FOW and aquaculture operate independently, but there is scope for these two industries to share the same maritime space: either fully integrated (with tanks in sub-structures for example, should they proceed), or co-located and perhaps using some of the same infrastructure such as moorings and anchorage, or side by side with access corridors for operations and maintenance (proximity-location). Full integration is unlikely in the short- to medium-term given the known pipeline of combined activity[140] although the success of the Aqua Wind Tower and similar projects may go some way to demonstrating the technical feasibility of this.

7.29 As an additional point, the installation of small-scale FOW (or indeed fixed-bed) turbines that are off-grid and used to power aquaculture only is another possible synergy. Learning in this regard can be gained from the Albatern collaboration with AquaBioTech[141], and with MOWI[142] to power aquaculture production sites by wave energy. In both projects, as well as providing renewable energy from Albatern's wave converters, they also work to dampen wave energy and provide a degree of protection to the farm.

7.30 From a land-based infrastructure and equipment point of view, there are undoubtedly shared requirements, such as port facilities for operation and maintenance activity. Oil and gas and piled offshore wind maintenance is undertaken in the deepest water locations in inshore waters, such as Dales Voe and Sullom Voe on Shetland. Aquaculture and FOW will require similar port facilities and services. There are a number of other deep-water port developments underway in the Highlands and Islands that, when completed, may be suitable to service offshore aquaculture and FOW: this includes Nigg Energy Park's South and East Quay developments, Kishorn, and Stornoway's deep-water port development. These are well-positioned to provide suitable locations for onshore maintenance. However, the provision of shared facilities onshore needs to reflect space requirements for processing and transportation of aquaculture produce including seaweed (the high-water content means it needs to be processed close to where it is landed as it is not cost-effective to transport it 'wet'). Previous studies have identified a lack of adequate processing facilities as a constraint on growth for aquaculture (and fisheries) produce.[143]

7.31 It is worth noting that the port infrastructure in Scotland and indeed elsewhere in the UK has historically worked against development of the supply chain and allied sectors such as seafood processing. This is compounded by the remoteness from consumers and the short shelf life of seafood, including live produce. As a result, much of the activity is undertaken elsewhere. For offshore wind, necessary marine equipment (turbines, blades, etc.) is typically manufactured in other countries such as Spain and shipped directly to the site – availability of deep-water ports is a crucial factor underpinning this although other factors, such as industry structure, also feature. In the case of seafood processing, much of the produce is transported by land to the central belt and beyond for secondary value-added

[140] https://thefishsite.com/articles/can-aquaculture-co-locate-with-offshore-energy-projects

[141] http://maribe.eu/wp-content/uploads/2016/11/b-4-albatern-and-abt-final-report-abt.pdf

[142] http://www.scottishenergynews.com/albatern-wave-energy-array-set-to-power-scottish-fish-farms/

[143] ekosgen, for Marine Scotland (2020) Supporting the Economic, Social and Environmental Sustainability of the UK's Marine Sectors

processing. For the sector to grow and develop, improved transport links from relatively remote production and landing sites to key markets and distribution hubs is vital.

7.32 However, as noted earlier there has been significant investment in port infrastructure in the Highlands and Islands over the last decade and there are commitments and proposals for further investment and development. This will be crucial enabling infrastructure for both aquaculture and FOW.

7.33 There are some potential on-site maintenance synergies, including for shared operation and maintenance visits to co-located or proximity-located sites for aquaculture production and FOW generation. However, the timings and frequency of required visits – at least for finfish aquaculture and FOW – do not necessarily align, although given that current operation and maintenance for aquaculture is substantively taken up by health and disease management activity, this could be considerably reduced at offshore locations, or covered by onshore staff. Additionally, shellfish and seaweed aquaculture require lower levels and frequencies of operation and maintenance, and so may align better with the requirements for FOW. However, a number of other issues exist, including time required for aquaculture operation and maintenance in more extreme environmental conditions, the exclusion zones required for major turbine maintenance works, and the suitability of certain vessels for shared logistics.[144]

7.34 The need for regular on-site operation and maintenance visits could be offset to an extent by combined accommodation barges in the case of either co-located or proximity-located developments. Currently, offshore wind and aquaculture are served by purpose-built barges; in the case of aquaculture these are combined feed and accommodation barges. Some design innovation would be required since both types of barge (as well as vessels such as well-boats and de-lousing barges used in aquaculture) currently have very different designs.

7.35 Work by the ORE Catapult on potential synergies identifies the need for greater use of automated systems to overcome such challenges in remote and extreme environments.[145] An important aspect of this opportunity is the development of systems and processes to gather data through remote sensing and monitoring, building on work being undertaken by CENSIS, or activity being delivered by the University of Strathclyde and soon to be augmented by its proposed Digital Automation Innovation and Testing Centre. Remote monitoring by satellites or drones – the latter perhaps in a similar way to that used by Cyberhawk[146] for the onshore energy sector – also offers a route through which monitoring of production and generation sites, co-located or otherwise, can be shared. Equally, data analysis and modelling through big data approaches, virtual reality, and the application of gaming technology can help enhance understanding of the impact of operations on the marine environment and inform future approaches to sustainable development. This will be invaluable in terms of both identifying test sites, and in a deploy-and-monitor approach to establishing live production and generation sites, especially co-located ones.

7.36 There are clear synergies in the engineering and equipment manufacture supply chain for offshore aquaculture and FOW. Established aquaculture engineering companies such as Gael Force already operate in other marine sectors. There are also signs that major energy engineering companies such as Global Energy Group[147] and Simply Blue Group[148] are expanding operations into aquaculture as the latter sector begins exploring offshore sites.[149]

7.37 The skills systems for aquaculture and offshore renewables are currently quite separate. This is largely a result of the different certification regimes between the two, although there are of course

[144] ORE Catapult, SRSL (SAMS Enterprise), Scottish Government (2019) Scottish Aquaculture and Floating Wind Synergies Feasibility Study Phase 1 Report

[145] Ibid., p.48

[146] https://thecyberhawk.com/

[147] https://gegroup.com/

[148] https://simplyblueenergy.com/

[149] https://gegroup.com/news/big-wins-for-scottish-supply-chain-as-global-energy-group-and-salamander-floating-wind-project-team-up

areas of overlap, e.g. boat handling. NAFC Marine Centre UHI is currently developing a Masters course in aquaculture with a major renewables element – recognising the need to reduce the carbon footprint of aquaculture production sites, and with a view to reducing reliance on fossil fuels and increasing onsite renewable energy generation.

7.38 There is evidence that engineering courses are increasing the level of climate emergency and sustainability content in their curricula although there is substantial scope for this to increase further. Consultees acknowledged that many of the skills required in both industries will be similar, and so there is potential for sharing skills, transferring skills, and achieving synergies in skills development of the existing workforce in response to new ways of working, and in the skills pipeline. Examples include boat handling; engineering and marine engineering; IT and tech skills for monitoring, data management, automation and so forth; as well as meta-skills such as problem solving, creative thinking and leadership. There are already some shared or cross-industry apprenticeships, with apprentices undertaking elements of aquaculture and engineering concurrently (e.g. NAFC Marine Centre/Shetland UHI). This demonstrates what can be achieved and there is potential for this to be extended into other parts of the marine economy. A key question is the extent to which separate certification for both aquaculture and offshore wind, given the specialist requirements in each industry will be required. A system that recognises and takes account of 'equivalencies' and 'prior learning' could achieve efficiencies and benefit individuals who would be better able to benefit from wider opportunities across marine sectors.

Synergies with other sectors

7.39 Some synergies between offshore aquaculture and FOW, and other sectors, are also evident.

7.40 The Wier and Wind project and NORA collaboration (discussed in Chapter 3) demonstrate the potential for exploiting synergies between aquaculture and bottom-fixed offshore wind. Exploiting the space within windfarms between turbines to maximise growing of extractive aquaculture products (shellfish and seaweed) benefits aquaculture production as well as bringing additional environmental benefits (such as carbon capture).

7.41 FOW has strong synergies with hydrogen energy, particularly production. FOW is well-placed to generate the scale of hydrogen that will be required as its use as a fuel for vehicles or heating of buildings increases. As discussed in Chapter 4, it also presents a solution in terms of overcoming the barrier to grid connection for generation sites offshore, where the distances involved preclude connection to the national grid.

7.42 There are also synergies to exploit between FOW and Oil & Gas. FOW can potentially be used to power ongoing Oil & Gas operations, in line with the Scottish Government energy strategy, which aims to decarbonise the extraction of fossil fuels, recognising their continuing role in the energy mix for some time to come.

7.43 Finally, with regard to the landside port infrastructure development necessary to support offshore aquaculture and floating offshore wind, there is an opportunity to contribute to the development and regeneration of ports in Scotland and meet the needs of other marine sectors. Ensuring a proactive and co-ordinated approach to port development across players from different sectors should be considered to overcome what can be a constraint to the development and competitiveness of different marine sectors, as well as extending port and harbour use to a greater range of diverse users and uses.

CHALLENGES AND BARRIERS TO ACHIEVING SYNERGIES

7.44 There are a number of challenges in achieving synergy between FOW and aquaculture and these principally relate to factors of co-location rather than areas such as R&D, skills development and improving port infrastructure.

Risk management

7.45 Co-location of aquaculture and FOW will require joint risk assessment and management protocols. There will also have to be an agreement on attitude to risk as multi-use sites may be deemed riskier by operators and insurers, since third party verification for insurance will also have to be satisfied for both elements. For example, if there is an equipment failure on a co-located site or one part of the operations fails or it is putting another operation at risk, how would prioritisation be agreed, managed, and implemented. It is likely that prioritisation would be strongly influenced by potential scale of loss in terms of value - most likely to be FOW rather than aquaculture. Disparities in value will lead to disparity in prioritising infrastructure and assets and this may not be acceptable to aquaculture operators.

7.46 Partners may perceive that they are exposed to investment risk that they are not totally in control of. They must rely on the other partner(s) to also mitigate risk, operate effectively, and maximise and share return on investment equitably. Added to this, there may be a concern that collaboration could dilute the benefits they accrue, and the solutions may be less effective in addressing their specific needs.

Intellectual property

7.47 If new products, processes, equipment, or software is developed in collaboration, then the question of ownership and how benefits will be distributed amongst partners must be agreed in advance. Added to this, it will be important to have a clear and binding agreement on ownership of Intellectual Property, including patents.

Industry operators

7.48 Aquaculture is an established industry, and finfish in particular, is dominated by large multi-national organisations. As an expensive and emerging technology, the organisations operating in FOW development and deployment are large, ambitious, and forward-looking. Involvement of these powerful players could be an advantage to collaboration and achieving synergies, but it could also present some challenges. Large businesses can have complicated, sometimes slow decision-making processes and if two or more are working together, there could be a time lag in progressing key activities.

7.49 Operators and supply chain organisations in FOW and aquaculture may not have a good understanding of the other sector and this could inhibit the realisation of synergies. Although both significant to the blue economy, they operate in different locations, have separate markets, and are involved in very different activities. It is likely that there is currently no, or very limited cross-sectoral communication or knowledge.

7.50 There may inevitably be some ‘jostling’ for leadership in a partnership between two (or more) powerful organisations. Realising synergies will require organisations to share information, knowledge and to ‘pool’ resources. There may be some reluctance amongst partners in this regard in terms of sharing commercially sensitive information and potentially risking competitive advantage.

7.51 In addition, there is a sense that the push for co-location is being driven by head offices in global companies that are not based in the UK. This can mean a lack of understanding of local circumstances, regulatory environments, challenges, and viability.

7.52 However, there is precedent for encouraging a greater degree of collaboration and co-opetition amongst major industry players. The ORION Project[150] (Opportunity, Renewables, Integration, Offshore Networks), is a partnership between the Shetland Islands Council and the Oil and Gas Technology Centre in Aberdeen, involving HIE and the wider UK energy industry.[151] The project’s aim is to establish Shetland as a centre for green hydrogen, capitalising on its existing energy expertise and infrastructure. Consultees noted that this project has arguably stimulated greater collaboration amongst major oil and

[150] https://www.apse.org.uk/apse/assets/File/Douglas%20Irvine.pdf

[151] https://www.shetland.org/blog/green-hydrogen-potential

gas players than at any time since the start of oil and gas exploration off Shetland. Additionally, a net zero industry group is being set up on Shetland. Membership of the group includes businesses and strategic organisations interested in net zero activities – and these are supply chain companies that operate in industries across the marine space.

Regulation and marine spatial planning

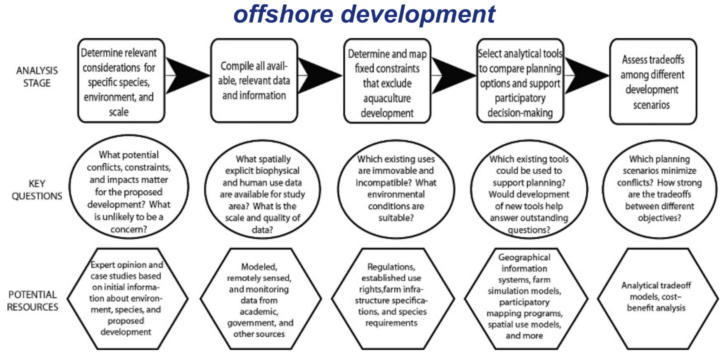
7.53 Legislation and regulation applying to developments in the marine space in Scotland can be complicated albeit absolutely necessary. There are various organisations with planning authority and jurisdiction depending on the location of the proposed site, for example Scottish Government, UK Government, Marine Scotland's Licensing Operations Team, Crown Estates Scotland, and local authorities. Offshore renewable energy developments are reactive, with operators responding to opportunities advertised by Crown Estates Scotland of areas that are open to lease (and only those areas are available, Aquaculture sites are proposed by the operator and so are proactive.

7.54 FOW and aquaculture have very different legislative and regulatory frameworks that they must adhere to which may prove difficult for co-location given that the frameworks do not easily lend themselves to multi-use sites. However, the main challenge may well be the ambiguity and inconsistency that exists in the various regulatory regimes that apply to aquaculture and FOW. This is compounded by a lack of shared understanding between regulators, which was identified through consultations and considered necessary for what is a relatively new area of marine development. This issue is not specific to Scotland; other countries have also had to examine how regulation can support co-location. It is being encouraged in France, and in the German part of the North Sea where integrated spatial zone management has been operating for over a decade and tools for co-location developed.[152]

7.55 Current planning constraints mean that finfish farms cannot be located off the north and east coasts of Scotland work against co-location with FOW. Relaxing this moratorium would be likely to result in some opposition from the public, other marine users, but relevant interest groups in particular.

7.56 Consideration also needs to be given to interaction with other marine uses and users. One planning approach is to avoid siting aquaculture in the most important areas for other ocean uses and users, but this will not necessarily lead to the best outcomes for all activities concerned. There are undoubtedly a number of information gaps that require ongoing investigation. However, it is recognised that making decisions about siting can still be informed by existing intelligence and supplemented by additional research findings as they become available, given that offshore aquaculture is likely to continue to develop in the meantime. One approach to spatial planning has been proposed for offshore aquaculture that can apply equally to FOW and co-located/proximity-located sites. This is summarised in Figure 7.1.

Figure 7.1: Possible approach to a participatory planning process for offshore development



Source: Gentry, et al. (2016)

[152] https://www.msp-platform.eu/countries/germany

Species selection

7.57 The evidence shows that offshore finfish cultivation is likely to be difficult due to the welfare and biological needs of fish. Salmon need regular tending, health monitoring and surface access. This frequency of both 'husbandry' requirements and harvesting to take to market means that it is best suited to near-shore locations. Currently, extractive aquaculture of lower trophic species such as seaweed and shellfish, in particular mussel farming, are the most likely types of aquaculture that would be suitable in offshore multi-use sites. They are relatively low maintenance, less resource intensive and they do not need to be fed so require less intensive management and husbandry. However, there is a question around the viability in terms of cost compared to value of the produce, and the risk for the aquaculture and the FOW operations. To be viable, it is likely that production sites would have to be very large to generate sufficient volume: since shellfish and seaweed production are extractive, yields per unit area decline with stocking density so large volume production needs very large spaces.

7.58 Although Scotland has a large and potentially very valuable asset in seaweed and the potential to cultivate relatively high value species, the policy environment means that the well-established industry in South East Asia has become increasingly dominant in the global market. There is also a question of where co-located sites might be in Scotland and if species are introduced there, for example from west coast to east coast water, whether they will thrive and what the impact on the ecosystem will be – though there is an expectation that local genetic stocks would be the default.

7.59 Whilst finfish would provide a greater financial return, there would be much higher capital, operational and maintenance costs and a greater need for transport and traffic to and from the site. Solutions would need to be found for regular and timely harvesting and transport to market as well as feeding and stock husbandry. Application of technology and automation undoubtedly have the potential to provide some of the solutions but there is currently no apparent solution for timely harvesting and transport to shore.

8 CONCLUSIONS AND REALISING THE SYNERGIES

INTRODUCTION

8.1 The research has demonstrated that there are a range of areas of potential synergy between aquaculture, FOW and potentially related industries. However, there are challenges to progressing and achieving the synergies which will require careful consideration, prioritisation, planning, and leadership.

8.2 This chapter draws the conclusions from the research and sets out the issues that must be considered to best exploit future synergies.

POTENTIAL SYNERGIES

8.3 There are a number of potential synergies between aquaculture and FOW. Realising these will contribute to a more efficient use of marine space and overcoming shared technical challenges.

8.4 Shared R&D and innovation can help break down industry silos and develop solutions that meet the needs of both industries more efficiently and effectively. Joint surveying and monitoring for shared sites can also help to reduce costs and risks in early stages of project development. Additionally, joint approaches can help to demonstrate greater economies of scale, particularly in a disrupted post-Brexit funding environment where ensuring maximum return on public investment is critical.

8.5 Co-location or proximity-location has potential, but neither are likely to be realised in the short-term. Nevertheless, there are some early projects being delivered, and these will undoubtedly help to prove feasibility of joint or nearby operations.

8.6 Shared requirements in terms of land-based infrastructure present opportunities for ports to serve both sectors, subject to addressing the bespoke requirements of each. Whilst there are a number of ports in the Highlands and Islands, historic under-investment in port infrastructure has seen ports elsewhere gain a competitive advantage in serving other marine sectors (e.g. bottom-fixed offshore wind, oil and gas decommissioning). More recent investment in port infrastructure has helped to address this but there remains a need for significant investment and strategic co-ordination to realise any potential opportunities. Regenerating and modernising ports is a critical area where public sector support is necessary. Some steps have been taken and are in place (e.g. through growth deals) to undertake improvements to ports and there are plans for more investment and development. However, a strategic, proactive, and co-ordinated approach is required to overcome what remains a significant constraint.

8.7 Synergies in operation and maintenance can be realised, but issues around scheduling, space requirements (particularly for FOW) and the suitability of vessels need to be addressed. In other forms of operation and maintenance, such as remote monitoring and data capture, there are clear opportunities to be realised, e.g. with regard to modelling of offshore conditions, or by implementing a joint deploy-and-monitor approach for co-located aquaculture and FOW activity. There are also signs that the respective engineering and equipment supply chains for each sector are already pivoting to take advantage of joint opportunities as they emerge.

8.8 More recent skills development for aquaculture and offshore wind is showing some convergence, for example in response to environmental concerns and climate emergency. There is scope for greater sharing and transference of skills between the two and more widely across the marine economy, and for this to be articulated more clearly and formalised. The existence of shared apprenticeships in aquaculture and engineering indicates that such an approach for a ‘whole marine space' shared apprenticeship is viable. However, under existing systems, licensing and certification remain separate given the relative specialisms in each.

CONSTRAINTS AND CHALLENGES TO SYNERGY

8.9 Collaboration is not straightforward and rarely takes place smoothly. The study identified the challenges that achieving synergy across aquaculture and FOW is likely to face. Some are tangible, such as finance and resourcing, and some are less tangible such as the attitude and benefits assessment of industry.

8.10 Addressing risk will be a crucial challenge, particularly with co-location. Operators will assess and prioritise the risk to their own operations if there is a failure, for example an equipment failure, stock loss (finfish), or a problem with accessing the site by support vessels or maintenance.

8.11 There is also a risk in collaboration that is not co-located. This centres on exposure to investment risk of partners. The theory is that collaboration will mean that risk is shared, but there may also be a possibility of collaboration increasing the risk attached to an activity and impacting on the likelihood of an individual organisation achieving its required return on their investment. For example, could the benefits be diluted beyond an acceptable level?

8.12 Linked to the question of risk are the commercialisation and Intellectual Property rights associated with any innovation, research, and development. For example, if a new component, piece of equipment or software is developed, there will have to be clarity on future ownership, rights and distribution of benefits and profit.

8.13 Achieving synergies will require organisations to work closely together, share information and potentially combine resources. There may be some reluctance to do this on the grounds of commercial sensitivity and loss of competitive advantage. There is also currently a lack of any real depth of cross-sectoral knowledge and understanding between organisations in FOW and those in aquaculture, and with major businesses operating in each, there may be some concern about the balance of power where they are proposing to work in partnership.

8.14 Marine spaces in Scotland, and the range of uses and users requires strong and comprehensive regulation. The regulation, planning and licensing processes and legislation are very different for FOW than for aquaculture. This will act as a barrier, or at least a challenge for co-location and will be an important area for further research, review and 'smoothing'.

8.15 There remain questions around the aquaculture species that are suited to being produced further offshore given current and emerging practices. Further research will be required, for example, on how to remove barriers for finfish farms in deeper water, more energetic environments, and further from shore for husbandry and harvesting. Currently seaweed and shellfish appear to be more realistic in terms of production, but as lower price produce, the financial viability may make it less attractive for producers.

PRINCIPLES UNDERPINNING THE REALISATION OF SYNERGIES

8.16 In examining the synergies and how these might be demonstrated to target audiences, it is useful to have a set of principles that will underpin activities and interventions to catalyse the work that will be required. These principles may be fine-tuned over time but at this stage, the following framework should act as a guide to realising cross-industry synergies:

- Development of the synergies will be strategic, aimed at benefiting partners, industry, and Scotland's economy.
- Collaboration will focus on understanding common or related issues to be addressed and working collectively towards defined benefits.

- There will be clarity of the process, the commitment, the resources and the anticipated outcomes for each industry and each partner. This will include ownership of any IP developed and commercialisation of joint innovation and development activity.
- There will be robust risk assessment and management, ensuring transparency of risk and no unacceptable risk for any partner.
- Collaboration will be planned, systematic, monitored and reviewed.
- There will be an exit strategy, a process, and defined triggers.

PRIORITISING SYNERGIES

8.17 The work has identified a number of potential areas for collaboration in pre-operation activities as well as operational synergies associated with co-location, proximity-location, and the supply chain.

8.18 It will not be feasible, or effective to try to work towards all of these at the same time, and some will be more readily achievable than others. Some potential synergies may also be more attractive to potential partners than others, for example by offering particular benefits or being perceived as lower risk, which in turn may increase the appetite to pursue them. There may also be tactical advantages in focusing on an area in which there could be a 'quick win' to demonstrate the benefits, that synergies are possible and to test the process, what works, what is less effective and any risks or issues that need to be managed better or differently.

8.19 There will be a number of factors and criteria that will likely influence how the potential synergies are prioritised for action. Examples include attitude and appetite by partners; access to finance and resources; alignment with and contribution to policy; and achievability. The prioritisation should be undertaken working very closely with, and being driven by industry, along with other potential partners such as research organisations and public sector or other agencies.

8.20 There may be more than one collaborative partnership that forms and works together at any given time and on different types of activities, in the pre-operational stage and during operations. Ideally these collaborations should be visible and the learning from the process and the outcomes (as appropriate) shared to catalyse further and more collaboration, and to maximise the reach of the benefits in FOW, aquaculture and related areas. This will ensure that the benefits and progress impact at industry and national level, rather than being limited to individual operators.

INNOVATION IN COLLABORATION

8.21 Collaboration rarely happens without a catalyst. The catalyst may be reactive, for example through a chance discussion at a meeting, informal networking, or movement of key personnel from one organisation to another and identifying an opportunity.

8.22 The catalyst for collaboration can also be deliberate and proactive, for example through specific activities and initiatives that bring businesses and organisations together to explore areas of opportunities and mutual interest and share knowledge. In some cases, these can be semi-permanent and physical such as shared workspaces and co-location on research and business parks and campuses, such as the Inverness Campus and the European Marine Science Park in Oban.

8.23 Achieving potential synergies will require partners to think innovatively and work in new ways. Many will be very well used to collaboration but perhaps less so in terms of cross-industry partnerships involving major market players and in such a high value but potentially higher risk context.

8.24 Achieving collaboration across FOW and aquaculture will require planned, proactive interventions to bring the two industries together, to build trusting relationships, identify areas of synergy and mutual benefit, and develop new ways of working. This is likely to require public sector intervention and clear roles in terms of responsibility and process for enabling, facilitating, brokering, funding, and capturing the learning.

8.25 Collaboration is likely to be a staged process and it will take time to progress along stages. The complexity and the time and resources that will be required should not be underestimated.

Capturing the value in Scotland

8.26 Whilst the focus of this research has been on identifying where synergies lie, actions to realise these must also seek to maximise the value that is captured in Scotland. With aquaculture and piled offshore wind currently, much of the value chain exists outside Scotland, either as a result of company ownership, or lack of access to facilities such as deep-water ports.

8.27 To capture the maximum value in Scotland, there needs to be sufficient strategic support for the development of necessary infrastructure, as well as an ecosystem that is supportive in developing joint/collaborative operations. This nascent body of joint industry activity is moving quickly, and so it is important to also move quickly to strategically establish the Highlands and Islands' and Scotland's position and reputation and capture the value. There is a solid basis of world-class businesses and research and innovation activities in Scotland and more specifically in the Highlands and Islands across both aquaculture and offshore renewables. Some key commercial companies are currently driving activity which is vital, but the overall development of the industry must be keenly and pointedly supported by the public and academic/research sectors.

8.28 Longer-term support for development of synergistic activity and the supporting supply chain will not only benefit the sectors but will also support wider social and community benefits in those locations that support land-based operations, as well as creating high-value jobs. As such, there is a clear need to ensure the skills resource is available alongside infrastructure and business resource, to maximise the realisation of benefits from growth of offshore aquaculture and FOW, and that this is done as equitably across the region's population as possible.

IMPLEMENTATION AND OPERATION

8.29 There is a clear need for marine planning and balancing of all marine use in offshore areas, not just aquaculture and FOW. Whilst the regulatory framework for each sector will need to be satisfied, pro-active marine spatial planning and management will be required. Greater clarity between the regulatory frameworks for each, as well as a shared understanding amongst regulators of the specific requirements for offshore aquaculture and FOW, is also required to overcome any ambiguity or inconsistency.

8.30 Marine sectors are inextricably linked by overlapping spatial requirements yet are not always tightly integrated and usually subject to very different regulatory systems. There is scope for more cross-sector engagement and collaboration which would help plan and balance the different uses and users, and ensure the sustainability of the sector overall, while managing environmental impacts. This will help to improve communication across industry stakeholders and strategic/public sector partners, enhancing cross-sector understanding, and improving trust between sectors and industry actors.

8.31 Taking an approach that recognises both the interdependencies and differences of marine sectors will require a strong partnership approach across the public sector, industry, and research organisations, including academia. Co-managing marine resources should be a joint responsibility for all those involved.

APPENDIX 1

Academics

- NAFC Marine Centre UHI
- National Oceanographic Centre
- SAMS
- Sustainable Aquaculture Innovation Centre
- UHI Aquaculture Hub

Industry informants

- Association of Scottish Shellfish Growers
- Gael Force Group
- Greig Seafood
- MOWI
- Scottish Salmon Producers Organisation
- Simply Blue

Strategic stakeholders

- Crown Estates Scotland
- Highlands and Islands Enterprise
- Marine Scotland
- MASTS
- Offshore Renewable Energy Catapult (ORE)
- Scottish Enterprise
- Shetland Islands Council

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean