



Best Practice Report and Current State Analysis of the Norfolk and UK Seaweed Sector in 2023

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Executive Summary

This report addresses challenges and opportunities currently seen in the UK seaweed sector, focusing on the opportunity that Norfolk has to build a seaweed industry. The present prolonged and unclear licensing process is one of the barriers discussed that is hindering industry growth and investment. Through the interviews conducted for this study, the central regulatory bodies responsible for the seaweed sector have proposed that streamlining applications and enhancing stakeholder engagement could improve efficiency.

The UK seaweed farming landscape is also addressed in the report, where the scaling-up of the UK total biomass production will be vital to establishing a competitive and sustainable industry. To achieve this, collaboration is advocated, urging a unified platform for communication, knowledge sharing, and partnerships within and beyond the sector. Learning from the Netherlands and other global successes will also be essential to ensure fast and sustainable scaling-up. The space constraints in UK waters necessitate solutions around co-existence and exploring co-location possibilities with wind farms, which several companies are investigating. Challenges include insurance risks and operational logistics, highlighting the need for partnerships and clear government policies for successful co-use projects. For seaweed sector product and service development, targeted research is required for industry progress.

The report concludes by emphasising the key factors that can support the acceleration of a seaweed industry in Norfolk. It highlights the importance of building local capabilities and supply chains and fostering solid relationships through long-term contracts. In Norfolk, seaweed biomass presents opportunities in agriculture, bioplastics, and food product development, with the potential to ease environmental pressures from pollution and coastal erosion. Collaboration with the fishing industry and co-location with energy companies could create additional local employment and access prospects. Establishing a biorefinery and a seaweed nursery locally could significantly boost production and awareness. This should therefore be a key focus point alongside supporting seaweed cultivators that want to farm in the area to accelerate a seaweed industry in Norfolk.

This report was conducted as part of the Seaweed in East Anglia (SEA) project. The project is delivered by Hethel Innovation in collaboration with The Centre for Environment, Fisheries and Aquaculture Science (Cefas) and University of East Anglia (UEA).



Main Takeaways:

- The main barriers preventing seaweed cultivators from establishing farms and scaling up are shared between the UK sector and the industry in the Netherlands. The main challenges include the current licence application process, accessing funding, the present price point of UK-grown seaweed, high set-up and operation costs and resistance from other marine users.
- Multiuse at offshore wind farms, co-use and co-existence are already being explored as options to utilise space at sea through various projects in Europe, including in the North Sea. This could be a viable opportunity outside Norfolk in the Southern North Sea, which currently is the home of several wind farms, if a clear statement from the UK government on their position could be issued and the current logistic hurdles could be overcome.
- There are multiple UK companies that offer services to support the domestic seaweed sector, as well as companies that create products from the biomass. Support from the service companies will be essential when scaling up the sector, especially to meet data and research needed for cultivation site applications. Many UK companies are currently using seaweed sourced from other countries in their products, mainly due to price points. However, all companies interviewed in this study were willing to modify their products and/or operations to be able to use locally farmed seaweed in their products if sufficient biomass were to be available locally.
- In Norfolk, there is the opportunity for a seaweed industry to grow the economy in the region, provide green jobs and support coastal communities. This can be achieved by offering an additional income for fishers, harvesting and processing jobs and by using the products made to benefit the region, such as using seaweed fertilisers in agriculture practices to improve soil health and reduce overall carbon footprints.
- There are several aquaculture networks in the UK. However, there is a lack of a domestic unified platform that can facilitate knowledge sharing and networking with partners across the whole seaweed value chain and act as a single voice for the sector.

Purpose

The purpose of this report is to review the current state of the UK seaweed sector and identify best practices adopted in other UK areas where the seaweed sector is more developed, as well as in the Dutch seaweed industry. The report also aims to identify how best to build a seaweed economy with sustainable and socially responsible supply chains in Norfolk.

The report will be published on the SEA project webpage and included in the final project report.

Study Design

This report is based on the findings from 23 semi-structured interviews conducted with people working in the seaweed sector, particularly for organisations that operate across the seaweed value chain in the UK and Netherlands (Table 1). Most people interviewed are regular participants in the Algae Innovation Platform (AIP) meetings, run by Hethel Innovation in Norfolk. The interviews took place online between June and September 2023, and the interview questions can be found in Appendix 1.

Table 1. Number of interviews per stakeholder group from the UK and Netherlands. A full list of the stakeholders interviewed for the study can be found in Appendix 2, Table 1.

Stakeholder	United Kingdom	Netherlands
Seaweed Cultivators	4	
Regulators	3	
Energy Companies	2	
Processors	2	
Businesses Products	3	
Businesses Services	7	2

Regulators in the UK Seaweed Sector

Current Status of UK Seaweed Sector Regulators. Several organisations are currently responsible for regulating the UK seaweed sector. Some of the central regulators were therefore interviewed as a part of this study for their input on how they view the current industry and how they can aid with accelerating the sector.

The Marine Management Organisation (MMO) is the regulatory body that is responsible for issuing marine licenses for activities in English waters, including for sector-specific licensing decision-making. Licensing decisions are likely to impact seaweed aquaculture, as activities related to the construction and running of a seaweed farm may be subject to marine licensing ([Do I need a marine licence?](#)). The MMO is also responsible for ensuring applicants have the right support and documentation to obtain a licence at the end of the process. Guidance includes advice on what is expected from the application in terms of information and data. Pre-application services from the MMO can be accessed for a fee. To support their role in issuing licences in England, the MMO also generates evidence that can inform strategic or site-specific decision-making.

Additionally, the MMO focuses on stakeholder engagement and intelligence gathering and looks into how different sectors can coexist in the marine area, while reducing conflicts. Marine plans are made regionally, and the MMO stated in the interview for this study that it is important for them to communicate with the seaweed sector and ensure the industry are informed on, and can input into, plan production and drafting processes. Particularly, industry feedback is sought regarding issues, opportunities and challenges relating to aquaculture in the marine area so that marine plans can address them. Here, opportunities may be a particular focus due to the developing nature of the seaweed farming industry. The collection of data and evidence relating to aquaculture can both support policy writing, and also inform monitoring with regard to effectiveness of the MMO's plans and policies. In Norfolk, the MMO has a marine plan for the East of England and has specified local marine planners and regional officers who can help with planning, local implementation and monitoring.

The Crown Estate (TCE) is another main regulator for the seaweed sector in the UK. TCE is an independent commercial business created by an Act of Parliament, with a diverse portfolio of UK buildings, shoreline, seabed, forestry, agriculture and common land (*The Crown Estate, 2023*). Their primary role in the seaweed sector is in terms of leasing seabed to growers to allow them to produce and harvest seaweed. This includes enabling and ensuring space for different types of farming activities, such as small inshore farms as well as larger offshore operators. Through the interview, TCE

highlighted the importance of diversity in the sector and that it is essential that the regulatory framework can respond to sector development needs. TCE also works to encourage and accelerate the developing seaweed industry by providing leases to early-stage seaweed operators at a reduced rate compared to leases for other developments of the seabed. This is in addition to investing in research and policy-related activities that can help increase the seaweed sector delivery of environmental, social and commercial value.

TCE acknowledged during the interview that they are aware of the barriers that are slowing down the development of the seaweed sector in the UK; furthermore, they are already working on addressing and resolving some of the challenges. Their efforts to tackle this have so far been focused on direct engagement with the government to communicate issues such as statutory consenting, supply chain challenges, investment needed for research, evidence gathering and other focused activities. From a local perspective, TCE sees the East Coast of England and Norfolk as a focal point for activity and has been working with companies in the region looking to scale up their seaweed farming or securing an area of seabed for seaweed cultivation. TCE is also an active member of the regional AIP network (See Appendix 3, Table 1).

The third main regulator in the UK seaweed sector interviewed for this study is the **Department for Environment, Food & Rural Affairs (Defra)**. Defra's Marine and Fisheries department manages and regulates the UK seafood sector and ensures that the decisions that the government takes in this sector, seaweed included, are based on accessible, relevant and appropriate scientific expertise evidence, outputs and data. This scientific expertise and evidence supports regulatory and policy development activities, and Defra commissions research and development activities where there are gaps in the evidence base. Defra works across the interests of different stakeholders in the UK and collaborates with many other organisations. One of Defra's executive agencies is **Natural England**, responsible for nature conservation and the potential impact of seaweed cultivation in the area up to 12 nautical miles from the coast. Beyond 12 nautical miles, the **Joint Nature Conservation Committee (JNCC)** becomes involved regarding nature conservation impacts. Another executive agency Defra works closely with is the **Environment Agency**, which is responsible for water quality and some aspects of coastal habitat management. These three bodies operate semi-autonomously to develop their regulatory vision and work with the **Centre for Environment Fisheries and Aquaculture Science (Cefas)**, whose primary responsibility is to conduct research, development activities and scientific advice to support interests. Natural England, the JNCC and the Environment Agency were not interviewed for this study, and Cefas is one of the SEA project partners.

Other regulators potentially involved in the marine licencing process for UK seaweed aquaculture are listed in Table 2.

Table 2. Additional regulators in the UK seaweed sector and their responsibilities.

Regulator	Main Responsibilities
Maritime and Coastguard Agency	Produce legislation and guidance on maritime matters and provide certification to seafarers (<i>GOV.UK</i> , 2018).
Historic England	The government's statutory adviser on the historic environment, championing historic places and helping people to understand, value and care for them (<i>Historic England</i> , n.d.).
Trinity House	A charity dedicated to safeguarding mariners, providing education, support and welfare with a statutory duty as a General Lighthouse Authority to deliver reliable, efficient and cost-effective aids to navigation services (<i>Trinity House</i> , n.d.).
National Federation of Fishermen's Organisations (NFFO)	The NFFO is the representative body for the fishing industry in England and Wales. The NFFO exists to provide a voice for fishermen and leads policy change for the benefit of their members and the wider UK fishing industry. Work to help ensure fishing interests are fully considered at all levels from high level policy through to individual marine licence decisions (<i>NFFO</i> , 2021).
National Trust	A conservation charity that looks after the nation's coastline, historic sites, countryside and green spaces, ensuring everyone benefits (<i>National Trust</i> , n.d.).

Challenges & Opportunities. One of the main bottlenecks mentioned by the companies interviewed for this study is the time it takes to obtain a licence to cultivate seaweed in the UK. Furthermore, it was repeatedly discussed through the interviews that the leasing and licencing permitting processes need streamlining as they are deterrents for startups and inward investment, uncertain in duration and not very transparent in terms of how decisions are made. However, the interviewed organisations also presented many solutions for how the industry could work with the regulators to improve the leasing and licencing permitting challenges.

In the interview conducted with representatives from the MMO, it was recognised that the **marine licence application process** for seaweed in the UK to date has been tricky for applicants and that the guidance needs to be improved in terms of what is expected from the applications. The main reason applications are unsuccessful is the need for more evidence to back up the applications on how the developments may impact marine space. This could be questions such as: what the impact on biodiversity and water quality in the area is as well as other direct and indirect benefits derived through seaweed that can help build up the business case. To overcome this, the MMO is currently collaborating on a guidance document that will be published in autumn 2023 with Cefas, Defra and Natural England. The guidance document includes information on what is needed in a licence application for seaweed cultivation, including the importance of navigational risk assessments, one of the main reasons for failed applications. The guidance is intended to help companies submit better-quality applications and lead to more successful applications.

Another example of an initiative to address issues and delays caused by the licencing application is the Aquaculture Enterprise Zone (AEZ) concept described in detail in Case Study 1.

It has also been proposed by several organisations interviewed for this study that the **sector works together to identify where the evidence base has gaps** when it comes to providing information for licence applications. Working with environmental consultancies and other sector groups who have been through a similar process and development, and learning from their experiences could also be a way to overcome this barrier; in fact, representatives from other sectors can be invited to industry networking platforms to share knowledge. Creating a single regulatory entity responsible for aquaculture development in the UK was also proposed.

The need for a **unified platform to draw the seaweed sector together in the UK** is another idea that most of the interviewed participants mentioned and it was clear from the regulators interviewed that there is a need for better engagement with the industry and the government. As seen in Appendix 3 Table 1, the UK already has several well-developed networks around aquaculture. Still, there is a need for a unifying platform that can act as a single voice for the sector when engaging with regulators and government while communicating coherent arguments about the sector's benefits. It has been mentioned through the interviews that regulators also find it challenging to **communicate with the industry**, where a coherent platform might aid with this and provide straightforward access to sector stakeholders.

Stronger communication between companies in the sector and regulators could also overcome any technical knowledge barriers on the regulators'

side of what seaweed growing is, what it involves and what the potential risks are. If this is understood better by regulators, this might also help speed up the licencing application process. A platform would also enable regulators to be more accessible to the industry. This could also accelerate the process of developing new regulatory standards and approaches to managing the sector more efficiently. More facilitated conversations between regulators and policymakers could also create a better balance between long-term policy and the different departments of government and non-governmental bodies that are responsible for getting it delivered.

Some of the issues that the regulators have encountered with licences for seaweed cultivation involve **spatial planning**, where some areas identified for aquaculture development are close to marine protected areas, established fishing grounds or near a designated path for other activities. Hence, some of the areas initially chosen are not always the most appropriate, and the approved farm location is often not the same area as originally applied for. A common seaweed industry platform could therefore also share spatial planning data easily accessed by applicants. The concept of a UK-wide seaweed sector platform is discussed in more detail in Case Study 3.

To summarise, the main challenges in the seaweed sector identified by the regulators include:

- lack of availability of new production sites and protected space,
- difficulties in co-existing with other marine users and competition for space (especially in inshore areas),
- lack of experience and knowledge,
- lack of centralisation in the sector,
- challenging and unclear licencing and consenting process especially for new companies (decentralised process),
- lack of collaboration between main partners across the supply chain,
- poor or insufficient water quality,
- insufficient infrastructure especially in older ports,
- limited consumer demand and unfavourable changing environmental conditions.

However, all these barriers could be overcome by collaboration and better communication within the sector.



Case Study 1: Aquaculture Enterprise Zone Project

Background – The AEZ project is led by Additive.earth and commissioned by TCE to tackle the licencing application barriers. Additive.earth is located in Devon and has previously worked on a project to quantify the aquaculture opportunity for Devon in partnership with TCE.

The Project – The AEZ project is looking at creating a national strategy for England and Wales for aquaculture enterprise zones. This concept focuses on creating a supporting environment for new and existing aquaculture businesses by creating 25 square kilometre areas allocated and prioritised for aquaculture via a head lease from TCE to a local planning authority or a Local Enterprise Partnership (LEP). This will enable local authorities to issue leases, which will lower the time it will take to get a licence as the assigned places for aquaculture will be pre-agreed.

Through the AEZ, permitting and licencing are done via the local planning authority using a coastal concordat, which enables them to act as a single point of contact with regulators. The environmental impact and habitat risk assessments, where potential habitat loss needs to be considered, as well as public consultation, will also be pre-done at the zonal level where the assets are held and kept up to date; these can then be accessed and adopted by individual applicants for subleases.

As a part of their work, Additive.earth has also set up working groups with regulators to discuss how licencing and permitting would work best within an AEZ and the adoption of the assets from a zonal level.

Another opportunity with the AEZ project is to reduce the costs and complexity associated with entering the sector as a seaweed cultivator and securing statutory consent by using the zones as an area for testing. This will enable a shortcut through the consenting process, where growers who are at a pilot stage can get a space within the overall leased area and test their model with limited risk and costs. This system can also lower the barrier to secure investment for cultivators as it removes the current uncertainties around achieving a licence.

Considerations & Next Steps – The AEZ project has been getting mixed feedback from current seaweed cultivators, but the project team are keen to speak to the industry about the barriers and how they could be resolved. Existing seaweed farmers have shown some resistance to the concept as the time it currently takes to get a licence works as a temporary stop for competition from entering the market.

As well as this, some of the existing cultivators want to avoid other companies getting an easier route before potentially outcompeting them. However, this could be overcome by informing the sector about the need to collaborate and spreading awareness of seaweed opportunities in the UK. In fact, one way to get the biomass needed to accelerate the seaweed industry in the UK and negotiate contracts with larger end-users to get better price points for seaweed biomass is lowering the barriers to establishing new seaweed cultivation sites and thereby increasing the UK's production volume.

Seaweed Cultivation Activities in the UK

Current State of Seaweed Cultivation in the UK and Norfolk. There are currently 27 aquaculture licenses granted to operate within the United Kingdom (numbers from Cefas, Oct 2023) (See Table 3), where most producers of seaweed are either micro- or small companies. In Norfolk there is currently one company that has obtained a marine licence for seaweed aquaculture, starting in autumn 2023. Additionally, there is also another company applying for a licence for seaweed aquaculture in the area (See Case Study 2).

Wild harvest of seaweed is currently still the predominant production method in the UK, but to create a competitive and sustainable industry, the sector needs to accelerate the amount of cultivated biomass via aquaculture.

Table 3. List of seaweed aquaculture licenses granted to operate within the UK separated by devolved administration (England, Northern Island, Scotland and Wales). The data is obtained in October 2023 from Cefas.

Seaweed Company Name	Commercial / R&D	Country	Location	Farm Size
Algapelago Marine Limited	Commercial	England	Bideford Bay - North Devon	100ha
Aqua Botanika LTD	Commercial	England	Thatcher's Rock - Torbay - Devon	10ha
Biome Algae	Commercial	England	St Austel Bay - Cornwall	
Green Ocean Farming	Commercial	England	Portland Harbour - Dorset	6ha
Green Ocean Farming	Commercial	England	Torbay - Devon	3ha
Jurassic Sea Farms	Commercial	England	Portland Harbour - Dorset	
Norfolk Seaweed LTD	Commercial	England	Blakeney Harbour - Norfolk	5ha
Penmayn Limited	Commercial	England	North Cornwall	1000m x 1000m
SeaGrown	Commercial	England	Scarborough - Yorkshire	500m x 500m
The Cornish Seaweed Company	Commercial	England	Porthallow Cove - Cornwall	
Turning Tides LTD	Commercial	England	Folkestone Harbour	1500m x 1500m
West Country Mussels of Fowey	Commercial	England	St Austell Bay - Cornwall	800m x 1300m

Islander Kelp	Commercial	Northern Island	Rathlin Island	
Aird Fada	Commercial	Scotland	Lock Scridain - Isle of Mull	50ha
Argyll Aquaculture	Commercial	Scotland	East Balvicar Bay - Seil Island	60,000m ²
GreenSea Solutions Ltd	Commercial	Scotland	Loch Sunart	15,400m ²
Kaly Group Ltd	Commercial	Scotland	West Side Loch Bay, Loch Dunvegan - Isle of Skye	405,000m ² (40.5ha site area; growing area 16ha)
KelpCrofting	Commercial	Scotland	Pabay & Scalpay - Isle of Skye	13ha
Lochnell Seaweed	Commercial	Scotland	Argyll and Bute	950m ²
Mara Seaweed LTD	Commercial	Scotland	St. Andrews Bay - Fife	3,282,400m ²
SAMS	R&D	Scotland	Kerrera & Port A' Bhuultin - Argyll	c. 35ha
Sea02 Ltd/ Hebridean Wildfoods Ltd	Commercial	Scotland	Lock Erisort - Isle of Lewis	230m ²
Seaweed Farming Scotland Ltd.	Commercial	Scotland	Fife and Argyll	800m ²
Shore / New Wave Foods	Commercial	Scotland	Southern end of Kerrera Sound	300,000m ²
West Coast Seaweed Ltd	Commercial	Scotland	Badachro - Gairloch - Wester Ross	
Câr-y-Môr	Commercial	Wales	St David's - Pembrokeshire	3.5ha
Seaweedology LTD	Commercial	Wales	Pembrokeshire	4ha

Companies in the UK that harvest wild seaweed often also carry out the initial processing and manufacture their own products before retailing them, which can give more process control and involvement. An example of such a company interviewed for this study is **Dorset Seaweed**, located in Dorset. They produce and sell plant feed biostimulants for home gardeners and retail their products to local garden centres and through their website. Dorset Seaweed currently only source native species local to Dorset and have a 3-kilometre area licence to harvest a maximum of one tonne of seaweed through TCE, following Natural England's guidelines for harvesting.

Biome Algae is another seaweed cultivator and processor interviewed, based in Devon and Cornwall and has been operating since 2020. They focus on scaling up and currently have licence applications submitted for several large farms in the area. The aim is to operate five different farms across Devon and Cornwall, employing 200-250 employees once their ambitions have been realised. Their first proof-of-concept farm was co-located with a

mussel farming company. They have since then scaled up, further developed their farming models and now have a production capacity of 60 wet tonnes of biomass, which are then processed and sold to end users. Biome Algae currently works with cosmetic and pharmaceutical companies, vegan food and feed markets, biostimulants, and biomaterials. To be able to tap into these markets, Biome Algae conducts research and development activities to create extracts from their seaweed, where the goal is to establish their own biorefinery in the future.

Biome Algae has a processing capacity of up to 11 tonnes of seaweed, with plans to scale up, which is needed as they aim to farm 250-300 hectares by 2026-27 to produce 10-20,000 tonnes of wet seaweed by 2030. The seaweed species in focus is natively grown sugar kelp, and they currently get their seedlings from the Dutch based company Hortimare. Biome Algae is also working with Hortimare to diversify its offering to grow two additional brown or red seaweed species. This year, Biome Algae will place 44,000 meters of seed in the water. However, as they scale, the quantities of seedlings needed will be challenging to import. Accordingly, Biome Algae has the ambition to establish a hatchery in the South West for native species, collaborating with other farmers and using Hortimare for their expertise so that local cultivators will have fast and easy access to stocks. They also focus on producing data to drive their operations forward and make the most out of their sites. The data collection done by Biome Algae is also intended to address knowledge gaps in the industry and support statements that are being made in the sector around carbon sequestration and biodiversity benefits. Biome Algae also aims to achieve zero waste and lower emissions to achieve carbon-neutral operations, for example, by using new hybrid and electrical vessels that can bring in 40 tonnes of seaweed daily over two trips.

Some companies combine seaweed cultivation with wild harvest as well as the initial processing, manufacturing and selling of their products. The Cornish Seaweed Company is a good example of this kind of company that was interviewed for this project. They harvest around 20 tonnes of seaweed from the wild and cultivate about three tonnes of kelp a year on a 500-metre line. They are currently farming sugar kelp and get their seedlings from Hortimare in the Netherlands. Once harvested, the Cornish Seaweed Company dry their seaweed and pack it up before sending their produce to their mainly UK-based customer base.

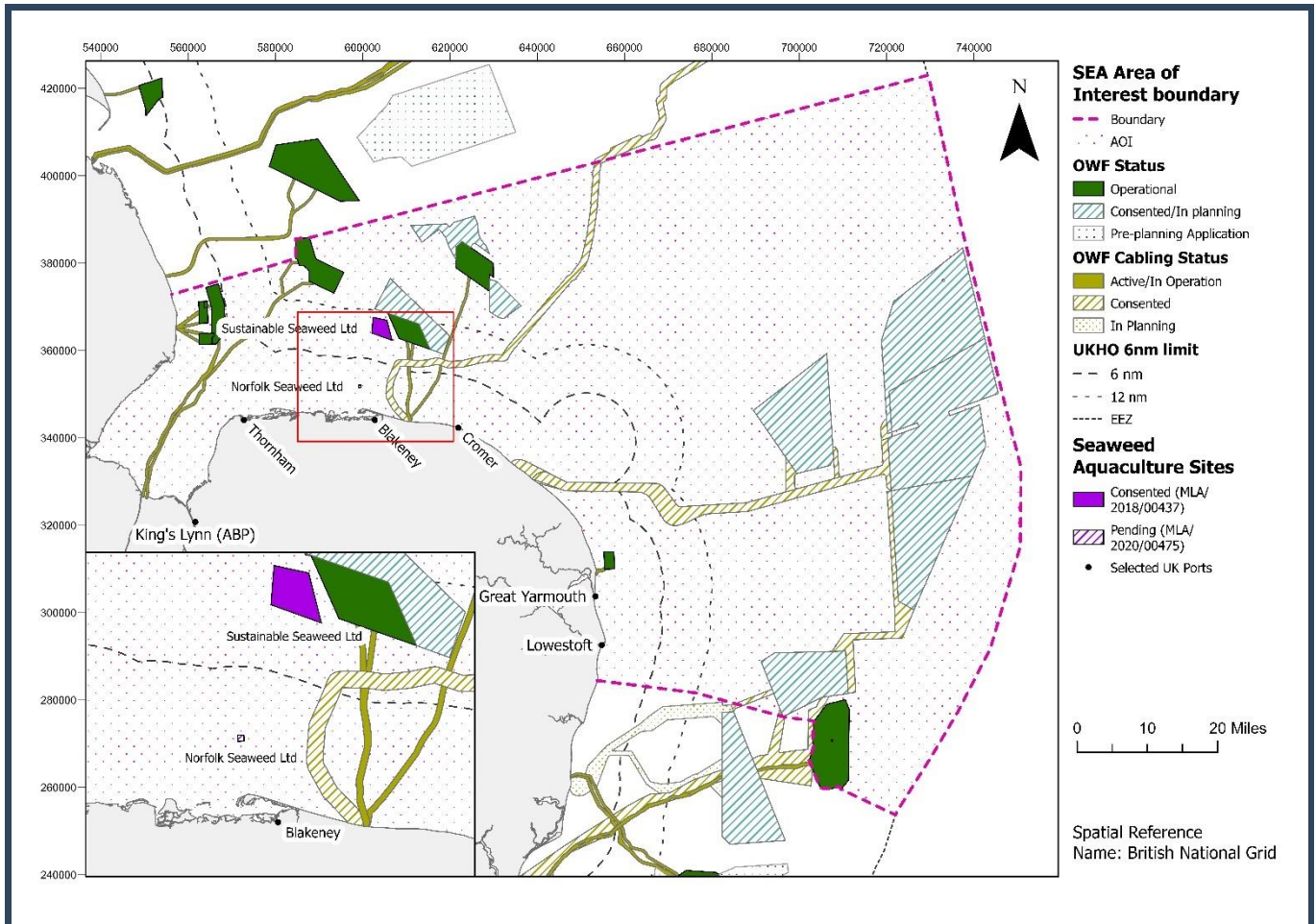


Case Study 2: Seaweed Cultivation in Norfolk

Norfolk Seaweed – In Norfolk, Norfolk Seaweed is currently the only company with a licence to farm seaweed. They are located in North Norfolk, with their sea farm planned for three miles north of Blakeney Point in open water. The company was established in January 2020, and the application for a sea farm licence was submitted to the MMO in October 2020; the final licence was issued in June 2023. Their first lines of seaweed are predicted to be in the water in autumn 2023. The biomass will be dried before selling it, and they plan to develop in-house processing facilities to enable local production of seaweed products for regional use and are interested in collaborating with biorefineries for further product development. Initially, Norfolk Seaweed is planning to farm sugar kelp at their 25-hectare 500x500meters site; here, a proof-of-concept operation with two seaweed horizontal long lines with around 300-400 metres of seeded twine is predicted to be in the water for at least one season. The seedlings have been processed for them by the Scottish Association for Marine Science (SAMS). They are also exploring the addition of vertical growing lines being attached to the horizontal line to increase the volume of seaweed grown. This is to test the feasibility of this system and how it responds to the North Norfolk winter. Data and observations collected could be shared with other cultivators.

Based on the knowledge from the proof-of-concept phase, Norfolk Seaweed can apply for a variation of their licence to increase the number of lines in their 25-hectare area. After the initial trial using sugar kelp, they would also potentially investigate farming other native seaweed species. Norfolk Seaweed's sole focus is on native species, and their licence also states that they need to get their seaweed spores from a 130-kilometre area around their farm.

Sustainable Seaweed – The second company aspiring to cultivate seaweed in the North Norfolk area is Sustainable Seaweed. They have submitted their application for a seaweed aquaculture licence and expect to hear the outcome of their 1540-hectare application in March 2024. A farm of this size would mean a considerable increase in biomass available in the region, which could positively impact the prospect of a seaweed industry in Norfolk. The plan is to cultivate sugar kelp or other brown seaweed species, such as *Laminaria* and *Alaria esculenta* (winged kelp), on 2-dimensional mats that can produce 60-80 tonnes per hectare. They have also explored processing capabilities at Egmere in Norfolk and are interested in investigating the use of their biomass for food applications as well as for biostimulants and animal feed in the agriculture industry. They are obtaining seed stock from SAMS and are interested in co-location opportunities with local energy companies.



Picture 1. SEA project area of interest including the locations of the Norfolk Seaweed cultivation site and the Sustainable Seaweed site. The map was obtained from Cefas in October 2023.

Opportunities & Challenges. As mentioned in the section above, the main barrier for new seaweed growers to enter the market is the **complexity of the licence application process**. For example, it took Norfolk Seaweed almost three years to get their licence to farm seaweed.

Currently, there seems to be a **mismatch** between the government's high-level **policy ambitions** for more sustainable aquaculture in UK waters and the **regulatory processes** set up to regulate UK aquaculture. This mismatch may be tackled with better communication with the government, potentially via a centralised industry platform to create a policy framework that balances the current requirements.

Another topic discussed in the sector is smaller versus larger farms, where the current licence environment has led to many farmers submitting **applications for smaller sites** around 20-100 hectares to be less

regulatory and condition-driven. This also allows the cultivator companies to scale up their operations, one farm at a time, where they can map and collect data on impact and performance at different or current and potential sites to see if they provide distinct results. Smaller farms can also make it easier for seaweed farms to co-exist with other sectors. Applying for one large cultivation area, such as the Sustainable Seaweed site (Case Study 2), can be costly for the company to establish, and the conditions on the licence can also be challenging to meet. A larger farm can also meet more resistance from other sectors and make the cultivating company heavily dependent on one site, which could increase the business model's risk.

A substantial current bottleneck stated by the companies interviewed is the **requirement to consult the statutory consultees** such as Historic England and Rural England when a new licence for seaweed cultivation is to be issued (Table 2). The statutory consultees can object to an application; the interviewees suggested that the process could be improved if statutory consultees backed up their concerns with evidence for why the site is not suitable.

From the interviews, it is clear that producers want to be compliant with being sustainable and meet regulatory needs, but they do not always know what is required or what **monitoring** needs to occur. This could be solved by making information more accessible through the proposed platform. With **clearer guidelines**, the farmers will be able to provide more research and evidence of the positive biodiversity effects around a farm site to back up claims and address the full impact of seaweed farming. This includes the long-term impact of farming, not just baseline data of what the area looks like now but also how this area might change with time.

In Scotland, seaweed farming is mostly seen as a **low-impact activity**, where the sector is supported by SAMS, the largest and oldest independent marine science organisation. SAMS delivers marine science for a productive and sustainably managed marine environment through innovative research, education and engagement with society (SAMS, 2023). Such a view might potentially aid the acceleration of the industry in England and Wales, where collecting more evidence from current farming sites could contribute to changing the view. To be able to do this, it is also important that producers take responsibility for **not making false claims** regarding biodiversity gain and carbon sequestration capabilities to ensure investment, as this would take away credibility from the sector.

Another farming challenge that will require more research and potential collaboration with other European countries is to **make cultivation more efficient** and increase the amount of biomass in kilos grown per meter. This is vital to scale up the UK seaweed sector as there currently are few buyers for British-grown seaweed at current farming scales, though a UK combined

platform could be used to find buyers for smaller volumes of seaweed. As an example of collaborative efforts that have already been initiated, Biome Algae is working with three seaweed farmers in their region to help them with their licence applications, setting up, sharing technology and knowledge and giving them access to machinery. One of these companies is a current fishing company that is interested in investigating seaweed cultivation to add to its portfolio.

Some seaweed farmers, including Norfolk Seaweed, are exploring the possibility of **growing seaweed both during the winter and summer seasons**. The best crop is expected to be produced during winter, but experimenting with cultivating seaweed through the summer season as well could increase production and ensure all-year usage of their equipment and facilities. The Scarborough-based company SeaGrown operates a 25-hectare offshore seaweed farm and has been leading a project under the Biomass Feedstocks Innovation Programme to apply their experience to create an innovative, automated end-to-end seaweed farming system. This project is worth mentioning in this section, as this innovative system might open up the seaweed industry to year-round production, open-water sites and greater assurance of optimal biomass yields (GOV.UK, 2022).



Picture 2. SAMS seaweed farm in Oban. Photo from Cefas taken in May 2014.

The **cost of seedlings** is another barrier for start-up growing companies, as this can be as high as £2 per meter. The price for seedlings is likely to become more affordable as the industry grows and the demand rises; this is probable to be the same for the current high set-up and running costs for seaweed farms, where harvesters and vessels could be shared amongst seaweed farmers in areas with multiple farms including the Norfolk area in the future.

Many companies are **unaware of support networks**, such as the AIP in Norfolk (See Appendix 3, Table 1 for more information). Engaging more with networks and potentially being a part of a unified platform for the UK could overcome the challenge many growers face with receiving **funding** and often having to rely on self-funding in the initial stages. The funding received to date has mainly been EU grant funding, funds from investors and small levels of local grant funding. Some seaweed farmers have also benefited from funding schemes such as the UK Seafood Fund (*GOV.UK*, 2021). In Norfolk, Norfolk County Council and North Norfolk District Council have contributed to seaweed sector development with support and grants for farming and projects to accelerate the industry. The World Wide Fund for Nature (WWF) has also supported the development in Norfolk by aiding Norfolk Seaweed with getting their licence.

Another barrier to establishing seaweed farms is **resistance from other sectors**, such as the fishing industry. This has been a more significant challenge in England and Wales than in Scotland, where seaweed farming has been a long-standing industry in some communities. As the seaweed industry is already well integrated with other activities in Scotland, new seaweed businesses are meeting less resistance than experienced in other parts of the UK. In Scotland, there are also people who used to work in the fishing industry that now farm seaweed, which limits the competition between the two industries. In some places, local resistance also seems less prominent when the company that wants to establish seaweed production is local to the area compared to an outsider company, but this is not always the case. However, being local to the area can provide other benefits, such as knowledge of the waters and having easier access to a boat for farming activities. In the context of Norfolk, it needs to be mentioned that Norfolk has a considerably larger competition for space than other coastal locations, which makes good communication even more vital when it comes to co-existence. There are also already measures in place to ensure communication between the sectors, as there is a requirement for new companies farming seaweed to publish their intention to cultivate in local newspapers, which is open for the public to comment on and engage with.

Access to local initial processing and biorefinery facilities and skills will also be vital to scaling up and creating industries. In Norfolk, Norfolk Seaweed

will operate at a lower scale, starting by harvesting their seaweed by hand. Once their farm reaches a considerable size, they will need more workforce or harvesting equipment to handle the volume of biomass. This will be the case from the beginning for Sustainable Seaweed if they obtain their licence to farm as their site is considerably larger than the farm operated by Norfolk Seaweed (Case Study 2). For them, automation technologies and technological innovations that can aid with harvesting and other operations will be essential.

A positive trend from the growers interviewed was a general **openness to sharing information and knowledge** with other companies in the sector. Norfolk Seaweed is one of these companies interested in increasing the number of seaweed farms in the area and supporting other prospective farmers in the East of England and beyond. Additionally, Biome Algae has plans to market and sell its intellectual property so that other cultivators can access their knowledge, experience and operation models when they scale up. This is also where a UK-wide platform would provide beneficial communication channels and forums for information sharing.



Case Study 3: A UK-Wide Seaweed Sector Platform

The Challenge in the UK – Even though several active operating networks exist in the UK (See Appendix 3, Table 1), the UK is currently lacking a joint platform and a single voice for the sector.

An Example From Norway – The Norwegian Seaweed Association (NSA) in Norway is a good example of a joint national platform for the seaweed sector. The NSA was established in March 2021 by merging two Norwegian seaweed networks (*NSA, 2023*). Further, the NSA is an arena for developing complete value chains within food, feed, ecosystem services and other innovative areas with cultivated and hand-harvested macroalgae as a resource (*NSA, 2023*). For the NSA, companies for the purpose of farming, small-scale harvesting, production and/or providing seaweed can apply for membership, where membership requires buying a share in the Association and a yearly fee (*NSA, 2023*).

How This Can Be Replicated in the UK – In the UK, the main current networks could join up and create one entity through a nationwide platform, including complete value chains, while still having local industry meetings. This could play an essential role in scaling up the UK seaweed sector and supporting regional development. The platform could provide access to stakeholders in the industry, regional forums, quarterly/yearly

sector meetings, awareness webinars, and access to resources from regulators and scientific data.

Reports and evidence for licence applications and funding opportunities with forums to discuss and find collaboration partners could also be featured on the platform, enabling communication. Sharing publications and projects could also limit duplication of research done in the sector.

Another use of the forums could be collaborating with partners to apply for licences to share space at sea, which is encouraged in the marine plans from the MMO. Organisations from other sectors, such as energy companies and the fishing industry, could be a part of the platform to ensure mutually beneficial, constructive and early process communication, which could resolve any challenges before a potential licence application for seaweed cultivation. Establishing good communication routes with the long-established fishing industry will be especially important. However, for this to work, businesses across the seaweed value chain need to join and engage with the platform once it is established.

To initiate the platform, a membership model requiring purchasing of shares and monthly/yearly fees could be explored, where the platform could start with a 1-3 months free trial for new members to experience the value before committing.

Needs From the Sector. More investment for research, setting up, equipment and facilities is needed to scale up the seaweed industry in Norfolk and the rest of the UK. For this to happen, the seaweed sector needs to provide a stronger argument for why investing in the industry is a good idea and how they will get a return on their investment for both public and private funding. **Linking up with potential buyers and end-users** before starting to farm, potentially through the proposed platform, could also aid with strengthening the business plan and make investors more confident in investing in producing companies.

A unified seaweed sector platform could also enable cultivators to navigate the statutory licencing process easier as the platform could offer that **one place for information, resources and guidance** for applications. Additionally, it would create an understanding regarding which regulator has ownership over the changes that need to occur in the sector to make it more efficient, ensuring that the change points are targeted at the right organisation. The platform could therefore help signpost questions and tasks to the right people in the sector, both from a regulator side and a stakeholder point of view.

A question raised at the Seagrass EU 2023 conference and by some of the companies interviewed for this project is whether the industry can grow to the scale needed without **subsidiaries for seaweed farmers from the government**. This is an interesting concept yet to be explored further in the UK. A similar model to what was used to accelerate wind farming activities in the early 2000s could be considered, where this level of support from the government would show that the sector is a priority for development and increase the industry profile.

Energy Companies, Co-Location & Co-Existence

Current Position of UK Energy Companies and Co-Location Projects. The limitation of and competition for space is a barrier to establishing a seaweed industry in Norfolk with multiple seaweed cultivation sites. A solution to this could be to locate seaweed farms within or close by present nearshore and offshore wind development in the waters off Norfolk. This activity is often referred to as co-location or multiuse of space at sea, which can also include sharing space with other aquaculture activities such as oyster and mussel farming and lobster and crab potting. Co-location opportunities are therefore worth exploring when looking at creating a seaweed industry in Norfolk.

Presently, **Vattenfall**, a Swedish multinational energy company, has development plans off the coast of Norfolk with the construction of the Norfolk Offshore Wind Zone and was therefore interviewed for this study. Vattenfall has two ongoing co-location projects involving seaweed, the Olamur (win@sea) and the SeaMark projects. The Olamur project is in progress at Scandinavia's largest offshore wind farm, Danish Kriegers Flak, and is a proof-of-concept project to test the co-location process between offshore wind and aquaculture and learn from potential challenges that occur. At Vattenfall's Danish Kriegers Flak site, the co-location project involves the growing of blue mussels, sugar kelp, sea lettuce and dulse that are produced on lines at the offshore wind farm. A number of monitoring and research activities will also take place (*Vattenfall, 2023*).

The SeaMark project is a four-year project funded by Horizon Europe. The project started in July 2022 and is delivered by a consortium led by Ocean Rainforest comprising 25 international, cross-disciplinary partners. SeaMark has been awarded a €9 million Horizon Europe grant to upscale seaweed production and market applications across Europe (*SeaMark, 2023*). Vattenfall's engagement in the project focuses on collecting data and sharing knowledge about the technical and economic feasibility of offshore seaweed cultivation.

Equinor was also interviewed and is a Norwegian state-owned multinational company and the UK's largest energy supplier. Off the Norfolk coast, Equinor has the Sheringham Shoal and Dudgeon wind farms, where a proposal has been submitted to double the capacity of both farms. An application for a development consent order was submitted in late summer 2022 and accepted. They have now undergone a planning inspectorate examination, where a decision on the extension projects is expected in quarter one of 2024. Equinor also currently has a seaweed carbon solutions project, which is a joint industry project taking place in Trøndelag, Norway. The goal is to

develop scalable technology for open ocean seaweed carbon dioxide (CO₂) removal and assess environmental impacts, quantifying actual and potential net CO₂ removal and outlining the possibilities of quantifying seaweed carbon removal as a CO₂-offset mechanism and business case. The project is conducted offshore with a module contracted by the Faroese company **Ocean Rainforest**, a good example of collaboration opportunities in the sector. Equinor also welcomes fishing activity into the seaweed cultivation area.

Equinor's focus is on research and development to support their ambition to meet net zero by 2050 as well as their biodiversity position and contribute to a net positive impact. With seaweed, Equinor is interested in seeing the results of their project in Norway and the feasibility of the solution for future opportunities to use seaweed as a nature-based solution for carbon sequestration. They are also interested in seaweed restoration projects to support the biodiversity position of the company and are involved with an external carbon sequestration cultivation project and a couple of seaweed restoration projects.

Accordingly, Equinor is actively looking into seaweed cultivation co-existence opportunities within their operations for the future. With their current seaweed carbon solutions project in Norway, they are hoping that the biomass from the project can be made into products that could sequester carbon and potentially provide carbon credits. So far, biochar, which is a solid residue of at least 80% elemental carbon, has been the main product that they have been looking at producing, as well as the deposition of biomass to the deep sea. If not for carbon sequestration purposes, Equinor hopes that the seaweed they grow can contribute to scaling up the seaweed industry and potentially make other products in demand.

Table 4. Offshore wind farms and developments in East Anglia, which could be potential locations for co-location activities. The data is extracted from 4C Offshore’s global offshore renewable map (www.4coffshore.com, n.d.).

Offshore Wind Farms in East Anglia	Owner	Project Status	Number of Turbines
Sheringham Shoal Extension	Equinor ASA (previously Statoil ASA), Green Investment Group (GIG), Equitix Limited, The Renewables Infrastructure Group Limited (TRIG)	Consent Application Submitted	27
Dudgeon	Equinor ASA (previously Statoil ASA), Masdar, China Resources (Holdings) Company Limited. 华润电力	Fully Commissioned	67
Dudgeon Extension	Equinor ASA (previously Statoil ASA), Masdar, China Resources (Holdings) Company Limited. 华润电力	Consent Application Submitted	34
Race Bank	Ørsted Power (UK) Limited, Macquarie Capital Group Limited, Macquarie European Infrastructure Fund 5 LP, Spring Infrastructure Capital Co., Ltd	Fully Commissioned	91
East Anglia Hub - TWO	ScottishPower Renewables (UK) Limited	Consent Authorised	56 - 67
East Anglia ONE	ScottishPower Renewables (UK) Limited, Green Investment Group (GIG), The Renewables Infrastructure Group Limited (TRIG), InfraRed Capital Partners Limited	Fully Commissioned	102
East Anglia Hub - ONE North	ScottishPower Renewables (UK) Limited	Consent Authorised	41
East Anglia Hub - THREE	ScottishPower Renewables (UK) Limited	Pre-Construction	95
Norfolk Vanguard	Vattenfall AB	Consent Authorised	120 - 145
Norfolk Boreas	Vattenfall Europe Windkraft GmbH	Consent Authorised	100
Sheringham Shoal	Equinor ASA (previously Statoil ASA), Green Investment Group (GIG), Equitix Limited, The Renewables Infrastructure Group Limited (TRIG)	Fully Commissioned	88

Opportunities & Challenges. There are many opportunities but also challenges that have been discussed when it comes to the co-location topic. One challenge that has been flagged is the **insurance risk to energy companies** of having seaweed cultivation within their operation area. Furthermore, it has previously been discussed that having a co-user inside a wind farm will lead to more insurance claims and increased risks for the energy company. At the same time, the interviewed companies suggested that a co-user can also de-risk offshore development projects in terms of marine biodiversity gains and also by adding value, which de-risks investments in the overall wind park. With that being said, **for seaweed cultivation to de-risk an offshore wind project, safety guidelines and legal requirements need to be adhered to, as well as having a clear site map over the activities to aid with operations**, as co-location still has the potential of causing logistics challenges. For their security, developers will also need reassurance or an **agreement with the co-user** that they will stay at the site, as removal and decommissioning of equipment in the park would be a financial concern. UK seaweed cultivation is currently developed in nearshore conditions, where most farmers will not have experience with harvesting and monitoring in offshore conditions. Since most UK seaweed farmers work near shore, **offshore farming will likely require further training and investment into new equipment**, which can be costly for the seaweed farmer. This is also a matter to consider in Norfolk, as current and future planned wind farms located in the area are primarily located offshore and in highly energetic conditions.

Another practical concern on the energy company side for co-location with seaweed aquaculture within or nearby offshore wind farms is access to the site. These sites will also require far-reaching vessels, where **equipment and vessels** could be shared where possible, not only between seaweed cultivators and wind farm operators but also with local fishers. Conversely, it is acknowledged that extensive and specialised equipment is needed to conduct seaweed harvesting at scale offshore. The sharing of vessels between the energy companies and the seaweed cultivators could, however, be useful for monitoring purposes. An area that could be explored is to create a transition pathway for fishers into the seaweed industry to offer a secondary income and to support local seaweed operations. A barrier here is the current boat coding rules, which dictate what activities you can use a boat for, where a boat, in some cases, could be restricted to only conduct fishing activities.



Case Study 4: Co-Location & Co-Existence Opportunities in Norfolk

Vattenfall is currently exploring the opportunity to assist seaweed farmers that are interested in co-location by partnering with them and, for a small fee, providing them with a space and letting them use their contracts for the certifications needed as well as vessels, infrastructure, instalment and equipment to drive the costs down and lower the barrier to explore this option. This model could potentially solve the current challenge of setting up co-location pilot projects in UK waters to prove concepts. After the seaweed has been harvested and processed for its intended use, Vattenfall is also keen to investigate the potential of buying by-products from the biorefining of seaweed, such as gas for heating and other usage. Vattenfall has, through the interview, expressed an interest in exploring this concept in Norfolk.

Equinor is also interested in co-location with seaweed aquaculture at their sites and is currently investigating its feasibility as well as operation logistics, operational efficiency, environmental impacts, potential implications and risks, and how they could work with local communities. In Norfolk, Equinor has already explored oyster restoration as an option for their sites as well as for Equinor more broadly. Additionally, Equinor has been communicating with the local fishing community and is exploring co-existence with fishing activities inside their wind farm with specific types of gear that they can use inside the park. Collaborations like this could be in conflict with other co-existence, such as seaweed cultivation. On the other hand, wind farm co-location with seaweed cultivation nearby the development site instead of inside the park has recently been discussed as more viable because of reduced logistical challenges.

As with any project, all main partners need to see the benefit of their contribution. As well as a potential added insurance risk, the return on the initial investment for large infrastructure projects such as a multiuse project could take a long time, which makes it even more important that there is a genuine desire from the energy company to co-locate. Therefore, it is especially vital to identify benefits and value creation associated with seaweed cultivation within or nearby a wind farm. In addition to increasing the biodiversity around the site, another possible value creator for the energy companies could be seaweed carbon sequestration potential and carbon credits. This is a topic often discussed in seaweed forums. However,

carbon accounting is needed to be able to show the amount of carbon sequestered by seaweed at one particular site, something that is very complex and still under investigation by researchers. Despite that, if a good model for carbon accounting at one site could be developed, this would give energy companies a direct financial interest in having seaweed cultivation nearby or inside their parks as they then could use seaweed production to offset their emissions in other places as well as reduce the footprint of the offshore wind farm itself. The potential of using the co-located farmed biomass to contribute to the food and feed security of Europe was also mentioned as a potential value creator for the energy companies.

Needs From the Sector. For co-location between offshore wind and seaweed cultivation to take place in Norfolk and elsewhere in the UK, **good collaborations and partnership formations** will be essential. This is something that was stressed through the interviews for this study, especially because the energy companies, in most cases, do not have internal skills for seaweed cultivation. **Local skills, knowledge, collaboration and partnerships** will therefore be essential to ensure that the biomass is processed and utilised after offshore harvesting. Relationship building with local universities was also something mentioned as crucial.

However, the main takeaway from the companies spoken to in the interviews is that for the energy companies to engage with co-location projects in Norfolk and the UK, they need the **UK government to be clear about their policies and their position on co-use** as this currently is their primary barrier to consider projects in UK waters. This is mainly because of the investment risk in terms of resources and money invested in planning, resources and infrastructure if the government goes back on its statements. A report published by the UK government on their position regarding co-location and how the permitting process would work is something that could enable further conversation on co-use projects in the UK. As an example, the procedure that the North Sea Farmers has published on their website to help multiusers realise their multiuse concept in the North Sea region could be replicated for UK waters. Their multiuse procedure aims to form a predictable and transparent process towards a successful permit application for all stakeholders involved, which would be a great resource to also have in the UK (*North Sea Farmers, 2023*). The Dutch government has also been clear on its position regarding co-location, where they have set up '**Community of Practice North Sea**' to stimulate the development of multiuse pilots by bringing interested parties together, sharing experiences and learning from each other in a context of existing and developing spatial and social claims. This development is part of the **government's strategy** to find a balance between offshore wind energy development, nature conservation and seafood production (*Steins et al., 2021*). This is also

something that could be explored in the UK that would encourage both energy- and aquaculture companies to investigate co-location opportunities further.

Another barrier identified is that seaweed cultivators have been approaching energy companies individually to discuss collaborations. From the energy companies' side, it would create a stronger argument for investigating co-use opportunities if several **seaweed companies cooperated** to start a conversation with the wind farm developers. Establishing multi-partner co-use projects could further increase the awareness of such projects, making a compelling case to the government for why we should create more multiuse spaces. On the energy company side, some of the wind farms in the UK are run by consortiums (Table 3), which can make it challenging to start conversations on multiuse. Furthermore, many energy companies have been operating for a long time and have reached a considerable size where decisions take time. Because of these considerations, it has been recommended by the developer companies that seaweed farming companies interested in co-location are prepared to be fast and flexible so that when the government hopefully releases their updated policies on co-use at sea, they are ready to take advantage of the opportunity and have developed plans prepared to be discussed with energy companies. Multiple companies working together on multiuse projects could also reduce the costs of the project and allow for asset sharing and coordinated operations.

A couple of other challenges and ideas were also highlighted by the companies interviewed for the study. The current lack of a single voice for the seaweed sector is a barrier when it comes to enabling other activities such as co-location and multiuse of marine space. Another point was around the importance of **collaborating with the ports** regarding operations and logistics around co-location, especially around harvesting of biomass and vessel activity. In Norfolk, many ports could be used for this, such as Great Yarmouth, Wells and Kings Lynn. Port accessibility and availability are essential and would require further investigation if Norfolk wants to scale up the seaweed industry considerably in the future. As mentioned previously, it would greatly aid the industry if multiuse projects developed business models that could be copied by others as well as recorded and shared results to enable learning from all aspects of the operations. This could also help overcome another challenge seen with co-location, which is that there are few proven aquaculture technologies for offshore applications. Lastly, the topic of subsidies from the government for co-location and cultivation initiatives was considerably mentioned to enable the upscaling of the UK industry.

Service Providers

Current Status of Service Providers Supporting the Seaweed Industry in the UK. Seven companies providing services for the seaweed industry were interviewed for this section. One of those companies offering processing services is **Eco-Cascade**, based in Kyle of Lochalsh on the West Coast of Scotland. The company has been operating since the 1st of April 2023 and processes fresh seaweed from local farmers at their facility. They can also support seaweed cultivators from further afield, but then the seaweed will have to be delivered frozen. The services that Eco-Cascade provides include washing, drying and storing or alternatively washing, chopping and refrigerating the seaweed before distributing it. Eco-Cascade has received full funding from the Scottish Government for infrastructure and equipment for the plant, and Highlands and Islands Enterprise has also supported with funding for staff.

Eco-Cascade is the only service provider to offer processing support to seaweed farmers in this area in Scotland, and the seaweed they process is either stored, dried on site, returned to customers or sent off to end customers like a biorefining company. Eco-Cascade mainly works with *Alaria esculenta* (winged kelp) (See Picture 3 below) and *Saccharina latissima* (sugar kelp), the main species grown on the West Coast of Scotland. So far, in 2023, they have supported three farmers, with possibly three more being supported in 2024. Another processing company interviewed and operating in Edinburgh is **Biomara**, which is developing novel technology and a unique bespoke biorefinery concept to valorise different levels and components of seaweed. Biomara also connects seaweed farmers with markets. They are still in an early research phase but are looking at offering processing services for a couple of different seaweed species to support local farming needs. As Norfolk currently does not have any processing facilities for seaweed, companies like Eco-Cascade and Biomara are good examples of processing companies that aim to support multiple seaweed cultivation sites in an area.

WWF supports the seaweed industry with grants and funding for projects and aims to facilitate sustainable growth of the industry in the UK. Some of the ways in which WWF is contributing to the industry acceleration is by enabling conditions in the UK such as social- and political licence, supporting producers directly and building demand for seaweed in targeted areas where, if applied, it could support broader positive impact such as carbon, nitrogen and phosphorus improvement for avoided emissions, biodiversity restoration and food provision. WWF also helps build research and evidence needed to verify the claims being made around seaweed aquaculture, whether that is in terms of social or environmental benefits. To

deliver the associated benefits, the seaweed industry in the UK needs to reach a significant scale, where the WWF is keen to support the industry to get to this stage.



Picture 3. *Alaria esculenta* (winged kelp) from the SAMS seaweed farm in Oban. Photo from Cefas taken in May 2014.

In Norfolk, WWF is currently funding a “whole scale” project looking at how the management of an area can be improved so that it includes activities on land, rivers, and the ocean, considering the ecosystem as a whole. Hence, WWF is currently working with several stakeholders in Norfolk that have specific projects in the area. This includes supporting Norfolk Seaweed with obtaining a marine licence for seaweed aquaculture. Additionally, WWF has one research project, being run by the Westcountry Rivers Trust, focused on mapping the flows of nitrogen and phosphorus from the land, predominantly from sewage and agriculture, through the freshwater system and understanding how much is sequestered or remediated first by salt marshes and then potentially by seaweed. Based on the excess nutrient availability off the coast of Norfolk, WWF is trying to

understand, as a part of this study, what the yield of a seaweed farm (farming a couple of different species) here could be.

WWF has also recently won funding from the Coop Carbon Fund to complete seaweed biostimulant trials on farms in East Anglia to try to understand how much synthetic fertiliser could be replaced by seaweed-derived biostimulants, the associated costs as well as the impact on yield, soil carbon and soil health. With their work, WWF hopes to increase the understanding in Norfolk of why seaweed cultivation could benefit the area and thereby contribute to the social licences to operate.



Case Study 5: Collaboration Enabling Seaweed Trials in Norfolk Agriculture

In addition to Norfolk Seaweed gaining their seaweed farming licence, the prospect of Sustainable Seaweed establishing a larger cultivation site, and local companies eager to include seaweed in their product offering, there are several seaweed-related projects currently taking place in Norfolk.

Holkham Estate, near Wells-next-the-Sea, is working on a project with **Norfolk Seaweed** and **Central Pharma Biotechnica**, which specialises in agricultural biostimulants and biofertilisers, conducting field trials for the production of biostimulants from seaweed and of fibre (the by-product from the extraction process that can be used as organic fertiliser). These products can be used to make agriculture activities more environmentally friendly, and Holkham Estate is working in partnership with three other farms to share data and perform trials.

Furthermore, Holkham Estate is also interested in contributing to other parts of the value chain in Norfolk and has equipment and land available that could potentially be utilised to support the seaweed industry. Thanks to its proximity to Norfolk Seaweed, Holkham Estate could host processing and biorefinery facilities. They are also interested in having conversations with other local companies in the industry and partnering up to support local developments where possible.

Additionally, Holkham Estate is keen to potentially trial seaweed applications in their cattle feed. This could be investigated using locally sourced seaweed, although native species of brown seaweed have been shown to decrease the methane concentration of total gas produced at the 5% inclusion level in a study from 2022 (*Künzel et al., 2022*), compared to red species of seaweed that have shown 80% reduction of emissions (*Roque et al., 2021*).

The Seaweed Alliance based in Wales has been supporting the seaweed industry since 2017, representing the voice of the seaweed sector in the UK. They have recently led Project Madoc in Wales, a feasibility study to look at the potential for a seaweed industry in Wales and building it based on cultivated native seaweed species. **Seas the Opportunity** is an additional service company linked with the Seaweed Alliance, focusing on developing the wider blue economy.

Cultivocean is a London-based company looking at project potentials all over the UK. Their journey in the sector started by looking at seaweed farming at scale co-located with offshore wind farms. However, their focus has now shifted towards biodiversity gain and how to improve the biodiversity within wind farms. Their new model offers a platform that enhances biodiversity on the seabed where there are anchor points that allow for scaling up of aquaculture as needed. Cultivocean then sublets the sites to farmers and holds the insurance policies towards the wind farm operators. A small lease fee paid by the seaweed farmer would cover the licencing, the insurance and day-to-day operations. The seaweed model of the Cultivocean platform focuses on creating special-purpose vehicles with the wind farm operator and other companies looking for biodiversity net gain or marine net gain as well as cost mitigation. The model also looks at how costs can be recovered through credits, carbon dioxide removal and biodiversity gains so that co-location is incentivised, which will aid with scaling this opportunity much quicker. Companies like Cultivocean that has experience with working with offshore wind farms can also help with bridging the gap between how seaweed farmers and offshore wind farm providers operate in terms of standards, best practices, procedures, quality, and health and safety. Sharing such knowledge could further increase the wind farm operator's confidence when it comes to establishing and managing co-location projects.

Data and research to provide an evidence base for seaweed cultivation is becoming increasingly important in the industry. Two companies offering such services are **ARC Marine**, based in Devon and **ANB Sensors**, located in Cambridge. ARC Marine is an eco-engineering company that can look into the ecological impacts of a seaweed farm and the selection of species for an area. They also supply moorings (including for seaweed farming) with carbon-neutral and plastic-free concrete made from recycled materials and have supported Biome Algae at their sites. ARC Marine has also worked towards demonstrating co-location possibilities and offers advice on moorings to find the best solution and design for a specific site. ANB Sensors specialises in pH sensors and is interested in supporting the seaweed industry in Norfolk. They work with partners to monitor the environmental effects of inshore seaweed farming and farming within offshore marine turbine clusters. Current customers include aquaculture, ocean and freshwater environmental monitoring companies and research bodies in the UK and worldwide. ANB Sensors also work internationally to provide sensors for monitoring the impacts of infrastructure on water quality.

Opportunities & Challenges. One of the main barriers when it comes to service providers in the seaweed sector is the **availability of processing companies and facilities**. Similarly to new seaweed cultivation companies, the **initial set-up costs** for processors are high. Companies that want to establish a processing facility will, therefore, likely require funding to pay for initial infrastructure, which can be difficult to obtain. A way to overcome this could be for processor and biorefinery providers to make long-term contracts with farmers to provide security and thereby attract more investment. Processing is also a labour and energy-intensive part of the seaweed value chain. A couple of other factors that need to be considered are that processing capabilities in terms of volumes in the first year usually are less than expected and also take longer than many anticipate, so it could be wise to start with a lower biomass volume before building up the capacity. There could also be unanticipated issues with brand-new machinery when first fitting it into the operations, so this should be factorised into the set-up time. Different processing will also be needed for separate seaweed species as they dry differently from each other.

Another element to consider for processing facilities is the **amount of biomass** that can be processed simultaneously. For example, Eco-Cascade cannot part out more than 150kgs at a time because the weight will compress the seaweed in the middle that will consequently anaerobically digest. **Storage** for seaweed is a further factor to consider, as the processing facility needs to have enough space to store the seaweed coming in and refrigerate it until the machinery is available for processing. There will also likely be a backlog of seaweed to process, especially if the facility supports several seaweed farms, so storing is essential. Having a refrigerated container is, therefore, something to consider. However, the freezer needed for seaweed processing needs to be able to go down to -30 °C and can be costly. It could therefore be considered to freeze and store the seaweed offsite at a bulk freezing facility if this is available in the area. This might be a cheaper option for the seaweed processing company, as such a freezer, in most cases only will be needed for a part of the year because of the nature of the seaweed harvesting cycle. However, sharing facilities such as freezers can reduce operational costs, though it will require good planning. The potential of sharing the plant outside the main seaweed season with other sectors needing the same facilities could also be investigated. Processing equipment purchased and meant to support the seaweed industry can be used for other drying purposes over the winter, such as for grains from the distillery industry. Processing seaweed from wild harvest could also ensure year-long operations, where this can be done sustainably.

If the processing company is supporting more than one seaweed farm, it would be beneficial to create a **schedule during harvesting season** as the cultivators are likely to harvest at similar times, and there is a need to fix the

biomass shortly after harvesting. This is also why most processing facilities start with supporting one farm and then build up their services around that before eventually supporting multiple farms. Various **types of processing** can be used to stabilise the biomass, where drying is the most labour and energy-intensive process. Hence, it is crucial to establish whether the end product really requires extensive drying of the seaweed or not. This is therefore an opportunity for the processing company to save both time and money but requires that the end user and market are known.

With the processing of seaweed intended to be used for food production, there are **food safety procedures** that need to be followed. This can create a challenge for the processing facility if they support more than one seaweed farmer, as it will require tighter scheduling procedures. This is particularly true for plants that handle some seaweed that will be used in food as well as seaweed intended for other uses because the biomass which will be used in food needs to be scheduled for the early part of the season before biofouling takes place (which can drastically reduce the seaweed quality). Seaweed for other purposes will be scheduled for later in the season after all the seaweed needed for food applications has been processed. The processing schedule produced for the plant also needs to be fluid as issues with harvesting might occur where a gap can be filled by another company for efficiency as well as aid with the limited availability of the processing plant. Good communication with the seaweed cultivators is therefore essential. Lastly, it is important not to mix up batches from different farms for **biosecurity** reasons. Therefore, if the plant only has one drying system, only biomass from one customer can be dried at one time. Fermentation opportunities could be further explored in the future to extract bioactive compounds from seaweeds and to potentially overcome many of the barriers currently experienced with processing as the biomass would be managed quickly, as well as removing the need for large and expensive drying and freezing facilities.

From the interviews conducted, it is clear that **more research on the techniques of processing and customer feedback for processed seaweed products** is needed. For processing companies that sell treated seaweed to different markets, feedback is essential to improve and optimise processes and product development. Getting in front of customers, building awareness and sales outreach were other barriers mentioned by the processing companies. Companies like Biomara could help connect the growth and potential in the industry to those in the markets and companies by developing specifically targeted products that are in demand. **Access to talent** in terms of seaweed knowledge and skills needed for process and product development is also a challenge for this part of the value chain. In Norfolk, a processing facility of size will be needed to host multiple farms in the area. Addressing the local skills gap in the seaweed sector early on and

providing educational opportunities will therefore be important. Companies that are interested in setting up processing facilities in Norfolk could also **collaborate with more established companies** elsewhere, like Eco-Cascade in Scotland, to learn from their experiences when it comes to optimal operations and logistics and the skills required.

UK monitoring companies supporting the seaweed industry appear to provide their services mostly abroad. Even though there has been a more significant focus on the need for data, the perception is that many companies in the UK still are not fully aware of what the monitoring equipment can be used for and the potential it has to help scale up the seaweed industry. This also goes the other way as many new monitoring companies are still learning about the UK seaweed and aquaculture market and establishing contacts. Like most companies in the UK seaweed value chain, sensing and monitoring companies interviewed also stated that most of their funding comes from internal investment or unspecific Innovate UK funding competitions. An opportunity mentioned several times throughout the stakeholder interviews was the potential of creating **standardised monitoring approaches**, which would highlight the need for these services. Monitoring of environmental impacts around a seaweed farm will also help get access to long-term impact evidence of seaweed aquaculture and help scale up the sector in the future, where artificial intelligence and machine learning capabilities will be essential to provide this data for the industry and deliver accurate results. However, for this to occur, access to seaweed cultivation sites will be needed for testing and modelling.

Needs From the Sector. There is a need for **strong network building and knowledge sharing** to support the seaweed industry. This is also needed for seaweed cultivators to know who to contact for different services and support. From a processing view, if the industry regulators want to grant more licences that will encourage more companies to set up and start farming seaweed, there need to be available processing services in the local area to fix the biomass once it is harvested. Accordingly, there is no point in scaling up local farming activities and available biomass if there are no processing facilities available. To prevent this from happening, there needs to be more funding and support available to establish processing and biorefinery plants. To secure funding, the processing companies will likely need to find collaborators and downstream partners, which could be found through the UK-wide platform proposed.

More research in processing knowledge will also be required when scaling up the industry, where collaborations between new and more experienced processing plants and knowledge sharing will be essential. **Visits to other**

countries that have a more established industry to see how other places do processing and how they tailor it to fit the needs of local seaweed farmers is another way that could support the scaling up of the industry in the UK. Crown Estate Scotland is also working to make sure that everyone who applies for a licence to cultivate seaweed has a robust plan for their operations, including how and where they are going to get their seaweed processed after harvesting, as well as what their end markets are.

Products

Current Position of Companies Involved With Seaweed Product

Development in the UK. Seaweed has many opportunities for implementation into our food system, products and materials. On the materials side, there is a lot of research and development taking place and new products appearing on the market. Most companies operating in this space are using a variety of seaweed species, where some use refined extracts and others unrefined biomass in their products. Because of the high current price for UK-grown seaweed, many companies are sourcing their seaweed from outside of the UK. These companies might also get their seaweed from abroad because they require large biomass quantities. Due to the relatively small number of present seaweed farms in UK waters, UK seaweed cultivators are currently not able to meet such demands, making it too unreliable for companies to source their seaweed from within the UK. As an example, **Notpla**, a London-based all-natural seaweed and plants biodegradable packaging solution company, is currently sourcing their seaweed from Northern Europe, Southeast Asia, and South America. This seaweed both comes from wild harvest and cultivation and is bought either as already processed extracts or as dried biomass. Most companies acquiring seaweed to include in their products prefer buying extracts or biomass that has been dried to a particular specification, as the companies do not usually have in-house expertise and machinery when it comes to processing raw materials, which requires milling, drying and storing facilities.

Regarding product demand, the companies interviewed for this study, such as Dorset Seaweeds and Cornish Seaweed Company, stated that most of the demand for their products comes from local or domestic customers. Many UK companies in this part of the seaweed sector value chain also operate on a business-to-business model and do not sell directly to end users.

In terms of accessing grants and funding, businesses operating in this space have experienced the same challenges as other companies in the seaweed industry. As funding sources, especially London- and West England-based companies have benefitted from local awards that have encouraged interest and investment. Norfolk-based businesses have also reported through the study that they have received support through local Innovate UK services and councils. On the contrary, it has been challenging to secure larger grants for development needs. The support received has mainly been mentoring to start up a business, help to navigate different funding opportunities and writing of grant applications.

Opportunities & Challenges. Wild harvest is still the primary seaweed production method in the UK. Consequently, a considerable amount of the biomass available on the UK market for purchase to be used in products is wild-harvested seaweed. **Wild-harvested seaweed is also often cheaper and available in larger quantities** than cultivated seaweed, which currently is a barrier for UK seaweed cultivation companies when it comes to finding markets for their produce. Seaweed cultivation is seen as the most sustainable way to obtain biomass, and companies interviewed for this study that currently are sourcing wild stock are working with their partners to manage the **transition from wild harvested to cultivated seaweed** to ensure sustainable industry growth. However, it is worth mentioning that companies interviewed for this study that currently use wild-harvested seaweed in their products work consciously to only source wild seaweed from sources that harvest under strict quotas and that follow local guidelines.

For example, **Dorset Seaweeds**, a producer of biostimulants from wild-harvested seaweed, has local garden centres in Dorset as their main customers. They are interested in supplying the wider UK agriculture industry, but the amount of biostimulants needed to supply this sector is unachievable with their current business model, as this would require large quantities of seaweed for production. Dorset Seaweeds is presently operating in small batches to keep it sustainable with their wild harvest and would have to start cultivating seaweed or sourcing seaweed from other farmers to be able to deliver to additional markets. This then presents other obstacles because of the present barriers to setting up a cultivation site, high price points of UK-cultivated seaweed and the ease of obtaining this locally. Another challenge for Dorset Seaweeds and other UK companies producing seaweed products is competition with **similar products currently available from overseas companies** at a considerably lower price and a higher volume. For this to be resolved, the end user needs to see the value in paying more for a local product supporting local businesses. This is especially because the price point for UK-grown seaweed is unlikely to drop below seaweed prices from the Asian market because of lower labour and operation costs. More research into UK seaweed product development is therefore needed to **add value to the components extracted** and thereby increase the value of UK-produced products.

There are also UK product manufacturing companies that use **seaweed that cannot be farmed in UK waters** and that are not found native to the UK coast, such as many red seaweed species. These companies therefore have to get their seaweed from elsewhere as most seaweed cultivators in the UK grow native brown seaweed species. Attaining raw material supply sustainably is consequently a challenge for the product-producing companies to grow. A way to overcome this is to grow the seaweed species

in demand that cannot be farmed in UK waters in **cultivation tanks on land**. However, the companies interviewed for this study that currently use seaweed that cannot naturally be sourced in the UK were all interested in opportunities to access and investigate using locally farmed seaweed. To enable this, collaborations and partnerships to create the infrastructure within the sector will be needed. Additionally, **establishing solid and strategic partnerships with local seaweed farmers** will be vital to sustainably sourcing the biomass and extracts and ensuring availability, as product demand could exceed the seaweed supply. Relying on a single supply of seaweed to obtain their raw material is also a risk factor for the business, so securing multiple suppliers is vital to ensure that the biomass needed is available. As an example of this, Notpla is already collaborating with other companies across the seaweed value chain as well as research groups to try to find ways to incorporate new UK native species into their materials to mitigate their environmental impact.



Case Study 6: Opportunities for Complete Local Supply Chains in Norfolk

There are companies that currently do not have seaweed products in their portfolio that would like to explore this resource to add to their offering. One of the companies in this category is the Norfolk-based company **Roll Materials**, which would like to use seaweed as a raw material in their biomaterials and manufacture this locally. They are also looking at using kelps and other brown seaweed species for their material development, which could be sourced locally if the volume required was available, enabling them to reduce logistic costs and their carbon footprint.

Like **Notpla**, Roll Materials would also consider tailoring and researching their product composition to be able to source the seaweed species available from local farmers, as sourcing the biomass from outside of the UK is not an option they consider. For their operations, Roll Materials would purchase dried seaweed before extracting the needed components and could be one of the most significant users of seaweed in Norfolk. Their aim is to have a pilot plant set up within two years and start production within three to four years. For their first product, they are targeting the agriculture market by looking at creating a mulch film to replace the current low-density polyethene film used in farming. This presents a great opportunity for a complete Norfolk supply chain and will also support local agriculture and farmers who have expressed an interest in the product to make their operations more environmentally friendly.

For the import and export of seaweed products and raw materials, it is presently found **difficult to navigate the regulations** around many seaweed-based products, including single-use plastics, for companies developing alternative products using seaweed. This is a potential barrier for the seaweed sector development as the difficulties with adhering to regulations and moving materials could impact where a company decides to place their operations; in a worst-case scenario, this can lead to a company moving its operations abroad.

A last point to discuss with UK-produced seaweed products is the **vast opportunities and diversity of end products available**. This brings great prospects for the sector but could also be a barrier as the supply chain and infrastructure need to be built to support the development. Hence, **focusing on too many products could therefore prohibit growth**. A way to tackle this could be **for each regional seaweed industry to find its unique selling point (USP) so that efforts can be focused on delivering the specific product, including seaweed production, processing, manufacturing and distribution capabilities**. A UK-wide seaweed platform could also help identify the UK's USPs and aid with building up an international competitive offering. This could additionally enable the **settling of price points**, which is needed to make a local and UK seaweed sector viable and bring certainty to business models, processes and the route to market. For this, it should be considered where seaweed products sustainably could compete with other products in demand in the UK, as well as focusing on creating products from seaweed species native to the UK.

For UK seaweed food products, smaller-scale farming and wild seaweed harvest currently give the best quality and control. However, the aim for the future is that large-scale seaweed cultivation will be able to provide the same standards. UK-cultivated seaweed at scale also has opportunities in the biostimulant market and replacing high carbon products and petrochemicals in current plastics.

Needs From the Sector. It is clear from the companies interviewed that **local and UK seaweed availability is the most significant barrier** for companies to have a complete domestic supply chain and that **good communication between seaweed farmers and the companies** buying/using the seaweed will be needed to secure this. This is especially important regarding the specific species and volumes available from the cultivator and what is needed for production from the company using the seaweed. Furthermore, because of the growing cycle, there needs to be an extra focus on communication around the quantities available as the seaweed biomass will not be accessible in continuous supply. However, as most of the seaweed will undergo initial processing and be purchased either dried,

frozen or as extracts and not as fresh biomass, this should not be too big of a challenge. **Partnership agreements between cultivators and producers** will also benefit the seaweed farmers and their investors as it will ensure the demand and return on investment.

More public education and awareness around seaweed to justify the higher price of products made from local seaweed and to understand the value of UK-grown products (instead of importing biomass) is also needed. The price of seaweed and products could be driven down by scaling up the sector and overall UK seaweed production, but with the current volume of biomass produced in the UK, the prices are likely to remain high for a while yet. To be able to further explore using local seaweed in their product development, companies have stated that **connections to local universities and expertise through networks** will be essential for the research. Accordingly, strategic partnerships will be vital to scale up the UK seaweed industry, drive the costs down and establish local and domestic supply chains, where companies creating seaweed-based products also are requesting a unified platform that brings all the stakeholders together.

Seaweed Activities in the Netherlands

Current Status of the Overall Dutch Seaweed Industry. Similarly to the UK, the Netherlands is also building their seaweed industry, and most people in the sector will have heard about the North Sea Farm 1 project funded by Amazon. The farm will be the world's first commercial-scale seaweed farm located between offshore wind turbines off the coast of the Netherlands, designed to test and improve methods of seaweed farming while researching the potential of seaweed to sequester carbon (*Amazon, 2023*). As knowledge sharing is a central focus of the SEA project, companies across the value chain in the Netherlands were contacted for information about how the industry is developing there. However, only two companies were interviewed for this study after inviting 12 organisations to participate, which might limit the overall insight of the industry.

One of the companies interviewed for this purpose was **Hortimare B.V.** located in Heerhugowaard in the Netherlands. The company has a mission for breeding seaweed and has a passion for reforestation, operating since 2011 and serving a global market. Hortimare works at the front of the seaweed value chain, delivering seaweed seedlings to growers and researching new species and breeding methods. Additionally, they are working towards breeding specific species or crosses of seaweed, yield improvements, breeding specifically for temperature and disease resistance and for particular compounds that are wanted by specific industries.

Hortimare's main focus is on kelp and supporting kelp growers that need seedlings either directly seeded or twine seeded that can be wrapped around their cultivation lines. For direct seeding, Hortimare uses a specific glue, which hopefully will lead to upscaling of seaweed cultivation in the future. For the seedling market, Hortimare has benefitted from being an early mover in the industry and has few competitors, the closest being SAMS in Scotland and Seaweed Solutions in Norway.

The **Royal Netherlands Institute for Sea Research (NIOZ)**, located on the island of Texel and in Yerseke, in the Netherlands, is the Dutch national oceanographic institute and was also interviewed for the SEA project. Their primary focus is to research selected seaweed species to investigate issues such as how these species react to elevated water temperatures. NIOZ also offers services for research purposes.

The sector in the Netherlands is currently benefiting from EU funding as well as government funding for projects. Based on the interviews, local governments have been more reluctant to provide support in the Netherlands and have fewer pots of money that match seaweed projects. The grants offered by local governments have mostly been smaller, and

businesses often have to rely on investment from their shareholders or angel investors. This is not distinct from the current situation in the UK. However, the industry in the Netherlands is still gaining from larger cross-country and EU-funded collaborations such as the UNITED and SeaMark projects.

Opportunities & Challenges for Collaboration. Unfortunately, no seaweed farmers in the Netherlands were interviewed for this study, though it seems like businesses across the value chain in both the Netherlands and the UK are experiencing many of the same bottlenecks. One challenge that was comparable across the two countries is that it is difficult to make profits in the seaweed industry and the need for investments in the sector for it to be able to scale up and be viable. The progress in accelerating the industry in the Netherlands is currently slow, and there is a need for more support from the government. Funding into processing technology and biorefinery capabilities is especially needed, but for the industry to move forward, investment is required across the whole supply chain, from seaweed cultivation to the production of end products.

The importance of **robust networks** is also a focus in the Netherlands, especially when it comes to establishing licences and regulations that are not too strict. In the Netherlands, current policies are strict on where seedling materials can originate from, as they now need to be from an area close to the farm site. This could be a potential challenge for the growth of the industry in the Netherlands and could limit farmers if they want to move the location of their farms.

Farmers in the Netherlands have, like the industry in the UK, had some reluctance from other marine industries, where especially the shellfish farming community have shown resistance. However, this has in the Netherlands been overcome by developing the North Sea Programme for 2022-2027 (spatial planning), which highlights how the North Sea is partitioned and how to achieve good environmental status in one of the most intensively used seas in the world (*North Sea Programme 2022-2027*, 2022). It is also noted that seaweed companies in the Netherlands have found it more **challenging to collaborate with the UK due to Brexit** and the changing import and export regulations.

As mentioned, the Netherlands focuses on strong network building, where the North Sea Farmers is their central network organisation that hosts events and provides communication opportunities for the industry. This platform is seen as essential for the sector to share knowledge and bring the whole value chain together. North Sea Farmers is also working as a marketing channel for seaweed opportunities and acts as a voice for the industry. Additionally, the North Sea Farmers has an offshore test site located 12 km off the coast of Scheveningen. The test site is a breeding

ground for start-ups and scale-ups that want to test their innovations in demanding offshore conditions, and a permit has been issued for a 6 km² site, divided into six plots, all covering 1km² (*North Sea Farmers.org*, n.d.). Networks like the North Sea Farmers allow knowledge sharing between different industries in the Netherlands, for example, collaborations between the shellfish and the seaweed industry in specific areas through the North Sea Programme.

Models like NIOZ, where shareholders can **rent facilities** (e.g. tanks) from the institute to conduct experiments, could be relevant and replicated in the UK. This model is similar to what has been seen in South Korea, which currently is one of the largest seaweed producers in the world. The industry in South Korea has several novel features, such as most of the research being done on improving seaweed seedlings and producing strains that can handle the future climate with increasing water temperatures, all funded by the government. NIOZ also **publishes** all their results, which can be accessed by the rest of the industry and benefit the seaweed sector not only in the Netherlands but also elsewhere. There is also an opportunity for universities in the Netherlands and the UK to collaborate more closely and **exchange data and research facilities** with the results to be shared to benefit both industries.

Further collaboration opportunities could be for growers from both countries to cooperate regarding producing enough biomass to meet buyer demands. A **seaweed farming cooperative exchange model** could be explored here, where farmers could grow seaweed and sell it into an exchange, which then would supply the seaweed to buyers who are interested in larger quantities. **Sharing of facilities for processing and refining** could also be explored as a part of the partnership, where the profits can go back to help develop the farms and scale up the cultivation and facilities further. The profits could be equally divided amongst the seaweed farmers depending on how much crop the individual farms contributed with. Another benefit of such a model is that the farmers could access larger customers and negotiate a set price for the seaweed, tackling the current price point issue for UK-produced seaweed. The possible collective exchange could additionally be expanded to include other nearby countries, such as Belgium and Denmark and could protect the supply of biomass to end users from potential supply chain disruptions.

Some collaboration between the countries is already taking place, where Hortimare is one of the leading seedlings suppliers to the industry in the South of England. There are also ongoing collaborations to create a biorefinery processing plant in Wales to support the acceleration of the industry there. The sector in the UK can similarly learn from industry best practices elsewhere, like the East Coast of America, which currently has a

vibrant aquaculture economy, as well as seaweed industries in Asia, where cooperative models at scale are more common.

Main Takeaways That Could Support Seaweed Industry Development in Norfolk

The findings from the interviews conducted for this report show that a seaweed industry in Norfolk has promising opportunities but faces the same bottlenecks and barriers seen across both the UK and Dutch seaweed sectors, which needs solutions for the industry to accelerate and meet future demands. We have identified six recommendations/solutions that can support the growth of a seaweed industry in Norfolk.

1. Facilitate the creation of end-to-end Norfolk supply chains

In Norfolk, the aim is to create a seaweed industry that supports the local community and delivers prosperity and environmental improvement. **Building local supply for the whole value chain** should also be in focus, as a seaweed industry in Norfolk could include not just producers, processing and distribution businesses but also the establishment of seaweed service companies (e.g., consultancies) that could bring additional economic value on a local scale. Another learning point that could be implemented in Norfolk to guarantee supply chains is **long-term contracts between collaborators in the value chain**. This could be initiated through local networks such as the AIP or the proposed nationwide seaweed platform. Additionally, this would reduce the financial risk associated with large set-up fees and equipment purchasing for local companies.

The **River Waveney Trust** is a local charity that could aid with linking up the supply chain in Norfolk. The River Waveney Trust is located in South Norfolk and North Suffolk and is interested in supporting a seaweed industry in Norfolk through the work that they are doing with the Waveney farming cluster and local agriculture. Consequently, River Waveney Trust can help link up local agriculture organisations and companies in the seaweed industry. Hence, it is in their interest to facilitate introductions to farmers for field trials and explore seaweed as an option to lower the nutrient levels in local waters, including nitrogen pollution from farming. **Facilitation support with the local agriculture community** will also be essential to share information about seaweed capabilities and how products such as fertilisers are made, what is in it and how to use it. How seaweed biostimulants and feed perform versus chemical fertilisers or animal feed currently used will also need to be understood, as well as associated costs. It is likely that the farmers would want to see additional benefits to reducing the amount of chemicals in the fertiliser they use, such as larger yield returns and improved soil health.

2. Focus on seaweed product development that supports Norfolk's agricultural sector, the local food industry and development of bioplastics

Another factor that could help accelerate the industry is **identifying Norfolk's USPs**; product development to support the county's agriculture activities, such as **biostimulants and animal feed**, could be a good focus. In fact, the total farmed area in the East of England is 1,398 thousand hectares, justifying this focal point (*GOV.UK*, 2023). Considering the local interest in bioplastics and the recent investments to support local food manufacturing with the Broadland Food Innovation Centre, as well as the capabilities at the Quadram Institute (specialising in global challenges in human health, food and disease), it is proposed that **Norfolk USPs could be centred around the use of seaweed in agriculture, food and bioplastic applications**. Building an industry based on specific end products is needed to make a local industry viable and bring certainty to business models, processes and the route to market. However, it should also be considered that delivering products for these industries will require **available biomass at scale** to meet the demand.

Seaweed farming in Norfolk could also offer **transitional opportunities for commercial fishing activities**. Hence, it is essential to collaborate and communicate with local fishing and potting communities regarding the potential opportunities a local seaweed industry could bring. However, it is also important to understand their concerns and worries and work together to find the best solutions, which could be done through **education and awareness sessions** with local groups as well as through current networks such as the AIP. A prospect for partnerships between seaweed cultivators and the fishing industry is especially welcome when it comes to **sharing operations and equipment in the future, as well as exploring co-existence**. Additionally, a local seaweed industry in Norfolk could provide alternative jobs for people living in coastal communities, such as harvesting and initial processing of seaweed, which are both labour-intensive jobs. There is also the opportunity for co-location with energy companies at present and future wind farms in Norfolk waters (see the co-location section on page 22, as well as Case Study 4 on page 26).

3. Create a Norfolk-based testbed for seaweed cultivation

Trial opportunities for seaweed co-cultivation activities would make it attractive for other seaweed farmers to establish themselves in Norfolk, where it could be an opportunity for **Norfolk to create a testbed for seaweed cultivation**. An initiative that could enable this is the AEZ project delivered by Additive.earth (see Case Study 1), which is interested in doing a pilot project in Norfolk and collaborating to make that happen.

4. Utilise business cluster networks to collect, monitor and share industry data

There are multiple marine protected areas in and around Norfolk that need to be considered when planning for projects and how seaweed cultivation activities will impact the species and habitats in the area. In this context, it will be important to focus on **monitoring and data collection** in terms of biodiversity and features that are of interest to future seaweed farmers and regulators, and that can be shared for transparency purposes and support future development. Access to monitoring environmental data and yields, for example, from Norfolk Seaweed and future farms such as Sustainable Seaweed, will also be important, as the energetic conditions in the North Sea increase the risk of losing crops during autumn and winter storms. Finding local monitoring and sensing companies through the suggested unified seaweed platform or local networks, such as the AIP, could be utilised to secure data collection for additional features such as currents, nutrient status, temperature, turbidity, crop health, readiness to harvest and pressure on moorings. The newly established Space East cluster also offers an opportunity for monitoring collaboration by providing access to companies with expertise within earth observation technology for data collection at potential or current cultivation sites.

5. Build a local biorefinery and seaweed nursery

In Norfolk, a **local biorefinery** would have a positive and potentially transformative impact on a seaweed industry, allowing the opportunity to explore additional local supply chains. For Norfolk to host a seaweed industry, more cultivators need to farm in the area; a local biorefinery could encourage other companies to establish seaweed farms in Norfolk. Norfolk Seaweed has also expressed an interest in having its own **seaweed nursery** in the future that could supply other growers in the region with spores from native seaweed species. They are also keen to **share facilities** with other seaweed farmers in the future and **share their learnings and expertise**. Both a biorefinery and a nursery facility in Norfolk could represent an opportunity for local job creation. **Knowledge exchange** between regional companies in the sector will also be essential as the sector grows to overcome other industry barriers, such as reducing the carbon footprint of operations and supply chains, as well as collaborating with local colleges and universities to develop skills.

6. Research the potential for seaweed to be used as an energy source

Other exciting opportunities mentioned for Norfolk by the companies interviewed include seaweed cultivation to reduce the impact of other

activities, such as thermal discharge from nuclear power stations and erosion protection. Another exciting prospect is to use the seaweed harvested to **produce energy in the form of gas after extracting the high-value elements** for other industries. This is an interesting possibility as Norfolk already has the infrastructure in place with gas pipelines that tap into the main UK gas supply route, as well as extensive anaerobic digestion capabilities driven by the agriculture sector. However, this concept needs more investigation and research before it can be explored further.

Originality/Value

The report provides an analysis of the current state of the UK seaweed industry as well as best practices and the opportunities that Norfolk can explore to build a seaweed industry, considering the lessons learned from present operations in the sector. The report has the potential to influence how initial seaweed supply chains are built in Norfolk as well as inform on the general state of the industry in the UK and the Netherlands.

A Special Thanks

A very special thanks to the organisations that allowed me to interview them for this study. Without you, this report would not have been possible to write. Thank you again for your time and engagement. It is much appreciated. Many thanks also to the fellow SEA project partners, Cefas and UEA, for their invaluable support in getting this report to the final stages.

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Appendix 1

Interview Questions

Interview questions for the 23 semi-structured interviews conducted with people working in the seaweed sector, particularly for organisations that operate across the seaweed value chain in the UK and Netherlands. The questions varied based on where in the value chain the organisations interviewed sits. Different questions can be found below for seaweed industry businesses, energy companies, seaweed cultivators and wild-harvesters and regulators in the sector.

SEA Project Interview Questions – Businesses

- Company name:
- Location of company:
- How long have you operated for?
- Size of company?
- In what capacity do you work with seaweed in your company/research/job? Where do you currently sit in the seaweed value chain (R&D; Producer/Grower; Processor; Manufacturer; Seller; Services; Multiple)?
- * Alternatively, in what capacity would you like to work with seaweed or the seaweed industry?

- Who buys your products/services? Do you know your main customer groups?
- Where does the main demand come from? Local, domestic, international?
- Where can customers buy your products/services?
- What has allowed you to establish a successful seaweed-related business in your area (local, domestic or international demand, funding, facilities, location, practices, expertise, cluster/network support)?
- Has there been any particular/beneficial support from the local community, councils, or government that has helped you to get where you are today?

1

- Any supply chain challenges that have been a barrier to establishing your business or any support that would have been beneficial? Are you experiencing any current barriers?
- Do you have growth plans/scale-up plans in terms of production or sales?
- What will allow you to realise these plans (e.g., support or services)?
- Is there anything else that you would like to add?

2

SEA Project Interview Questions – Developers

- Company name:
 - Location of company:
 - How long have you operated for?
 - Size of company?
 - In what capacity do you work with seaweed in your company/research/job? Where do you currently sit in the seaweed value chain (R&D; Producer/Grower; Processor; Manufacturer; Seller; Services; Multiple)?
 - * Alternatively, in what capacity would you like to work with seaweed or the seaweed industry?
-

- Are you aware of wind farm and seaweed aquaculture co-location opportunities (both for bottom fixed and floating wind farms)?
- Have you explored co-location with seaweed/aquaculture for any of your sites/development projects? If yes, where, and why/why not in East Anglia/Norfolk?
- What do you see as the benefits of implementing seaweed co-location for your company?
- What is your main concern, if any, with implementing seaweed co-location at your sites? In terms of, e.g., supply chains, engineering and logistics?
- What would be required for you to consider/do a co-location pilot project with seaweed in East Anglia/Norfolk? What steps/actions need to be taken to make a co-location pilot a reality in this region? Is there anything that regulators, industry or academia could do to help?

1

SEA Project Interview Questions – Growers

- Company name:
 - Location of company:
 - How long have you operated for?
 - Size of company?
 - In what capacity do you work with seaweed in your company/research/job? Where do you currently sit in the seaweed value chain (R&D; Producer/Grower; Processor; Manufacturer; Seller; Services; Multiple)?
 - * Alternatively, in what capacity would you like to work with seaweed or the seaweed industry?
-

- What species of seaweed do you farm? **Follow-up question:** Are there any other seaweed species that you would like to start farming in the near future?
- What is the size of your farm?
- Do you farm in open water or enclosed facilities (e.g., tanks) or a combination of the two? If in open waters, is the farm in coastal or offshore waters (if offshore, how far out)?
- Do you have your own seaweed nursery/hatchery facilities, or do you rely on a commercial nursery; if the latter, can you provide the name/details?

1

- What growing technique do you use? (Which substratum e.g., rope, textile, net, modular & do you use bio-binder or not?)
- Do you farm your seaweed in co-location with other aquaculture? If not, are you considering it when scaling up/within future plans?
- Do you farm seaweed in co-location with other activities (non-aquaculture related)? Would you be interested in co-location, for example, with offshore wind if there was an interested developer?
- How much seaweed do you produce each year? Are you planning to increase this in the next 5 years, and by how much?
- When do you transfer your seaweed out at sea, and when do you harvest your seaweed?
- Are there any specific processes that allow you to harvest successfully?
- Where are your initial processing facilities (washing, drying, cutting)? Do you do your own initial processing or use an external facility nearby?
- What has allowed you to establish a successful seaweed-related business in your area (nurseries; specific maritime location, local, domestic or international demand, funding, facilities, location, practices, expertise, cluster/network support, local supply chain, local community support)?
- Has there been any particular/beneficial support from the local community, councils, or government that has helped you to get where you are today?
- What challenges have/are you encountering with farming, processing, market etc.; e.g., what is the main bottleneck for you at the moment?
- Do you have close access to a biorefinery if this is needed to create your end product? **Follow-up question:** Do you think the presence of a biorefinery close by has had/would have had an effect on your business?

2

- If not to a biorefinery, where does the seaweed go after initial processing - own use, local use/products (what products)/businesses, domestic use, international use and what for.
- How does/did the buyers find you, and do you think your specific location is a criteria for them to buy from you?
- Local, domestic or international buyers? Repeat business?
- How do you overcome possible harvest yield uncertainties?
- Is there anything else that you would like to add?

3

SEA Project Interview Questions – Regulators

- Company/institution/department name:
 - Location of company/institution/department:
 - How long have you operated for?
 - Size of company/institution/department?
 - In what capacity do you work with seaweed in your company/institution/department/research/job? Where do you currently sit in the seaweed value chain (R&D; Producer/Grower; Processor; Manufacturer; Seller; Services; Multiple)?
-
- How are you/how can you support the seaweed industry in the UK?
 - How are you/how can you support the seaweed aquaculture development in Norfolk?
 - How do you think that the industry can collaborate better with regulators to ensure scaling up and advancement of the industry? How can we ensure a collaborative approach and increase the level of conversation?
 - Do you have any concerns or see any barriers with scaling up the UK seaweed industry?
 - How do you think that we best can work together to achieve a more streamlined licence application and permitting approach for seaweed farming in the UK?

1

- How can the seaweed aquaculture development in Norfolk ensure compliance with environmental and industry-specific regulations?
- How can a seaweed industry in Norfolk help achieve environmental objectives?
- Is there anything else that you would like to add?

2

Appendix 2

Stakeholders Interviewed

Table 1. Stakeholders interviewed for the ‘Best Practice Report and Current State Analysis of the Norfolk and UK Seaweed Sector in 2023’. An overview of the 23 companies interviewed, including their location and their purpose can be found below.

Organisation/Company	Location	About
Cultivocean LTD	London, SW17 9DR	Cultivocean develops integrated nature-based solutions to improve biodiversity within the marine environment, creates habitats for sea wildlife and facilitates mass cultivation of biomaterials through the installation of seagrass meadows, seaweed afforestation, artificial reef structures, and seaweed farming.
Equinor ASA	Headquarters: Oslo, Norway (but operate Sheringham Shoal and Dudgeon wind farms)	Equinor is an international energy company headquartered in Norway. With 22,000 employees in 30 countries, their ambition is to be a leading company in the energy transition.
Notpla LIMITED	London, E9 5EN	Notpla is a family of regenerative packaging materials, made from seaweed and plants. Behind these products is a company of the same name, deeply committed to making the planet a healthier place.
Roll Materials LIMITED	Norwich, Norfolk, NR13 3DY	Specialises in working with companies who manufacture or work with biomaterials, coated materials and self-adhesive materials.
Coke Estates LIMITED, Holkham Estate	Holkham Estate, Wells-next-the-Sea, NR23 1AB	The Coke family has lived at Holkham since the early 17th century. Holkham Hall, the Palladian style mansion, was built by Thomas Coke, the first Earl of Leicester, between 1734 and 1764. Since then, Holkham has been paving the way in agriculture and is now a thriving estate under the eighth Earl, with diverse businesses including farming, tourism and property.

ARC Marine LTD	Torquay, TQ2 5EG	ARC Marine is an award-winning eco-engineering company that brings nature-inclusive solutions to traditional marine industries. Based in Cornwall and Devon, they specialise in designing, manufacturing, installing and monitoring subsea protection structures in order to enhance and study biodiversity.
Eco Cascade CIC	Glasgow, G62 6BW	Eco Cascade is a seaweed processing enterprise and a Community Interest Company created to scale the emerging seaweed industry into a thriving regenerative industry, & to support other natural product creators along the west coast of Scotland with processing needs.
River Waveney Trust	Diss, Norfolk, IP21 4JP	The River Waveney Trust is an environmental charity dedicated to improving and protecting the River Waveney, its tributaries and catchment, making it a better place for people and wildlife. Proud to be part of the Rivers Trust movement, they are one of 60 local river trusts across the UK and Ireland.
The Cornish Seaweed Company LIMITED	Cornwall, TR12 6UD	A small team of passionate seaweed foragers and growers based on West Cornwall's rugged coast. They offer a range of organic dried seaweeds and flakes, seaweed shakers and SEASONINGS for use in everyday cooking.
BioMara LIMITED	Edinburgh, EH2 2ER	Biomara is a startup with a new team motivated to build an innovative, successful, high-growth business in the Scottish seaweed industry. BioMara's impact will be economic, environmental and social including job creation, community resilience and ocean health.
Defra - Department for Environment Food and Rural Affairs	Headquarters: London, SW1P 4DF	The Department for Environment, Food and Rural Affairs is a department of His Majesty's Government in the United Kingdom responsible for environmental protection, food production and standards, agriculture, fisheries and rural communities in the entire United Kingdom.
Dorset Seaweeds	Dorset	Dorset Seaweeds specialises in the production of seaweed-based plant feeds and soil enhancers. Their natural and organic seaweed concentrates are produced from seaweed harvested sustainably on Dorset's Jurassic Coast.

Additive.earth CIC	Barnstaple, EX31 3YB	Additive.earth are dedicated to driving the transition towards a sustainable future. Their mission is to expedite the net-zero and nature-positive impact from emerging nature-based solutions, with a bold target of redirecting £50 billion of private investment into nature and sequestering 2 billion tCO ₂ e by 2030.
Norfolk Seaweed LTD	Wells-Next-The-Sea, NR23 1NG	Norfolk Seaweed is an aquaculture business dedicated to sustainably producing <i>Saccharina latissima</i> (sugar kelp in the North Sea just off the Norfolk coast and developing new, exciting, environmentally friendly products.
Hortimare B.V.	Heerhugowaard, The Netherlands	Hortimare is the supplier of high-quality starting material to enable seaweed farmers to harvest good yields. They advise, support and collaborate closely with seaweed farmers in order for them to expand and scale up to essential volumes to make seaweed a competitive alternative for land-based products.
ANB Sensors LTD	Cambridge, CB23 2RF	ANB Sensors design and develop the next generation of calibration-free, solid state pH sensors used for measuring pH in all industries.
The Crown Estate	London, SW1Y 4AH	Across communities, land and the seabed, The Crown Estate own and manage land for the benefit of the nation. They are an independent business sitting between the public and private sectors, acting in the national interest both today, and for future generations.
World Wide Fund for Nature	Headquarters: Gland, Switzerland	The World Wide Fund for Nature is a Swiss-based international non-governmental organization founded in 1961 that works in the field of wilderness preservation and the reduction of human impact on the environment.
Vattenfall AB	Headquarters: Solna, Sweden	Vattenfall is a Swedish multinational power company owned by the Swedish state. Beyond Sweden, the company generates power in Denmark, Finland, Germany, the Netherlands, and the United Kingdom.
The Seaweed Alliance subsidy of Seaweed Forum Wales LIMITED	Conwy, LL32 8LT	Formed in 2017 as a not-for-profit, The Seaweed Alliance is a platform for industry, research, and governments to coalesce and unlock the

		potential, to advance an industry in the UK based on cultivated seaweed (macroalgae).
Marine Management Organisation	Headquarters: Newcastle, England	The Marine Management Organisation is an executive non-departmental public body in the United Kingdom established under the Marine and Coastal Access Act 2009, with responsibility for English waters.
Biome Algae LTD	North Shields, NE29 OAE	Biome Algae is scaling seaweed farms in the South West of England to build a blue economy.
Sustainable Seaweed LIMITED	London, WIT 6QR	Provides several seaweed species in dried/wet/frozen forms as well as seaweed extracts.

Appendix 3

Seaweed and Aquaculture Networks in the UK

Table 1. Current Seaweed and Aquaculture Networks in the UK. As there currently are several aquaculture and seaweed associated networks in the UK, an overview of the main groups can be found below. Some of the largest ones being the British Phycological Society, South West Aquaculture Network and the Pembrokeshire Coastal Forum and the additional networks mentioned below.

Network	Description	Reference
British Phycological Society	Charity devoted to the study of algae founded in 1952; one of the first to be established in the world and the largest in Europe. The society holds annual meetings, supports training courses, has ongoing biodiversity and conservation projects and coordinates education and outreach activities.	<i>(The British Phycological Society, 2022)</i>
South West Aquaculture Network (SWAN)	Extensive experience across marine and freshwater cultivation with support from world leading research institutes and UK government agencies. Members meet quarterly.	<i>(South West Aquaculture Network (SWAN), 2023)</i>
Dorset Coast Forum	Independent strategic coastal partnership, which looks at the long term, broad-scale issues facing the Dorset coast and its inshore waters. Linked to SWAN.	<i>(Dorset Coast Forum, 2023)</i>
Pembrokeshire Coastal Forum	A Community Interest Company that works to inspire, collaborate and deliver solutions for coastal communities, protect the coast and marine environments and providing independent stakeholder	<i>(Pembrokeshire Coastal Forum, 2023)</i>

	engagement, project development and partnership working.	
The Seabed User & Developer Group	Represents the UK's key marine industries. Working with government, its agencies and other stakeholders, such as environmental NGOs, the group supports the development of regulation and marine management that benefits both business and the environment.	<i>(Seabed User and Developer Group, 2023)</i>
Scottish Seaweed Industry Association (SSIA)	Based in Oban dedicated to the growth and innovation of the seaweed industry. Their vision is to promote Scottish seaweed, exchange knowledge, grow the sector, inform regulatory guidance, develop the sub-sector, explore and identify funding options and organise events to give exposure to the sector.	<i>(SSIA, 2023)</i>
Algae Innovation Platform (AIP)	Established by Hethel Innovation in June 2021. The network was founded after discovering a local interest for micro- and macro algae with a lack of a shared platform to communicate about initiatives. The AIP has in the moment of writing held 11 meetings and currently has 140 members of the network. The main interest of the platform has been seaweed where the aim of the AIP is to collaborate to better understand what is needed to develop a viable and sustainable seaweed and microalgae industry in the East of England and discuss current barriers to development as well as knowledge sharing and networking.	Hethel Innovation, Oct 2023



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