BIM
Ireland's Seafood Development Agency

SUPPLY AND VALUE CHAIN ASSESSMENT OF IRISH FARMED SEAWEED

Rialtas na hÉireann
Government of Ireland

Arna chomhchistiú ag an Aontas Eorpach

Co-funded by the European Union

Prepared By: **Laurence Knell, Ronald Macintyre, Gráinne Millar**

Strategic Innovation Partners Ltd
5 Auburn Road
Dún Laoghaire
Co Dublin

Contact: Laurence Knell,
laurie@strategicinnovation.ie

Date Issued: 9th May, 2024

CONTENTS

INTRODUCTION

The last two decades have seen a dramatic increase in the volume of seaweed farmed around the world. Valued at approximately €15 billion in 2021, the global market for seaweed has been forecast to reach almost €25 billion by 2028 (CBI, 2022). As of 2023, annual global seaweed output was estimated at 35 million wet tonnes, of which approximately 97% was farmed, with the majority being produced in China, Indonesia, the Philippines and Korea. In contrast, the total European harvest is currently estimated to amount to only 300,000 wet tonnes, less than 4% of which is farmed. As a subset of this, production in Ireland is currently estimated to be only around 30,000 wet tonnes per annum from wild harvest (Vance et al., 2023).

As noted in the *National Strategic Plan for Sustainable Aquaculture Development 2030*:

> ***Seaweed is a versatile product, and its potential remains underdeveloped. There is great scope to increase the value of seaweed exports from Ireland with increasing interest in bioactives, in particular, from farmed seaweeds.***
>
> *(DAFM, 2022, p.34)*

Despite this apparent under-development, recent research has highlighted the importance of Ireland in the overall seaweed sector. As Banach et al. (2022) note: "in the European algae sector, there are a reported 225 companies producing macroalgae, with France, Ireland, and Spain having the most macroalgae companies". Irish farmed seaweed consequently offers significant opportunities for growth if the sector is managed and supported effectively.

Aims and Objectives

Building upon prior work, most notably the ***Irish Macro-Algal Cultivation Strategy to 2030*** (BIM, 2023), commissioned by Bord Iascaigh Mhara and launched in 2023, this report aims to provide a supply and value chain assessment of Irish farmed seaweed. In particular, this report aims to:

- Determine the primary and support activities for the Irish seaweed sector
- Analyse the value and cost of the activities
- Determine and assess key markets and routes to market
- Assess and evaluate competitor's value chains
- Evaluate customer requirements and value perceptions
- Identify opportunities to gain a competitive advantage through efficiencies, value-add and comparative advantage

In undertaking this analysis, we draw upon the seaweed value chain model developed by *the Interreg NWEurope IDEA* project, which provides a clear and coherent snapshot of the current seaweed value chain. Given that the Irish seaweed sector is a sub-sector of the overall European industry, this framework provides relevant insights to support the overall analysis and discussion.

Our key finding is that while there are significant potential areas for growth in Irish farmed seaweed, a number of key steps must be taken in order to achieve the potential of the macro-algae sector in Ireland. More specifically, in order to add value through and within the seaweed value chain it is vital that significant efforts are made to:

- Maximise efficiencies through the value chain to ensure the lowest possible costs, including through automation at various stages of production
- Provide consistently high-quality seaweed biomass, consistent volumes and specific varieties of seaweed to meet both current and future market needs
- Optimise the value extracted through each harvest by ensuring the maximum usage of products/extracts
- Target niche markets characterised by demand for a consistently high quality product, consistent volumes and specific varieties of seaweed
- Maximise revenues by focusing on higher value products and markets
- Establish a clear brand of "Irish farmed seaweed"
- Achieve greater environmental and social market upgrading by making production more efficient and accounting for the value of seaweed in relation to ecosystem services and carbon sequestration
- Enhance the social value delivered by seaweed farming within those communities where it takes place
- Continue to maintain a transparent and coordinated regulatory regime to ensure environmental sustainability, commercial reliability and consistency, and full traceability throughout the supply chain

While a number of these recommendations can be achieved by seaweed farmers working individually, we argue that structural changes within the broader seaweed sector and value chain will be required. In particular, we argue that maximum value will be achieved throughout the value chain by taking a coordinated, country-wide approach to the development of Irish seaweed. In this respect, we conclude that the most effective way of achieving these recommendations is through the establishment of an Irish seaweed cluster with appropriate knowledge transfer mechanisms and with greater integration into existing sectoral innovation processes. Key conditions and contingencies for the establishment of an Irish seaweed cluster are outlined with steps to its establishment.

This report on the value chain for Irish farmed seaweed is based on a wide-ranging analytical approach. It draws together insights and data from a number of key sources, including scientific papers, published reports, working papers, blog posts and other articles. Equally, it integrates international case studies and insights from a wide range of industry stakeholders who were interviewed for this process. Further detail of sources is available in the list of references.

UNDERSTANDING THE POTENTIAL **OF SEAWEED FARMING**

The future growth of seaweed aquaculture is likely to represent the largest component of the industrialization of the oceans yet seen.

(Duarte et al., 2022, p.186)

When examined globally, the farming of seaweed offers significant potential for growth and development. If done successfully, this will have tangible benefits not just for economies but also societies and the environment. As The World Bank's *Global Seaweed: New and Emerging Markets Report 2023* highlighted:

The seaweed sector has clear growth potential beyond its current markets and can help shape a world free of poverty on a livable [sic] planet. Enhanced seaweed production and improved value chains can contribute to meeting at least nine of the 17 U.N. Sustainable Development Goals (SDGs).

(The World Bank, 2023, p.xiv)

In a detailed analysis of the growth options for the seaweed sector in Europe, Barbier et al. (2019) argue that a multi-faceted approach is necessary to grow the overall market.

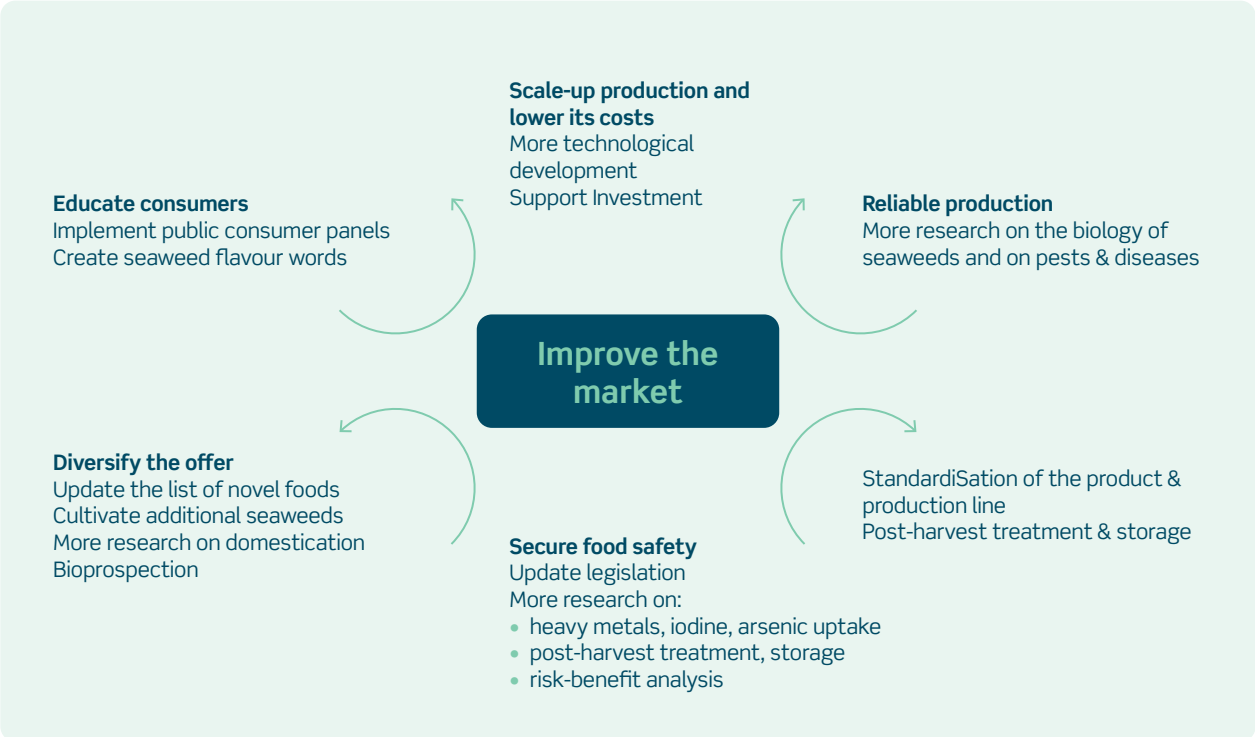


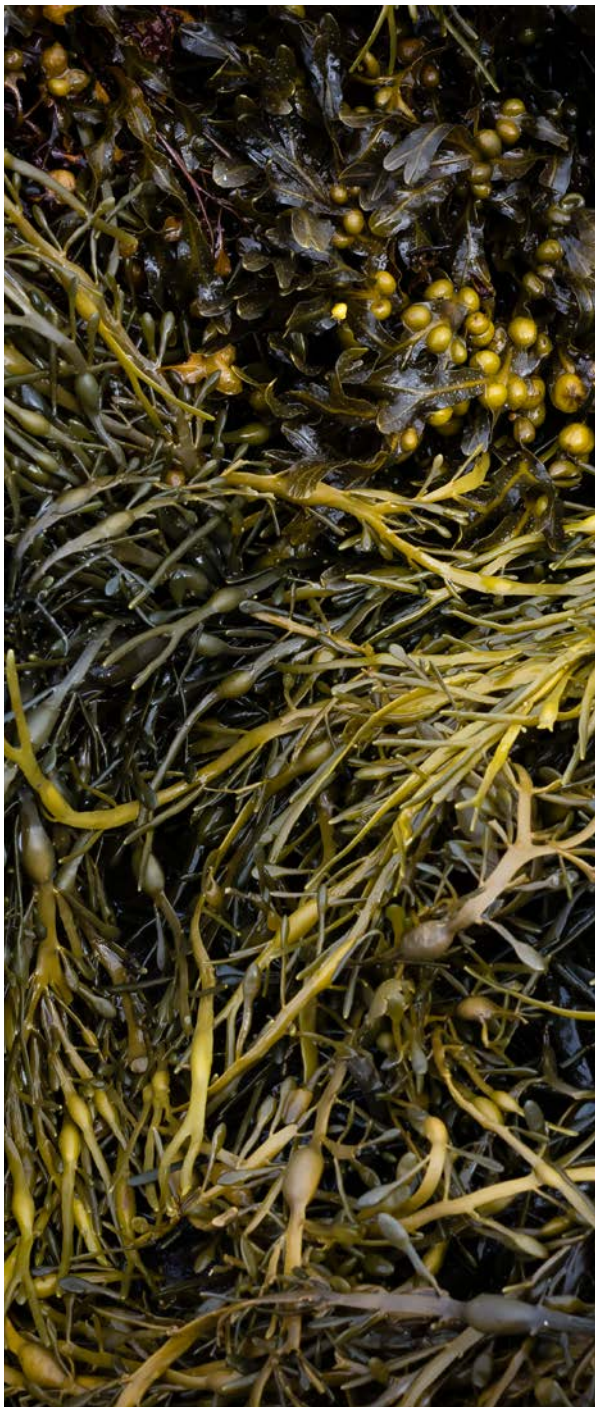
Figure 1: Steps to improve the European seaweed market (Barbier et al., 2019, p.156)

This perspective aligns with that expressed by stakeholders who indicate that the key factors hindering the further development of farmed seaweed in Europe are high prices, insufficient volumes and uncertainty of supply. The challenge posed for the entire European value chain by the lack of sufficient seaweed biomass has been highlighted elsewhere (see, for example, Wenäll and Leufstedt 2023). While favourable climatic and shoreline conditions (Mac Monagail and Morrison, 2020, p.1294) might combine to ensure that the farming of seaweed in Ireland is relatively resource efficient (Taelman et al., 2015), in itself this will not be sufficient to guarantee the volumes required to deliver economies of scale. Moreover, while increased volumes might support greater economies of scale, this is only one aspect of the overall value equation. As noted by The World Bank:

> ***The costs of all operational stages – cultivation, harvesting, processing, and transportation – need to be taken into consideration. It is often suggested that economies of scale will bring down the cost per ton of harvested seaweed, but with the cost of production mostly driven by human labor, farm processes will have to become significantly more automated to allow cost-efficient, large-scale production.***
>
> (The World Bank, 2023, p.20)

Although European companies can leverage their research capacity to deliver additional value, regardless of price or volume, which might be superficially appealing, the reality is yet to be determined. Opportunities to develop novel techniques for farming, processing and bio-prospecting unique compounds are important, however this value must be captured as intellectual property.

Importantly, an analysis of the kelp value chain and associated patents and publications found that it was only in relation to biostimulants that Europe was ahead of other regions (van den Burg et al., 2019), demonstrating that those capacities are equally present elsewhere. These same factors arguably apply to the overall expansion of farmed seaweed in Ireland and elsewhere in Europe.



A VALUE CHAIN APPROACH **TO IRISH SEAWEED**

*The term **value chain** refers to the various business activities and processes involved in creating a product or performing a service. A value chain can consist of multiple stages of a product or service's lifecycle, including research and development, sales, and everything in between.*

(Stobierski, 2020)

To analyse the value chain for Irish farmed seaweed we draw on the approach outlined by the Interreg NWEurope IDEA project (nd). Specifically, they refer to Algae Value Chains as

trains of activities that are required
1) to produce algae biomass,
2) to process this algae biomass into ingredients, and
3) to formulate the ingredients into marketable algae-based products.

(Interreg NWEurope IDEA project, nd)

The progression and interactions between these phases are captured in the following diagram:

IDEA

Implementation and development of economic viable algae-based value chains

Interreg North-West Europe IDEA

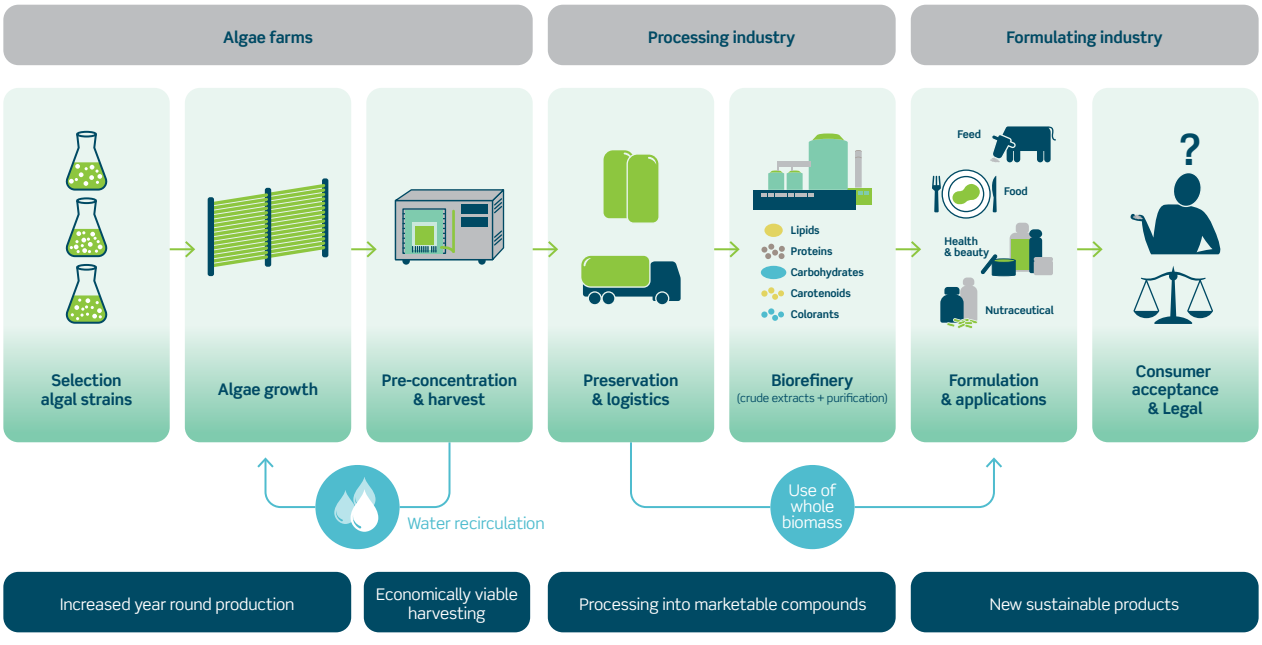


Figure 2: European seaweed value chain (Interreg NWEurope IDEA project, nd)

This perspective aligns with that of Jacinto and Pomeroy (2011, p.166) who note that progression through the value chain can involve the combination of physical transformation and the inputs of various producer services. This consequently highlights a key benefit of a value chain analysis: meaningful insights can be gained not only into the opportunities and challenges facing individual stakeholders, but also into the interactions between stakeholders and the importance of aligning interests in order to extract maximum value.

In undertaking a value chain analysis of the Malaysian seaweed industry, Nor et al. (2020) emphasise the relevance of this approach to seaweed farming. Specifically they argue that:

> ***the objective of carrying out such a VCA [Value Chain Analysis] is to identify the points where the product may be inefficiently passed on and the producer may be losing an opportunity to maximise market uptake. Capturing the value generated along the chain is only possible if the value at each link of the chain is known***
>
> (Nor et al., 2020, p.2162).

MODULARITY AND ASYMMETRY

Lange et al. (2020) highlight that the differing components extracted during the refining process mean that multiple seaweed value chains exist. Importantly, these value chains can be analysed to discern patterns and underlying structures.

The tendency to treat seaweed as a raw material and, consequently, as a commodity has led to the development of highly modular value chains. From this modular perspective (Gereffi et al., 2005), the suppliers of seaweed are essentially interchangeable within the value chain and the volume, price and quality of product are defined by the processers and, ultimately, those developing products. This perspective suggests that global seaweed value chains are characterised by *asymmetric modularity*, with dominant actors controlling the value chain (Selnes et al., 2021).

While global seaweed value chains consist of many smaller organisations, they are most typically price takers who have little control of either pricing or ultimate destination (van den Burg et al., 2021). Whether acting as intermediaries or end-users of seaweed products, these larger companies tend to be cautious in their approach to sharing commercially sensitive information such as volumes, prices, cost structures, final use and end-customer. Consequently, without appropriate collaboration and coordination throughout the value chain, the value chain for seaweed in Europe may tend towards the asymmetric modular model, with large organisations dominating the sector. This opacity makes the analysis of value chain much more complex, but also potentially much more dynamic as spot prices can be impacted by global factors largely unforeseen and out of the control of local suppliers.

There are, however, some exceptions to this pattern including for example the biostimulant value chain. Possibly reflective of the lower value and margins in the biostimulant market (van den Burg et al., 2021), the value chain is more integrated, with companies involved from production through to manufacturing and distribution. European research also suggests that the value chains for emerging product categories differ from the general pattern of modular global markets. For example, analyses of the European kelp market suggest that value chain governance takes the form of a complex array of Government actors, Non-Departmental Public Bodies, Research Centres (Universities and public-private partnerships) and private sector actors. The suggestion is that the sector is novel, products are not yet commercially viable or at scale, and the patterns are still emerging (van den Burg et al., 2019).

The role of extra-national actors should also be noted. In Asia and Africa, global non-governmental actors are playing a crucial role in supporting seaweed farming and developing local value. In Europe, NGOs are also active, and there are a range of European projects to explore and develop those value chains. These projects – including SeaMark (https://seamark.eu/), focused on research and development, and North Sea Farmers (https://www.northseafarmers.org/), focused on production – are an opportunity to develop alternate value chains based on collaborations with distributed actors as part of a networked governance model (Selnes et al., 2021).

The following section will examine each aspect of the Irish farmed seaweed value chain. While acknowledging that to a very large extent the final stages of formulation and sale to end consumers is beyond the scope of the Irish seaweed sector, it is nonetheless recognised that decisions made earlier in the value chain will have a direct impact on subsequent value extraction opportunities and the markets that can be accessed. Equally, a further outcome of a value chain analysis is insight into the key constraints facing a sector at each stage of production. This analysis will highlight opportunities, both in terms of opportunities for growth as well as for efficiencies and development.

PRODUCTION OF **SEAWEED BIOMASS**

Production of seaweed biomass can be examined in terms of three key areas:

- Selection and species
- Growth and cultivation
- Harvesting

Each of these are examined in turn below.

SELECTION AND SPECIES

Globally, 226 seaweed species are of commercial interest of which 10 are farmed at scale (van den Burg et al., 2018). The FAO suggests that six species account for over 90% of global seaweed production (FAO, 2022).

At present, the majority of seaweed production in Europe is from wild harvest, with only approximately 30% coming from aquaculture (Araújo et al., 2021). Recent research into European value chains suggests that the farming of macroalgae is dominated by three key species:

Saccharina latissimi... has the highest production volume (376 tonnes fresh weight (fw)) and the number of companies (26), followed by Alaria esculenta (107 tonnes fw and 16 companies), and Ulva sp. (50 tonnes fw and 10 companies).

(Banach et al., 2022).

Araújo et al. (2021) note that the focus on Saccharina Latissimi has been driven by a number of key factors: "broad geographical distribution..., early availability of kelp production protocols..., the potential for higher biomass yields... and rich nutritional content for human food and animal feed".

The concentration of production on a limited number of species has led to concerns regarding the increased intensification of production. This relates most particularly to the potential for increased levels of pathogens and parasites within seaweed farms. This aligns with prior research, which has highlighted that both biotic and abiotic stressors can pose a significant challenge to seaweed cultivation if not managed effectively (Ding and Ma, 2005; Loureiro et al., 2015). Recent European funding has consequently been directed at communicating academic knowledge of parasites and pathogens to farmers in Europe and Asia to minimise potential issues (Strittmatter et al., 2022).

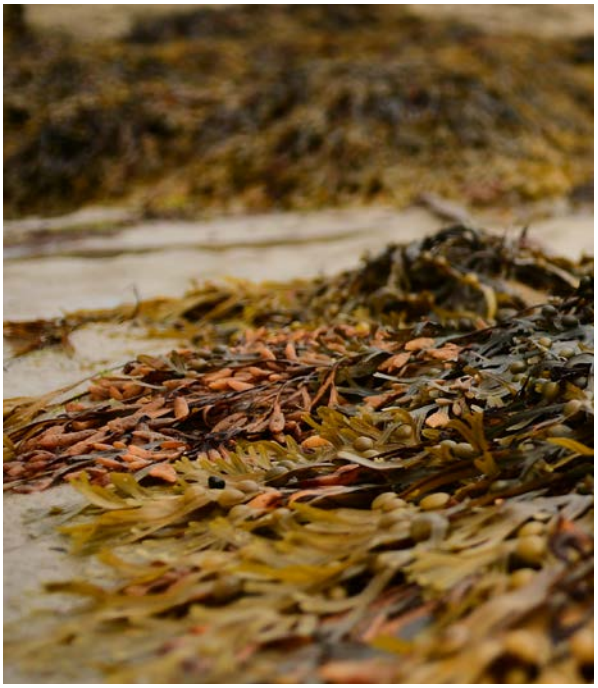
While the Irish environment offers suitable conditions for the farming of a wide range of seaweed species (Zhu et al. 2022, p. 176), in considering various alternative species a number of factors must be taken into consideration. These include:

- Species with properties that meet the needs of existing markets and uses
- Niche, "interesting" species that are suitable for novel, high-value uses within European manufacturing and are currently fully exploited
- Species that can add value across the value chain including social and ecological value
- Species that can be farmed at scale within the limits of supporting ecosystems

From a strategic perspective, the selection of species that meet the needs of existing markets may seem sensible or at the very least low risk. It would entail, however, direct competition with other European producers including France, Norway and those in the North Sea. An alternative approach would be to select species meeting the needs of under-exploited and potentially high value markets. In this regard, stakeholders suggest that greater emphasis could be placed on the cultivation of red seaweeds such as Palmaria Palmata and Porphyra/Pyropia spp. with demand expected in the areas of cosmetics and food (BIM, 2023, p.141). Linked to this, the Horizon Europe funded ASPIRE project led by researchers at the University of Galway, is seeking to:

develop fast growing seaweed strains by screening and characterising high yielding and robust Palmaria strains. The project will use advanced sequencing and bioinformatics tools (TASSEL pipeline) to identify the biochemical and genetic markers of high-yielding Palmaria strains

(European Commission, 2022a).



The dichotomy highlighted by the choice of species aligns with what Kim and Mauborgne (2005) define as “red ocean” versus “blue ocean” strategies:

In the red oceans, industry boundaries are defined and accepted, and the competitive rules of the game are known. Here companies try to outperform their rivals to grab a greater share of existing demand... As the market space of red oceans gets crowded, prospects for profits and growth are reduced. Products become commodities, and cutthroat competition turns the red ocean bloody. Hence we use the term “red” oceans.

Blue oceans, in contrast, are defined by untapped market space, demand creation, and the opportunity for highly profitable growth. Although some blue oceans are created well beyond existing industry boundaries, most are created from within red oceans by expanding existing industry boundaries. In blue oceans, competition is irrelevant because the rules of the game are waiting to be set. The term “blue ocean” is an analogy to describe the wider potential of market space that is vast, deep, and not yet explored.

(Kim and Mauborgne, 2005, p.106)

A note of caution must of course be struck. The introduction of exotic varieties of seaweed into the ecosystem has the potential to undermine messaging around locality and provenance, and significantly, there are potential biosafety and environmental considerations that should be taken into account.

GROWTH AND CULTIVATION

A key issue facing Irish seaweed are the cost structures related to both growth and cultivation. As previously noted, economies of scale can be gained through the further expansion of volumes, however these increases will only be marginal relative to the overall global scale production volumes of seaweed. Over 90% of the world's seaweed is grown in Asia, and of that, the majority (75-85%) is consumed in Asia as food (van den Burg et al., 2018). Given the prevailing cost of key inputs – most particularly labour – Ireland and indeed Europe more broadly will struggle to match the production costs of seaweed from Asia and elsewhere. Just as importantly, in the short- to medium-term the cost structures in Europe mean that European wild harvest will continue to be cheaper than seaweed farmed in Europe.

Several approaches have been suggested to address this. Key among these are attempts to focus less on *production costs*, and instead emphasise *production value*. In this context, value is understood broadly as including social, ecological, and economic value (Van Den Burg et al., 2021b).

For example, the Crown Estates in Scotland, responsible for managing both the seabed and foreshore on behalf of the Scottish Government, has noted that seaweed remains a relatively small component of the overall *Blue Economy* that includes fisheries, tourism and energy including renewables. Nonetheless, for those areas where seaweed is grown and harvested, the social benefits of seaweed are conceivably quite high. They suggest, for example, that seaweed farms and onshore facilities including processing, could create and sustain jobs in some of the most economically and socially fragile areas in Scotland (Crown Estate Scotland, 2022; Menzies et al., 2021; Scottish Government, 2022b). Similar potential no doubt also exists in Ireland given that the primary location of seaweed farming is along the western seaboard.

APPROACHES TO FARMING

At the present time, the farming of seaweed in Ireland is almost entirely undertaken at sea. Other, emerging options include land-based farming and integrated multi-trophic aquaculture (IMTA) – the combination of various forms of aquaculture production, including for example fish, seaweed and invertebrates, in order to take advantage of the trophic relationships between them (Chopin 2006). Barbier et al. (2019) summarise the key advantages and issues of each approach as follows:

Advantages	Techniques	Issues	Solutions
Traditional Local economy Promotes female enterprise	**Harvesting**	Potential over-exploitation of wild resources No legislation across EU Compliance Nagoya Protocol EU manual status not recognised	Define limitations/quota management/harvesting plan

Advantages	Techniques	Issues	Solutions
High yield & year-round production Easy to harvest Controlled environment Consistent of high-quality biomass Possibility to customize the chemical composition of biomass.	**Land-Based Cultivation**	Needs of space on land High infrastructure costs High operational costs Less available knowledge on production protocols	Refurbish under-utilized structures in coastal areas (e.g. earthen-ponds, shellfish storage units) Renewable energy Promote biomass in added-value markets (e.g. food, cosmetics, health products) Foster research in production of target species
Low cost Can be 1D, 2D or 3D Open space	**At-Sea Cultivation**	Low scale Farm location (nutrients, natural conditions, environment) Risk of escape Impact local genetic diversity Disease/multiple pests	Mechanisation & automation Env. condition monitoring Define geographical limits Balance inbreeding/ outbreeding programmes
Nutrient requirements Shared infrastructures & distribution channels Share investment and infrastructure (more viable on land-systems) Consumer acceptance	**IMTA**	Difficult to adapt traditional techniques of mono-aquaculture to combine the species. Best location for different species (depth, freshwater, estuary) Biosecurity Pests Lack of appropriate regulation	Best practices More research Modelling Collaboration with ongoing high-level trophic production sites such as salmon farm Simplify regulation; allow the co-exploitation of farming sites by different companies

Advantages	Techniques	Issues	Solutions
Space Cost infrastructure investment for systems that can be deployed in open sea	**Offshore**	Same as long line system International waters, resources beyond National jurisdictions Logistics	Best practices Modelling Collaboration with industrial fisheries and at sea transport companies are needed Collaboration with ongoing salmon farm developing activities in open sea

Table 1: Analysis of various forms of seaweed cultivation (Barbier et al., 2019, pp.67-68)

As noted by Barbier et al. (2019) various factors influence the preferred approach to farming. Specifically:

> ***The choice of cultivation technique depends on the life cycle and physical characteristics of the cultivated species. As a result, open-water, land-based farming and IMTA will need to co-exist in the future, with each technique offering its advantages and disadvantages... The selected cultivation technique may also depend on local parameters and cultural practices.***

(Barbier et al., 2019, p.67)

In a detailed analysis, Vance et al. (2023) explore the environmental, economic, and social impacts of six different harvest and cultivation scenarios of seaweed in Ireland:

- Wild harvesting: Manual cutting by foot
- Wild harvesting: Manual cutting by boat and rake method
- Wild harvesting: Mechanical cutting by seaweed trawler
- Cultivation system: small-size farm
- Cultivation system: medium-size farm
- Cultivation system: large-size farm

Due to the costs associated with capital equipment, fuel and labour, at-sea cultivation of seaweed in Ireland is largely uneconomical when compared against current Irish and global selling prices of seaweed.

A key alternative to at-sea or off-shore seaweed farming is land-based farming. Barbier et al. outline the key advantages and disadvantages of land-based cultivation of seaweed as follows:

- The advantages of growing on land are: full control over the main production factors (stocking densities, nutrient availability), consistency in yield and quality of the biomass, traceability, the ability to apply stress protocols to optimise the composition of target compounds. Land-based production is also easier to couple with on-site processing.

- The disadvantages of these systems include the need for land space, high infrastructure costs and energy expenditure.

Barbier et al. (2019, p.63)

A further challenge with land-based farming is highlighted by Zhu et al. who note that "the maintenance of seaweed on tanks is expensive and can lead to the stress of cultivated seaweeds and thereby, a previous selection of the seaweed species is required" (Zhu et al., 2022, p.177).

Three approaches to overcoming these challenges are highlighted in the literature, each of which would offer potential in Ireland:

1. ***Rehabilitation of existing and under-utilised infrastructures such as earthen ponds and shellfish storage tanks.***
2. ***Use of renewable energy to power production and processing systems.***
3. ***Combine seaweed land-based production with other activity such as fish hatcheries and/or farms.***

(Barbier et al., 2019, p.63)

While Vance et al. (2023) do not consider the option of land-based cultivation of seaweed it is assumed that the costs of this will be higher. This is most particularly so given that the likely remote location of any land-based farming of seaweed in Ireland means that it can be expected that infrastructure costs will be significant. Similarly, data highlights that the costs of energy to business in Ireland (both electricity and gas) are high. While the cost of gas is roughly in-line with the EU average, the cost to business of electricity is approximately 33% above the EU average (https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/prices/).

Internationally, there is significant work in Norway around producing and harvesting farmed seaweed, with a series of funded projects examining both opportunities and challenges. An examination of the financial viability of small seaweed farms in Norway (around 9 hectares) explored six production scenarios under which both the input costs and the production approach varied. Using Net Present Value calculations over a ten-year period the only profitable scenario was one where land and marine costs were kept to a minimum, equipment was rented and partial harvesting was employed (Gombau, 2022). Even under those conditions, however, minor changes to the cost of basic inputs significantly impacted profitability, highlighting the volatile nature of the sector for smaller producers.

Perhaps not surprisingly, a recent review of policy in Norway (Albrecht, 2023) indicates that while the public narrative may focus on small producers, the Norwegian approach to seaweed is underpinned by the lessons learned from the successful scaling of salmon farming. This implies a coherent, structured and industrialised model which may not be suitable elsewhere. Indeed, the research cautions against the automatic application of models from one context to another, including between jurisdictions.

One approach to enhancing the economics of seaweed production relates to greater sharing of costs, particularly in terms of the co-location of seaweed farms. This includes the promotion of seaweed as part of a pluri-active rural economy, with the local actors balancing other marine activities with seaweed farming and co-locating seaweed farms with wind farms (O'Shea et al., 2022; van den Burg et al., 2016). Equally, interest in IMTA has continued to expand (van Osch et al., 2017), as evidenced by The Marine Institute trials at Lehanagh Pool Marine Research Site (https://www.marine.ie/site-area/infrastructure-facilities/lehanagh-pool-marine-research-site) and work undertaken on co-locating seaweed and salmon in Scotland.

As of February, 2024, Norway has also updated its regulations to facilitate greater engagement with multi-trophic aquaculture (Gairn, 2024). Stakeholders nonetheless noted that much of the work on multi-trophic aquaculture has generally remained in the proof of concept stage and questions remain regarding the overall impact of IMTA cultivation due to the potential unpredictably of nutrients and high dilution stemming from the environment (Ramli, 2020).

CLIMATE IMPACTS

In addition to economic and social value, there is also interest in the potential value offered by seaweed farming for carbon capture and ecosystem services, including as habitats for wildlife and removing pollutants. As yet, the work on the role of seaweed in carbon sequestration is still emerging. It would appear that any potential climate benefit from seaweed (so-called *Blue Carbon*) will vary depending on the context in which is it grown, as well as the impact of downstream processes including transport, drying, processing, extraction techniques and so on. A complete lifecycle analysis would consequently be required to fully evaluate the actual versus claimed or potential climate benefits (Hasselström & Thomas, 2022).

ENVIRONMENTAL IMPACTS

Concerns have also been raised about the impact of intensive seaweed production on the marine ecosystem. This includes concerns over "exotic species" and the unknown nature of the effects of an extensification and intensification of seaweed farming (Banach et al. 2022), with questions about nitrogen use, shading and sediment and turbidity also emerging (Van Den Burg et al., 2021). Stakeholders from both the wild harvest and the farmed sector suggested a need for further research to map out potential externalities and validate claims around ecosystem services. They called for clear regulation of the sector to address concerns. Sector groups like North Sea Farmers also call for this as part of their seaweed industry roadmap (North Sea Farmers, n.d.).[1]

The push to validate these claims can be seen at a European and national level. Success in this area would support a better appraisal of the cost versus value perspective and help overcome arguments based solely on cost rather than value. Key to this will be better understanding the overall value-add of seaweed farming. This includes establishing higher standards for quality and sustainability as part of what might be termed a "market upgrading approach" to shifting market awareness of how seaweed is produced and the implications of this (van den Burg et al., 2019).

1 This point is emphasised by emerging research into value chains in Asia and the seaweed economy in places like Zanzibar. While seaweed has been an essential commodity for the Malaysian economy, production is dropping, and there is increased evidence of the use of undocumented migrant labour in the sector (Asri et al., 2021). (UNU-CRIS, 2021) Seaweed production in Zanzibar has been promoted as a gender-inclusive approach to sustainable development that provides financial freedom to the women and girls in the industry. However, it remains a precarious source of income, and the degree to which those involved fully benefit from the value of their produce needs to be clarified (Makame, 2022).

One of the main strands of the SeaMark programme – supported by the European Union's Horizon Europe research and innovation programme – is to explore ecosystem services associated with seaweed and develop an accurate measure of carbon capture related to wild and farmed seaweed and associated economic proxies (https://seamark.eu/about/work-packages/). The Scottish sector seaweed body is engaged in a similar (though slightly broader) exercise that looks at the value of seaweed farming to the overall ecosystem[2]. In that regard, adding value through emphasising the social and ecological benefits, validated through research and captured within legislation, is part of a sense that Europe can focus on quality and questions around provenance. One example of this is Seaweed First (https://seaweedfirst.org/), an initiative that seeks to apply the lessons from other brand value marks to set up a series of standards for European seaweed similar to Certified Organic and Fair Trade.

SEAWEED WITHIN THE COASTAL ECONOMY

Finally, there are concerns about seaweed's place within the coastal and marine economy. While seaweed has been promoted as a source of economic development in economically vulnerable areas in Europe (for example in Scotland) and globally (including in Zanzibar and more recently in Bangladesh (see for example Hossain et al., 2022)), its role is uncertain. Within wider narratives around the *Blue Economy*, there is increased recognition of a potential "Marine Squeeze", with multiple sectors seeking to operate in marine and coastal communities. In these instances, seaweed farming is not necessarily a priority and in the UK there have been some well-publicised cases of licences for seaweed farms being denied and seaweed farmers removing licence applications (e.g. https://fishingnews.co.uk/news/relief-at-climbdown-on-cornish-seaweed-farm/).

Work on the notion of social licences – a concept that originated in mining exploration – suggests that beyond meeting regulatory requirements, organisations need to assess the acceptance of development by the local community and more widely. Research in Scotland and France found that concerns about seaweed farms related to both extensification and intensification. Whereas in Scotland these related primarily to salmon farming, in France they stemmed from concerns about intensive agricultural impact. In general, there has been much greater acceptance of development when the socio-economic benefits to the local community are clearly articulated (Billing et al., 2021; Mather & Fanning, 2019).

2 Participants in this project include The James Hutton Institute, The Scottish Association of Marine Sciences and a private actor, KALy, see https://kaly.eco/. The work includes looking at areas as diverse as offshore wind locations sensors to inform site selection and developing a Biodiversity Credit scheme.

PROCESSING

Under value-adding, seaweed drying, storage and importantly, the extraction of bio-actives, are crucial areas needing attention for the sector to realise its full potential value to 2030.

The National Strategic Plan for Sustainable Aquaculture Development 2030 (DAFM, 2022, p.35)

As noted previously, this report advocates a dual strategy involving an increase in volume and focusing on niche products and markets. A key outcome of this will be economies of scale which will in turn justify the development of processing facilities in Ireland, including drying and a biorefinery. This point is explicitly recognised in the *BIM Irish Macro-Algal Cultivation Strategy to 2030* which notes that:

The feasibility of establishing processing activities above those presently available hinges on significant increases in biomass production. Enhancing the support infrastructure is likely to help growers to expand cultivation. However, any expansion in output is likely to create challenges for production and processing due to the investments required in developing these capabilities. This is also a view shared by several stakeholders with long-standing involvement in national and international seaweed sectors consulted during this project and several Irish growers.

(BIM, 2023, p.117)

The importance of this is highlighted by research into the extraction of value within the seaweed value chain in Indonesia. It found that within the Indonesian seaweed sector, farmers make less profit than intermediaries within the value chain, including processors and exporters (Wahyularassati et al., 2019). A similar pattern has been observed elsewhere. For example, research in Kenya suggested that the fluctuations in the price of seaweed as a raw material will impact communities that come to rely on it as a source of income unless they can move “up the value chain” into processing and product development (Mirera et al., 2020).

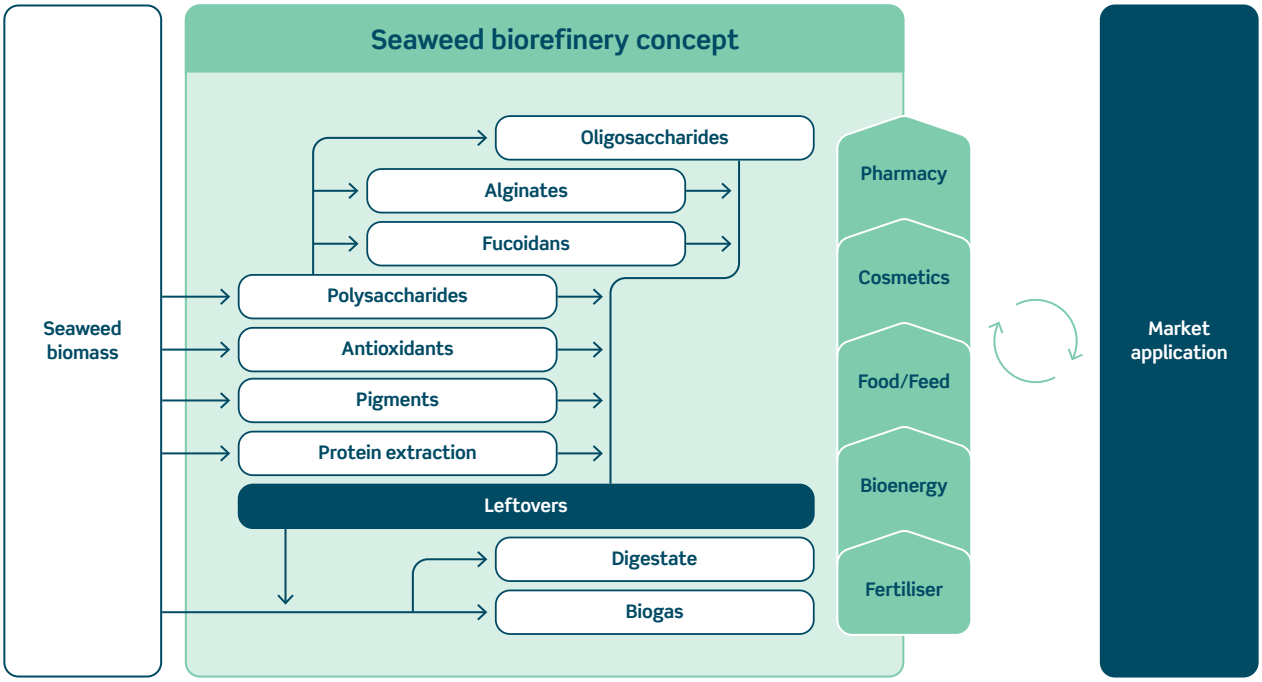


Figure 3: Seaweed biorefinery process (Balina et al., 2017, p.506)

Explicit in this model of biorefining process are what Baghel (2023) terms primary and secondary-level approaches:

> *the primary-level biorefinery approaches are advantageous over the secondary-level approach. They provide high-value products with a higher rate of biomass utilization, and extracted products have further opportunities for modification, derivatization, and use as per requirements.*

(Baghel, 2023, p.4).

Underpinning this conceptualisation is the desire to extract maximum value from the seaweed biomass. Lange et al. (2020) note that:

> *Full valorization of the high diversity of components found in red, brown, and green seaweeds will be achieved by application of new biorefinery technologies to seaweed processing. The principle of a cascading biorefinery, aimed at unlocking the full potential of the seaweed feedstock, is technically challenging yet highly rewarding. Through this principle, improvements become possible for all the three sustainability bottom lines—a better economy (more products and higher value from the raw material), a lower environmental foot print (bioprocessing substitutes for chemical processing and cuts down pollution), and a stimulated development in local and coastal regions primarily through increased livelihoods (more jobs and income).*

(Lange et al., 2020, p.25)

The importance of biorefineries being both local and nearby to support valorisation has also been highlighted (Lange et al., 2020) with The World Bank noting that "production facilities will need to be widely distributed to tap into high-value markets elsewhere. Localized processing will enable shorter supply chains, avoiding logistical complexity and reducing costs." (The World Bank, 2023, p.19). Given the costs inherent in transporting seaweed from remote locations in Ireland to biorefineries elsewhere in Europe this is particularly relevant. Although ratios of wet to dry seaweed vary (see Patarra et al, 2011 and Wickham et al., 2019), the costs of transportation for either are significant compared to those for extracts, whether primary or secondary level[3].

While this approach should yield greater added value and sustainability (Baghel, 2023), technical and operational challenges remain. Stakeholders interviewed emphasised that a key question for processors relates to the volume and value trade-off. More specifically: the higher value products from more involved processing (as in a biorefinery) are required at low volumes (e.g. pharmaceuticals, nutraceuticals, cosmetics, etc.), while the lower value products such as animal feed are needed at higher volumes. As a consequence, being a "big player" in nutraceuticals can entail being small player in biostimulants.

To address this, researchers are exploring more sophisticated and ecologically friendly technologies for processing using the "cascade" approach. The cascade approach seeks to achieve greater value from the available seaweed biomass by extracting high-value products like ingredients for cosmetics first and only then extracting lower-value products like biostimulants from the remaining biomass (Lange et al., 2020). As Balina et al. note:

> ***This approach increases resource efficiency and adds even higher value to used biomass, which is a part of circular economy. Increased resource efficiency also is saving the raw material supply, because biomass can be used repeatedly. With this principle usually the problem is that leftover biomass has to be transported from one location to another to continue with the next step of production, but biorefinery concept solves this problem since the concept is meant to be implemented in one location.***
>
> (Balina et al., 2017, p.507)

Nonetheless, biorefineries using the cascading approach may end up with challenges related to market positioning. The structure of value chains is such that while biorefineries may be able to integrate into the markets for those higher-value products, the remaining low volume of lower value biomass may struggle to compete with the integrated value chains of biostimulant specialists. Consequently, while the extraction of both higher and lower-value materials from seaweed biomass is clearly a technical challenge, stakeholders suggest there may also be operational challenges which will need to be addressed.

3 Baghlel (2023, p.4) defines primary level extracts as "the biomass components in their native state or a little bit modified, such as extraction of lipids, proteins, cellulose, minerals, carbohydrates, agar, alginate, and carrageenan" and secondary level as "final or end products like the production of bioethanol, biogas, bio-butane, bio-oil, bio-char, acids, etc. This type of approach use treatments like hydrolysis, fermentation, anaerobic digestion, pyrolysis, and hydrothermal liquefaction.")

We earlier noted the potential posed by the conscious selection of unique and novel varieties of seaweed for farming. A note of caution is struck in this regard by Lange et al. (2020) who highlight that:

> ***Besides the differences between the red, green, and brown seaweeds, their chemical composition also varies significantly between lower-level taxonomic groups, even at species or strain level. One more layer of complexity is that most types of seaweeds have strong seasonality in their composition… All in all, these differences in composition represent a potential for expanding the portfolio of products developed from seaweeds, but they also represent a challenge for optimized year-round feed stock supply and for developing the most efficient biorefinery conversion using the biomass to its full potential.***

(Lange et al., 2020, p.21)

Stakeholders interviewed suggest that despite the need for low biorefineries volumes to create higher-value products, they experience difficulties sourcing seaweed biomass. A key issue in this regard relates to the desire to work with one single supplier rather than aggregate across multiple producers and the need for a continuity of supply. Our proposed cluster solution may go some way toward mitigating these challenges.

FURTHER STEPS

While arguments for the development of biorefining capacity in Ireland would appear compelling there are a number of other considerations. The 2020 Cybercolloids report *Scoping a Seaweed Biorefinery Concept for Ireland* highlighted a number of key considerations which would need to be addressed prior to the implementation of a biorefinery solution in Ireland, namely:

- *what will be the tonnage of each key species and when will this biomass be available?*
- *is year-round cultivation an option for some species/growers?*
- *how variable are the key components in each species on a seasonal and locational basis?*
- *is there a preferential window for harvest to obtain maximum content of key components e.g. laminarin?*
- *is wild harvest of some species an option to extend cropping season and/or increase volumes?*
- *growers will have to collaborate to maximise opportunities and benefits, what form will this collaboration take?*
- *what will be the strategy for storage and logistics i.e. transport of biomass to any potential biorefinery/processing facility?*
- *processing from fresh is preferable if not always practical, ensiling or other pre-treatments could be considered;*
- *are existing facilities available in Ireland that could be used initially for a small/pilot scale biorefinery process? Or are new facilities to be established?*

(Cybercolloids, 2020, p.59)

While significant work has been done since that report was published, we argue that these questions remain valid today.

PRODUCTS **AND MARKETS**

The EU is currently one of the world's largest importers of seaweed, with the majority imported from China, South Korea and Chile for use in food and industrial applications including fertiliser (European Commission, 2023). According to the European Commission's *Towards a Strong and Sustainable EU Algae Sector, this* demand is expected to grow significantly over coming years with significant positive impact:

The Seaweed for Europe coalition estimates that European demand for seaweed could increase from around 270 000 tonnes in 2019 to 8 million tonnes in 2030 and reach EUR 9 billion in value in 2030 across all sectors, with feed, food and plant biostimulants (fertilising products) being the largest. Such an increase in production could create around 85 000 jobs, remove thousands of tonnes of phosphorus and nitrogen from the European Seas annually, mitigate up to 5.4 million tonnes of CO2 emissions a year and relieve pressure on the land.

(European Commission, 2022b, p.3)

Although the use of seaweed in various sectors in Europe has a long history, current seaweed farming primarily focuses on a narrow range of applications. Vazquez Calderon et al (2022) assert that:

61% of seaweed production companies in Europe direct their biomass production to food uses (36% as human food, 15% for food-related uses like supplements and nutraceuticals and 10% for feed). The 39% remaining are dedicated to cosmetics and well-being products (17%) and all other applications such as fertilizers and biostimulants (11%).

(Vazquez Calderon et al., 2022)

The potential to expand beyond these bounds was highlighted by The World Bank (2023) which outlined current and future product and market opportunities for seaweed, by both value and market segment:

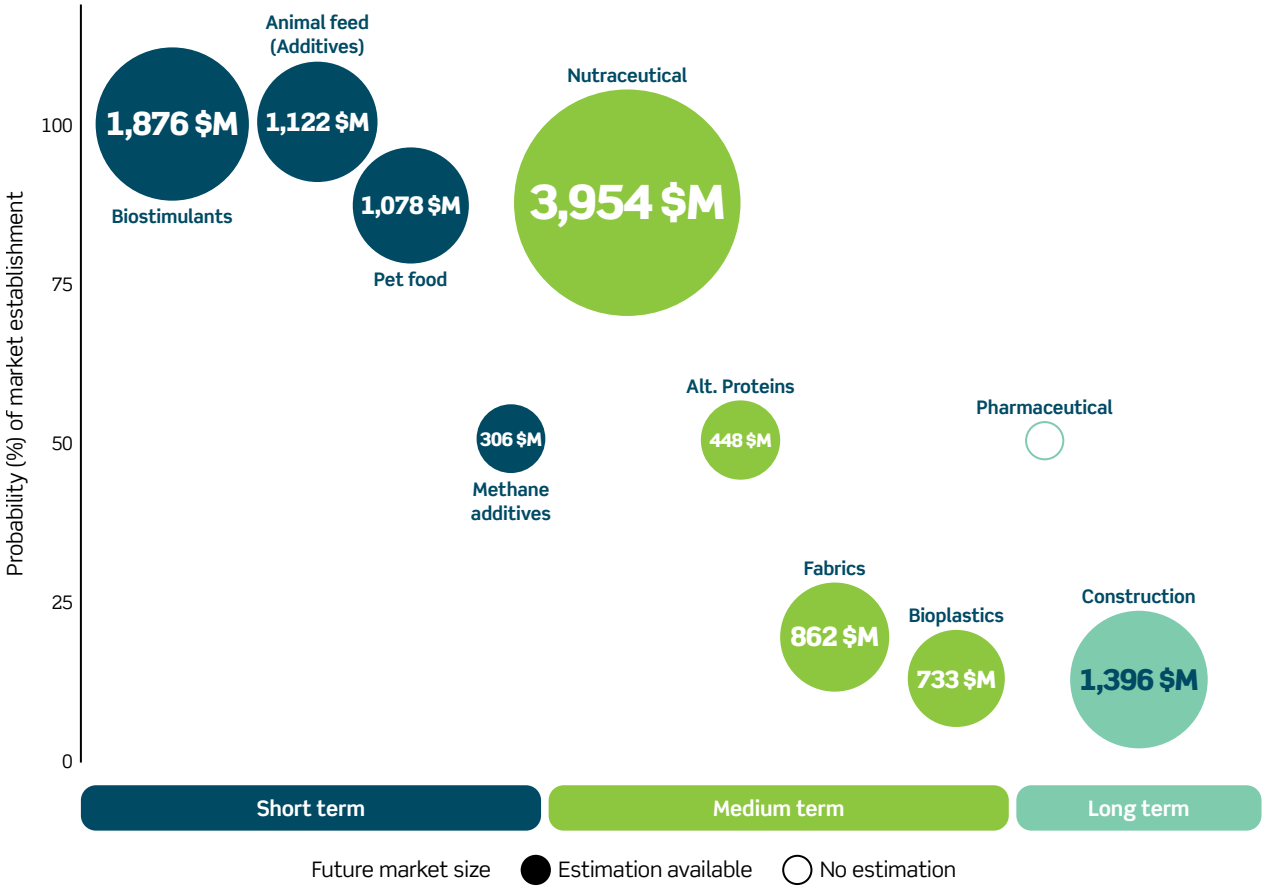


Figure 4: Predicted seaweed market size by 2030 ($ millions) with chance of market establishment indicated by colour on a high-level market horizon (The World Bank, 2023, p.xii)

As a foodstuff, the market for seaweed is most developed in Asia, where the majority of the world's seaweed is produced and consumed. Nonetheless, seaweed has traditionally played a vital role in diets in a number of European countries, including Ireland.

Stakeholders consequently highlight food as a key product category to underpin the development of European seaweed value chains, even if also potentially one of the most challenging. The suggestion is that while products clearly identified as seaweed attract interest from foodies and farmers' markets, they can struggle to reach the mainstream. Questions must therefore be asked about whether seaweed-derived foodstuffs should be treated as definitive seaweed products, or whether seaweed should be treated as either a hidden ingredient or a hero ingredient.

Seaweed is also commonly employed in cosmetics, and companies like L'Oreal are amongst the largest patent holders of seaweed compounds in the world (van den Burg et al., 2021). While these multinationals tend to buy in global markets, and seaweed might be a hidden ingredient, there are smaller firms developing specific seaweed-focused products. These products typically emphasise some of the key themes noted earlier: sustainability, European provenance, natural and high-quality cosmetic products.

While there is clearly scope for both diversification and specialisation by Irish seaweed producers, such aspirations (and indeed forecasts) should be treated cautiously. Taking the market for alginates as an example, varying reports suggest that the global market in 2022 was worth approximately USD657 million (Polaris Market Research,

2022) or possibly USD 855 million (Precedence Research, 2023) – a 30% difference – and that CAGR between 2023 and 2030 or 2032 will be 4.7% (Polaris Market Research, 2023) or 5.53% (Precedence, 2023). This compares to guidance from stakeholders active in the seaweed sector who suggested that the market for alginates is flat and is not expected to grow in the near term.

Equally, stakeholders suggest that the higher price point of farmed seaweed in Europe currently makes it uneconomical for use in biostimulants. There is nonetheless an argument for considering the use of farmed seaweed to overcome the uncertainties associated with a reliance on largely unregulated wild seaweed harvesting. This continuity of supply may also lead firms to explore options for moving into higher-value products.

MARKET POSITIONING AND DIFFERENTIATION

Regardless of the potential end use, any claims made typically rely on an image of seaweed as a sustainable source of ingredients. Drawing parallels with work on upgrading global value chains (Gereffi & Lee, 2016), seaweed forms part of social, environmental and, to an extent, local economic development narratives to upgrade the products. Ultimately, the economics of seaweed in Europe only makes sense if market upgrading exists. While a certain degree of upgrading will come about due to the quality of the products themselves (the physical properties and uses), some will come from social upgrading (more transparent and fairer value chains and supporting fragile economies). Subject to further research validation, environmental value and ecosystem services may also play a role. In each case, upgrading must relate to value added in a way that end-users and consumers clearly understand and claims need to be fully validated.

Upgrading also requires investment to validate compounds that have already been identified, exploring novel seaweed species, and searching for new compounds. It means validating environmental services practically and setting out criteria that provide stakeholders throughout the value chain with confidence that those practices deliver on the promises made and that the claims can be assured. It furthermore means validating claims about delivering social value and ensuring traceability to provide confidence across the value chain. This holistic approach to market upgrading needs top-down buy-in and bottom-up endeavour. It will require the establishment of connections between various academic disciplines and different private sector actors, with clear industry-academic links emerging and the support of political actors.

This suggests that effort will be needed across the Technological Readiness Level (TRL) scale. However, while there is a need for ongoing support for fundamental research at the earlier stages to identify species and compounds, the initial balance actors in the cluster should support the validation of the properties and claims, so TRL 4 or possibly 5 onwards. Validating claims in context and moving towards market readiness will build confidence in and within the cluster, which will attract those who operate earlier and later in the innovation process.

There is extensive research aimed at validating claims regarding the ecosystem services role of seaweed. This includes research considering the social models around fairer production practices and the emphasis on the role of seaweed in supporting fragile rural economies (Menzies et al., 2021; Scottish Government, 2022a). Nonetheless, in European terms, research is needed to validate claims regarding upgrading.

The emergence of complex public-private governance structures within the European seaweed value chain is arguably an attempt to enhance confidence in the claims made about products vital to the realisation of market upgrading. This perspective is affirmed by Selnes et al. (2021) who highlight that :

A systematic review of scientific publications published between 2010 and 2020 was executed for five markets: pharmaceuticals, bioplastics, biostimulants, alginate and cosmetics. It is concluded that innovation in the use of seaweed takes place across the globe and thus that a focus on high-value applications alone will not set the nascent European seaweed sector apart from established producing regions such as Asia. The studied global value chains are organised around strong lead firms that require suppliers to produce according to codified product characteristics.

(Selnes et al., 2021, p.1)

Key to success for Irish seaweed will be effective market positioning and differentiation. Drawing on Kotler's pricing strategies (see Doyle, 1998; Kotler, 1999), we suggest that this be achieved in two key ways:

- Highlighting Ireland's "clean and green credentials" and promoting both product and service quality
- Positioning Irish seaweed as a premium product and thus achieving medium to high price points compared to competitors

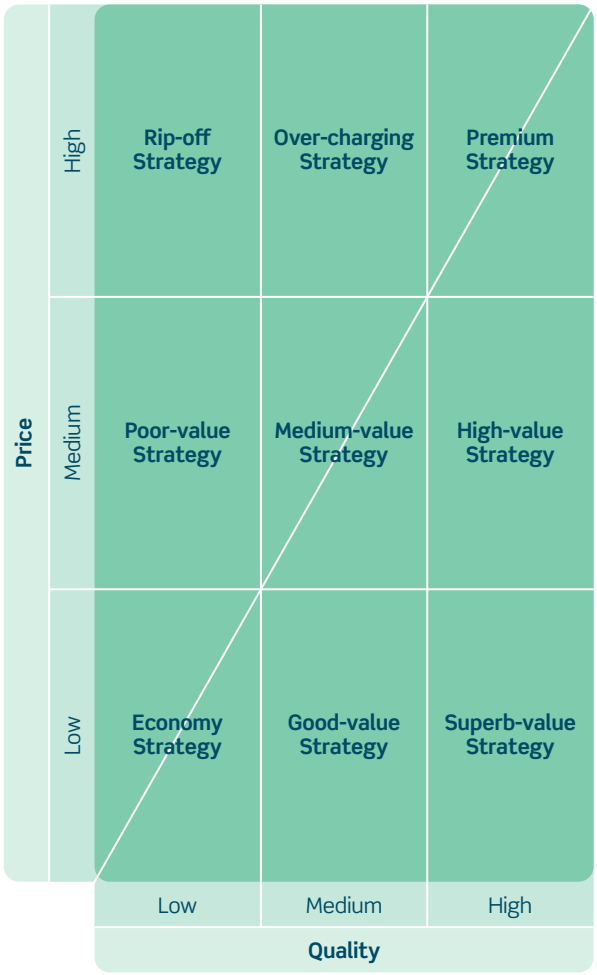


Figure 5: Kotler's Price/Quality Strategies
Source: https://www.mindtools.com/an7ep8c/kotlers-pricing-strategies

While branding will play a key role in successful differentiation, a focus on quality and consistency throughout the supply and value chains is vital. This will entail a focus on excellence throughout the end-to-end value chain to ensure that value upgrading is not only achieved but also clearly justified.

An important element of this will be effective and consistent regulation of seaweed farming and the various activities throughout the seaweed value chain. In this regard, regulation will serve not as a hindrance to development but rather as a justification for differentiation. As a member of the European Union, Ireland can lead the way in supporting consistent and coherent regulatory regimes for seaweed. Selnes et al. (2021) expressed it succinctly as follows:

The European sector need to develop ways of how to set itself apart from other producing regions and add value through novel applications. For this to happen the sector should explore and implement an upgrading strategy based on high quality production with strict standards for sustainability and safety. A joint effort to develop safe and sustainable products that meet the demands of regulators, lead-firms and consumers is then needed.

(Selnes et al., 2021, p.14)

As earlier noted, land-based farming of seaweed is ideal for ensuring quality outturn and meeting regulatory and customer requirements in terms of nutrients, contamination and consistency. As Mac Monagail and Morrison (2020) emphasise, however, this also applies to sea-based farming in Irish waters:

Open sea cultivation can provide an enormous quantity of biomass for several sectors, particularly relevant as demands for contaminant-free seaweed for use in nutraceuticals and pharmaceuticals appears to be increasing....

With the further development of new markets in pharmaceutical and human health applications, production of high quality health and food products with recognised traceability and testable safety standards will be of utmost importance to the successful commercialisation of contaminant-free raw material.... The continued refinement of existing cultivation techniques will likely improve quality control and traceability of products....

(Mac Monagail and Morrison, 2020, p.1295)

ENHANCING THE **VALUE CHAIN THROUGH AN IRISH SEAWEED CLUSTER**

This section builds on the challenges and opportunities for the seaweed value chain in Ireland, and suggests a key role for clustering as a way to address them.

Our research findings show that Irish farmed seaweed offers significant opportunities for growth if the sector is managed and supported effectively. Our findings also highlight that structural changes within the broader seaweed sector and value chain will be required if maximum value is to be achieved. This will include taking a coordinated, country-wide approach to the development of Irish seaweed, not only in terms of the opportunities and challenges facing individual stakeholders, but also to the interactions between stakeholders and the importance of aligning interests in order to extract maximum value.

This holistic approach to market upgrading needs top-down buy-in and bottom-up endeavour. It will require the establishment of connections between various academic disciplines and different private sector actors, with clear industry-academic links emerging and the support of political actors.

As noted earlier, without appropriate collaboration and coordination, the value chain for seaweed in Europe may tend towards the asymmetric modular model, with large organisations dominating the sector.

Analyses of the European market more generally suggest that value chain governance takes the form of a complex array of Government actors, Non-Departmental Public Bodies, Research Centres (Universities and public-private partnerships) and private sector actors.

The suggestion is that the sector is novel, products are not yet commercially viable or at scale, and the patterns are emerging (van den Burg et al., 2019).

The European seaweed sector needs to increase the collaboration and develop joint efforts to develop safe and sustainable products that meet the demands of regulators, lead firms and consumers. Stronger coordination in the value chain will facilitate further business development, by stimulating collaboration and innovations.

(Selnes et al., 2021)

As noted by Selnes et al. (2021), clustering and networked governance models are emerging in Europe as a way to address challenges and realise opportunities. We argue that a cluster approach is the most appropriate approach to support the further development of the seaweed sector and drive further development of the value chain. Today's economic map of the world is dominated by clusters, defined by the European Union in the following terms:

***Clusters** are understood as regional ecosystems of related industries represented through a group of firms, related economic actors and institutions that are located near each other and have reached a sufficient scale to develop specialised expertise etc.*

***Cluster initiatives** are organised efforts to support the competitiveness of a cluster and thus consist of practical actions related to the capacity of these clusters to self-organise and increasingly to pro-actively shape the future of the cluster. They usually follow a bottom-up approach, are implemented through a competitive process, and are often managed by specialised intermediaries, such as cluster organisations.*

(European Union, 2024)

Clusters play an important role as drivers of growth and innovation nationally, regionally and locally. They function as collaborative environments in which enterprises gain access to knowledge and collaboration with research institutions, other enterprises as well as public sector bodies. Successful clusters have been shown to:

- Increase the competitiveness of the regional or national economy through facilitation of collaboration between companies and research stakeholders
- Increase innovation capabilities and competitiveness especially of SMEs
- Support SMEs to better deal with technological and market challenges
- Develop and professionalise cluster management

SEAWEED CLUSTER CASE STUDIES

In order to understand the benefits of applying the cluster model to accelerate the development of the Irish seaweed industry across the entire seaweed value chain, the following seaweed clusters were examined:

- **North Sea Farmers** – a developing international cluster based on multi-use offshore farming.
- **Brittany Algae Cluster** – the French industry is clustered primarily in and around Brittany where a regional seaweed economy exists. The industry is well organised with a number of clusters and industry associations to support and drive the industry forward.
- **Norwegian Seaweed Association** – an industry with a rapidly developing seaweed farming sector and strong blue-bio ethos.
- **Zanzibar Seaweed Cluster Initiative** (ZaSCI) - one of the clusters formed under the Pan African Competitiveness Forum (PACF) and coordinated by Tanzania Commission for Science and Technology (COSTECH).

Brief case studies of each are outlined below with additional detail included in Appendix 1.

Case study 1 – North Sea Farmers

(Adapted from: https://www.northseafarmers.org/ *and* https://www.government.nl/binaries/government/documenten/diplomatic-statements/2023/04/24/ostend-declaration-on-the-north-sea-as-europes-green-power-plant/stend+Declaration+on+the+North+Sea+as+Europe%27s+Green+Power+Plant.pdf*)*

Background, Vision and Mission

North Sea Farmers (NSF) is a non-profit organization dedicated to fostering success in the European seaweed industry. They work across the entire seaweed value chain, promoting sustainability, education, research, and innovation. NSF primarily operates in the North Sea region.

Their mission is empowering seaweed as the raw material of the future. Their vision is that by 2050, the markets for building materials, food, agriculture and packaging are all using products and solutions with seaweed. No longer because it's a sustainable alternative, but because regulations and consumers have enforced the transition to circular value chains.

NSF aims to focus on a yearly production volume of 1-10mln tons of fresh seaweed using available space on land, salt water resources in sheltered areas but primarily at sea in the wind farms in the North Sea.

By 2050, the total production area of the seaweed sector will have increased to 1,000-10,000 km2. This is up to 3% of the total production area of wind farms as aspired to in the Ostend agreement.

NSF believe in seaweed as the raw material of the future. A raw material that does not need fresh water and land to grow. Which is renewable, and therefore inexhaustible. Which contributes to a clean blue planet, and is a source for new life in the sea.

Key Objectives of the North Sea Farmers are to:

- Facilitate knowledge exchange in the sector
- Identify knowledge gaps
- Close knowledge gaps by initiating & facilitating innovation / collaboration projects
- Identify (market) opportunities & trends
- Enable collaborations in seaweed value chains
- Represent the sector towards policy, markets and other sectors
- Give visibility to the seaweed sector and its players
- Ensure long-term perspective for NSF as sector organization

Members of the North Sea Farmers cluster include more than 100 paying member organizations such as:

- Over 40 internationally operating companies
- Almost all Dutch wind farm operators
- Universities and knowledge institutes
- Over 1,000 stakeholder contacts in Europe
- EU and Dutch governmental and regulatory stakeholders
- Nature, fishery and aquaculture NGOs
- Standardisations & certification committees

Examples of projects that have been achieved to date include:

North Sea Farm 1 – In collaboration with Van Oord, Algaia, and Amazon's Right Now Climate Fund, NSF are establishing a sustainable, nature-inclusive seaweed company integrated within an offshore wind farm.

Off Shore Test Sites – Located 12 km off the coast of Scheveningen, the OTS is an innovation hub set on 6 km² of North Sea territory. It serves as an incubator for start-ups and scale-ups aiming to challenge and validate their innovations in the real-world, demanding conditions of the offshore environment.

Case study 2 – Brittany Algae Cluster

(Adapted from: https://www.clusteralgues-bretagne.com/algae-cluster-4028-0-0-0.html*)*

Background, Vision and Mission

The *Brittany Algae Cluster*, an association created on April 6, 2023, aims to make Brittany a region of excellence and leader in the economic development of the algae sector. The cluster is a continuation of the work carried out by the Pays de Brest Algae Cluster which operated from 2018 to 2021.

The cluster aims to maximise the potential of Brittany's exceptional maritime position, which has all the elements necessary for the development of the algae sector, to take a leading place in a competitive European and international context. These include:

- An algal biomass unique in its quality, diversity and abundance
- Dynamic and innovative companies in the immediate vicinity of this resource
- Skills through the excellence of its higher education and internationally recognized research

Key Objectives of the Brittany Algae Cluster are to:

- Boost the circular economy and innovative companies in the algae ecosystem, promoting financial support for companies in the Breton sector
- Network and share a strategic ambition for the Breton algae sector, promoting the Breton algae sector and its societal commitment
- Encourage the emergence of collaborative projects with the prospect of creating activities throughout Brittany
- Create sustainable jobs and offer new activities to existing marine sectors
- Contribute to the fight against climate change by storing carbon and avoiding CO_2 emissions by replacing fossil-based products
- Take into account sustainable development and the preservation of natural resources at the heart of this sector in all the undertaken and supported actions
- Support food and energy sovereignty in Brittany

Membership of the Brittany Algae cluster includes:

an alliance of companies, the driving forces of this sector, regional authorities, higher education and research establishments, and financial institutions. The cluster management position is financed by Europe, the Brittany Region, the Technopôle Brest-Iroise, the CCIMBO, Crédit Agricole sea sector, Crédit Mutuel Arkéa and Crédit Maritime BPGO.

Case study 3 – Norwegian Seaweed Association

(Adapted from: https://www.norseaweed.no/*)*

Background, Vision and Mission

Norwegian Seaweed Association is a network organisation for seaweed farmers, manufacturers and small-scale harvesters. They develop complete value chains for food, feed and ecosystem services. Norwegian Seaweed Association run the Norwegian Seaweed Cluster.

Norwegian Seaweed Cluster was formed to develop a robust and effective innovation ecosystem for the seaweed industry. It was established in March 2021 by merging two Norwegian seaweed networks. From 2010 different organisations have been working to mobilize a new marine industry based on marine algae. Norwegian Seaweed Association has invited others stakeholders among R&D, suppliers and customers, investors and public funders to form a cluster for strengthening the seaweed industry.

Key Objectives of the Norwegian Seaweed Cluster are as follows:

Collaboration

- Exchange of knowledge and experience from seaweed farming and production as a viable industry in Norway
- Promote common interests to public authorities
- Formulate demanding issues for further research

Branding and markets

- Identify and explore national and international markets for seaweed products
- Create a common brand for Seaweed from Norway
- Exhibitions in Europe
- Market insight

Streamline production

- Professionalize farming and industry to become internationally competitive
- Create product standards for the seaweed industry

Product development and quality

- Guidelines for product development
- Food safety
- Updating laws and regulations

Production technology

- Effective seedling production
- Farming infrastructure
- Harvesting and preprocessing
- Processing units: drying, freezing, fermenting, blanching

Sustainability

- Monitoring ecosystem influence in seaweed farms
- Valorization of ecosystem services
- Regenerative aquaculture
- Sustainability strategies

Knowledge and Competence

- Conferences and seminars
- Focus Groups
- Study trips
- Exchange of experience
- R&D

Common Development Projects

- Partnership in research projects on behalf of the members
- Sharing of results from R&D projects

Members of the Norwegian Seaweed Cluster

The Norwegian Seaweed Association is funded by Innovation Norway and membership fees, and has around 70 partners from the whole value chain from start-ups, industry partners, R&D, suppliers, investors, customers and public funders.

Case study 4 – Zanzibar Seaweed Cluster Initiative

(Adapted from: https://seaweedcluster.or.tz/ *and Msuya, 2021)*

Background, Vision and Mission

The *Zanzibar Seaweed Cluster Initiative* (ZaSCI) is one of the clusters formed under the Pan African Competitiveness Forum (PACF) which is coordinated by Tanzania Commission for Science and Technology (COSTECH). ZaSCI started its activities in 2006 and is now working with seaweed farmers in eleven villages in Zanzibar and one village on mainland Tanzania.

In the Zanzibar Islands, seaweed farming started in 1989 as a commercial product. Currently it employs 25,000 farmers, more than 80% of whom are women. The importance of the seaweed industry to the Zanzibar economy lies in the fact that it is the 3rd largest industry that brings foreign currency to Zanzibar after tourism and the clove and has proved to be a sustainable and beneficial livelihood activity since the 1990s.

Despite the 30+ years of existence of the industry, there is still very little Value added, while 99% of the seaweed is still exported unprocessed as raw material for multinational companies abroad. The ZaCI vision is to be the best producers and sellers of quality seaweed and seaweed products in Eastern Africa. The ZaSCI mission is to tap into the existing scientific knowledge and farming experience on seaweed production and utilize it to bring innovation into seaweed farming to help farmers produce high-quality seaweed and make value-added products for food and income diversification.

Key Objectives of the Zanzibar Seaweed Cluster

The aim of the Zanzibar Seaweed Cluster is to combat challenges which are directly faced by seaweed farmers considering that since 1989 there has been no innovation (both in farming and value addition technologies) but only exporting of raw unprocessed seaweed. This is achieved as follows:

Innovation

ZaSCI mostly works in two areas of innovation:

- developing innovative deep-water farming technologies with the aim of increasing the production of the higher valued seaweed cottonii
- developing seaweed value added technologies

Awareness Raising and Market Development

In conducting its activities, ZaSCI observed that many people in Zanzibar and Tanzania in general do not know much about seaweed and its uses. For more than 10 years ZaSCI has focussed on raising its profile locally through marketing activities that raise awareness and knowledge of local usage of seaweed and increase the market for its seaweed products. They hold a **National Seaweed Day annually which** is supported by the Ministry of Trade and Industry, Ministry of Blue Economy.

New Product Development

In 2006, ZaSCI started its activities with a group of 21 women in one village, (Kidoti), in northern Zanzibar. The first activity was to produce seaweed powder which was used to make seaweed soap and body cream. Trials were made for these initial products in 2006, and in 2008 the first seaweed products to be produced by a Zanzibari (and Tanzanian) seaweed farmer — the powder and soap — were marketed. In 2019 ZaSCI had 25 groups that made seaweed products in Zanzibar. The products are made using the lower valued seaweed Eucheuma (commercially called Spinosum) so as to increase its value.

Members of the Zanzibar Seaweed Cluster

Currently ZaSCI has 3,700 members, out of them 500 are seaweed processors from 28 groups scattered across Unguja and Pemba.

COMMON FACTORS ACROSS CLUSTERS

The examples outlined above demonstrate the benefits of adopting a cluster approach to harnessing seaweed's potential for economic, social and environmental impact. There are a number of common factors across each of the examples that including the following:

- These not-for-profit organisations are dedicated to fostering success in the European and international seaweed industry through working across the entire seaweed value chain, promoting sustainability, education, research, and innovation.
- Each cluster has a clear vision and mission based on an ambition to establish regions of excellence and leadership in the economic development of the algae sector.
- Each cluster is made up of a diverse alliance/network representing the entire value chain that includes farmers, industry, regional authorities, Government ministries, higher education institutes, research establishments and financial institutions to develop a robust and effective innovation ecosystem for the seaweed industry
- Each cluster operates a diverse funding model that includes support from government agencies, not-for-profit sponsorship and membership fees
- The clusters have a clear work programme that focuses on facilitating knowledge exchange, identifies knowledge gaps and specific services for supporting, connecting, incubating, investing, and growing startups that create added value

- Each cluster has a strong focus on developing their brand, undertaking market research to identify market opportunities and trends and promotional activity to represent and raise the profile of the sector
- Each cluster is involved in facilitating collaborative projects among the members across the seaweed value chains with the prospect of creating sustainable activities and employment
- Each cluster has a focus on sustainable development and preservation

BENEFITS OF CLUSTERING FOR THE IRELAND SEAWEED SECTOR

The development of a seaweed innovation cluster is a model employed by emerging, developing and established markets in Europe and internationally aimed at strengthening communication, synergy, collaboration to drive added value, business continuity and the role of seaweed in increasing regional competitiveness (van den Burg et al., 2019; Selnes et al., 2021).

This perspective aligns with existing Irish government policy and with the existing seaweed strategy (BIM, 2023). Ireland's enterprise development policy as set out in *Enterprise 2025 Renewed – Building resilience in the face of global challenges* (Department of Business, Enterprise and Innovation, 2019) has identified the opportunity for Ireland to build on sectoral comparative strengths, while seeking out new opportunities for growth. This will be achieved through an intensified focus on collaboration, connections and clustering with the aim of deepening resilience and stimulating sustainable growth throughout the regions.

Further, the Department of Enterprise, Trade and Employment's *White Paper on Enterprise* (2023) recognises the importance of clustering to sustain and develop competitive advantage in areas of strategic importance and potential, linked in particular to the twin transitions of green and digital.

Ireland's seaweed sector is composed of a wide range of actors and organisations from government departments, state agencies, farmers, research institutes etc. Our research suggests, however, that the sector is constrained by a lack of synergy, collaboration and coordination between all the stakeholders and insufficient communication to develop the upstream and downstream industries. In essence, while Ireland has a critical mass of industry actors, with the sectoral skills and competencies to develop into a seaweed cluster, without the appropriate business, institutional and public supports, a robust and sustainable cluster model is unlikely to emerge.

With regard to the Seaweed/Algae industry, the *National Strategic Plan for Sustainable Aquaculture Development* (2023) recommends a framework for cooperation that brings together public authorities, industry, researchers, and educators, both at national and regional/local levels. This framework should include the development of innovation clusters for sustainable farming of seaweed. These points are further emphasized by recommendations outlined in *A Strategic Review of Irish Macro Algae Cultivation* (BIM, 2023) which identifies clusters as an organising structure, key to facilitating greater collaboration and a more integrated industry in an emerging seaweed landscape with three distinct regional clusters comprising growers in the south west, west and north west.

Figure 6: Ireland's farmed seaweed ecosystem

Clusters are designed to encourage intensive collaboration and interaction, sharing resources, knowledge exchange and contribute effectively in the process of technology transfer, technology diffusion, business networking, marketing and information dissemination. To achieve this, cluster members work together in groups formed according to the needs of the sector to achieve common goals. In this way cluster members collaborate to solve common problems rather than individually attempting to achieve separate parts of the problem. Key amongst these for the farmed seaweed sector in Ireland would be the achievement of economies of scale and greater consistency of quality and reliability of volumes. The aggregation of biomass volumes would in turn justify greater investment in the necessary supporting infrastructure to ensure the growth of the sector, including biorefinery, drying and processing facilities.

Government/State Agencies play a very important role in the formation of clusters with the design and implementation of policies to support cluster development at the growth phase. Equally, while the involvement of government can add credibility to a cluster, the lack of government support can be a threat to growth possibilities for a cluster. A key element of this support, most particularly in the initial periods, is financial support over a specific timeframe. This would primarily relate to funding a cluster management role and key cluster activities for a period of 5 to 10 years.

Figure 7: Key Activities of a Cluster, GM Innovations

Just as importantly, adopting a cluster model for the Irish seaweed sector could be an effective mechanism to deliver on key themes identified in the 2023 BIM strategic review of seaweed farming (BIM, 2023):

Collaboration

- Exchange of knowledge and experience from seaweed farming and production as a viable industry in Ireland.
- Lobby and Stakeholder Management – representing and advocating for the sector through involvement in multiple stakeholder groups, steering committees, and advisory boards. Policy input to governments, research institutes, and related organizations.

Branding and Marketing

- Create a common brand for *Seaweed from Ireland*
- Map the seaweed industry in Ireland and produce a directory that covers the seaweed value chain
- Harness potential of Seaweed Festivals to raise awareness

Market Development

- Research national and international markets for seaweed products.
- Create *Exhibitions of Seaweed from Ireland* to tour key markets in Europe
- Market insight

Product development and quality

- Product development and quality – Guidelines for product development/Food safety/Updating laws and regulations
- Production technology – Effective seedling production/Farming infrastructure/ Harvesting and preprocessing/Processing units; drying, freezing, fermenting, blanching

Sustainability

- Monitor ecosystem influence in seaweed farms
- Capture the value of ecosystem services
- Regenerative aquaculture and sustainability strategies

Knowledge and Competence

- Host conferences and seminars and participate in European conferences
- Organise study trips in Ireland and overseas to grow awareness and develop linkages
- Explore R&D opportunities and EU funding programmes
- Link with European seaweed clusters and networks

Common Development Projects

- Facilitate networking and partnership in research projects on behalf of the members
- Share results and impact of current R&D projects

Consequently, we argue that a key step to progressing Ireland's seaweed sector and maximising the value chain is the establishment of a coordinated and coherent macroalgae cluster involving all sectors and players from the ecosystem. While we identify diversity and non-alignment as important characteristics in the international clusters examined, the seeding of these clusters involved key state actors and agencies and the role of a lynch-pin organisation both to lead and to support the development of a seaweed cluster in Ireland will be crucial.

CONCLUSIONS AND **RECOMMENDATIONS**

This report builds upon previous research into the development of Ireland's macroalgae sector. In undertaking this analysis, we have sought to integrate a range of perspectives both to present a clear and coherent snapshot of the current seaweed value chain and to highlight where further efficiencies could be gained.

The report began with a review of the European and Global seaweed sector to examine Europe and Ireland place in those value chains. It highlighted that global value chains tend to be modular, and characterised by asymmetric power relations. As a consequence, seaweed is treated as a commodity and the primary producers are largely seen as interchangeable. In this context, producers are – moreover – highly vulnerable.

At present, the overwhelming majority of the world's seaweed is produced and consumed in Asia, with Asia consequently dominating the governance of value chains. Despite this, the report notes that emerging value chains associated with novel products in Europe have a different pattern, one of networked governance with a range of academic, public and third sector actors involved. This networked governance model associated with these novel products represents an opportunity not just for the European seaweed sector more generally, but also for the Irish seaweed sector in particular.

A key finding of this report is that while there are significant potential areas for growth in Irish farmed seaweed, a number of key steps must be taken in order to achieve the potential of the macroalgae sector in Ireland.

More specifically, in order to add value through and within the seaweed value chain it is vital that significant efforts are made to add value across the various stages of the value chain – production, processing and products and markets. More specifically these relate to:

- Further develop the farming of unique seaweed varieties targeted at current and future market needs
- Continue to refine farming techniques to ensure maximum efficiency and quality of seaweed biomass, including at-sea, IMTA and on-shore cultivation
- Maximise efficiencies through the value chain to ensure the lowest possible costs at each stage
- Further develop automation at all stages of production to reduce costs and enhance efficiencies
- Maximise the value extracted through each harvest by ensuring the maximum usage of products/extracts through enhanced local biorefining and processing capabilities
- Target niche markets by characterised by demand for a consistently high quality product, consistent volumes and specific varieties of seaweed
- Provide consistently high-quality product, consistent volumes and specific varieties of seaweed to meet both current and future market needs
- Establish a clear and recognised brand of "Irish farmed seaweed" to differentiate Irish-produced seaweed
- Further develop the brand of Irish seaweed by continued engagement with international forums, conferences and events

UPGRADING AND VALIDATION

Implicit within the need to act across the value chain to add value at each stage are two areas, market upgrading and the validation of the properties and claims regarding seaweed.

In terms of market upgrading this relates primarily to:

- Maximising revenues by focusing on higher-value products and markets
- Accounting for the value of seaweed in relation to ecosystem services
- Clearly articulating the provenance seaweed through with transparent value chains
- Clarifying and establishing the socio-economic impact of seaweed

With regard to validation this relates to:

- Engaging in research and development to ensure confidence in the benefits of existing and novel seaweed and seaweed-related products and services
- Investing in research to establish ecological and social value of production and across the value chain
- Ensuring full traceability throughout the supply chain
- Continuing to maintain a transparent and coordinated regulatory regime to ensure environmental sustainability, commercial reliability and consistency

DEVELOPING A MACROALGAE CLUSTER

While a number of these recommendations can be achieved by seaweed farmers working individually, structural changes within the broader seaweed sector and value chain will be required. In particular, we argue that maximum value will be achieved throughout the value chain by taking a coordinated, country-wide approach to the development of Irish seaweed. In this respect, we conclude that the most effective way of achieving these recommendations is through the establishment of an Irish macroalgae cluster with appropriate knowledge transfer mechanisms and with greater integration into existing sectoral innovation processes.

The report highlights key requirements for establishing an Irish macroalgae cluster. Specifically:

- *Strategy*: A clear vision and mission based on an ambition to establish Ireland as a region of excellence and leadership in the economic development of the algae sector.
- *Governance*: A collaborative governance model, with a clear "lead agency" acting to coordinate and unify activities across government departments and state agencies
- *Structure*: A networked structure focused on developing a robust and effective Innovation ecosystem for the seaweed industry, working across the entire seaweed value chain, promoting sustainability, education, research, and innovation
- *Membership*: A diverse alliance/network representing the entire value chain that includes farmers, industry, regional authorities, Government ministries, higher education institutes, research establishments and financial institutions

- *Funding*: a diverse funding model that includes supports from government agencies, not for profit sponsorship and membership fees, and promotes financial support and investment

With the appropriate structure and supports, an Irish macroalgae cluster can add value for the entire sector. It will facilitate the achievement of economies of scale and justify subsequent downstream investment in processing, refining and logistics, which will in turn result in enhanced efficiencies and economies. More specifically, these benefits would relate to:

- *Networking*: Facilitating knowledge exchange between stakeholders, identifying knowledge gaps and supporting the emergence of collaborative projects focused on creating sustainable activities and employment
- *Advocacy*: Representation of the sector, along with promotion and activities to enhance visibility
- *Growth*: Offering specific services to support to existing players who can act as anchors in the sector; connecting, incubating, and growing startups that create added value; supporting marketing, branding and market research to identify market opportunities and trends
- *Investment*: Coordinating investment in key activities to maximise value for the sector overall.

The report highlights a series of opportunities to grow the sector by focusing on adding value across the value chain and implementing structures to enable and facilitate that growth. This approach mirrors what is happening both nationally and internationally, with key state agencies working across the value chain with other state bodies and both private and third-sector actors to support the development of the sector.

ACKNOWLEDGEMENTS

We would like to acknowledge the contribution of a number of sectoral stakeholders who gave generously of their time. These included the following, along with a number of other contributors:

- Dr Charlie Bavington, Oceanium
- Antoine Erwes, Seaweed First
- Franck Hennequart, Algaia
- Steven Hermans, Phyconomy
- Dr Sarah Hotchkiss, Cybercolloids
- Dr Sebastien Jubeau, Cargill
- Dr Micheál Mac Monagail, Arramara
- Jennifer, O'Brien Sea & Believe
- Rhianna Rees, Scottish Seaweed Industry Association
- Dr Jules Siedenburg, University of East Anglia
- Dr Joseph Sweeney, University College Dublin
- Dr Charlene Vance, University College Dublin
- Dr Sander van den Burg, University of Wageningen

APPENDIX 1
CLUSTER CASE STUDY DETAIL

	North Sea Farmers	Brittany Algae Cluster	Norwegian Seaweed Association (NSA)	Zanzibar Seaweed Cluster
	(Adapted from: https://www.northseafarmers.org/ and https://www.government.nl/binaries/government/documenten/diplomatic-statements/2023/04/24/ostend-declaration-on-the-north-sea-as-europes-green-power-plant/Ostend+Declaration+on+the+North+Sea+as+Europe%27s+Green+Power+Plant.pdf)	(Adapted from: https://www.clusteralgues-bretagne.com/algae-cluster-4028-0-0-0.html)	(Adapted from: https://www.norseaweed.no/)	(Adapted from: https://seaweedcluster.or.tz/ and Msuya, 2021)
Background, Vision and Mission	**North Sea Farmers** (NSF) is a non-profit organization dedicated to fostering success in the European seaweed industry. They work across the entire seaweed value chain, promoting sustainability, education, research, and innovation. NSF primarily operates in the North Sea region. Their mission is *empowering seaweed as the raw material of the future*. Their vision is that by 2050, the markets for building materials, food, agriculture and packaging are all using products and solutions with seaweed. No longer because it's a sustainable alternative, but because regulations and consumers have enforced the transition to circular value chains. As a sector, **North Sea Farmers** aim to focus on a yearly production volume of 1-10mln tons of fresh seaweed. Using, available space on land, salt water resources in sheltered areas but primarily at sea in the wind farms in the North Sea. By 2050, the total production area of the seaweed sector will have increased to 1,000-10,000 km2. This is up to 3% of the total production area of wind farms as aspired in the Ostend agreement[1]. NSF believe in seaweed as the raw material of the future. A raw material that does not need fresh water and land to grow. Which is renewable, and therefore inexhaustible. Which contributes to a clean blue planet, and is a source for new life in the sea.	**The Brittany Algae Cluster**, an association created on April 6, 2023, aims to make Brittany a region of excellence and leader in the economic development of the algae sector. Brittany has all the elements necessary for the development of the algae sector to take a leading place in a competitive European and international context. • An algal biomass unique in its quality, diversity and abundance; • Dynamic and innovative companies in the immediate vicinity of this resource; • Skills through the excellence of its higher education and internationally recognized research.	**Norwegian Seaweed Association** is a network organization for seaweed farmers, manufacturers and small-scale harvesters. They develop complete value chains for food, - feed and ecosystem services. NSA run the Norwegian Seaweed Cluster. Norwegian Seaweed Cluster was formed to develop a robust and effective Innovation Ecosystem for the seaweed industry. Norwegian Seaweed Association (NSA) was established in March 2021 by merging two Norwegian seaweed networks. From 2010 different organisations have been working to mobilize a new marine industry based on marine algae. NSA has invited others stakeholders among R&D, suppliers and customers, investors and public funders to form a cluster for strengthening the seaweed rganiziy.	The Zanzibar Seaweed Cluster Initiative (ZaSCI) is one of the clusters formed under the Pan African Competitiveness Forum (PACF) which is coordinated by Tanzania Commission for Science and Technology (COSTECH). ZaSCI started its activities in 2006 and is now working with seaweed farmers in eleven villages in Zanzibar and one village on mainland Tanzania. In the Zanzibar Islands, seaweed farming started in 1989 as a commercial product. Currently it employs 25,000 farmers, more than 80% of whom are women. The importance of the seaweed industry to the Zanzibar economy lies in the fact that it is the 3rd largest industry that brings foreign currency to Zanzibar after tourism and clove trade and has proved to be a sustainable and beneficial livelihood activity since the 1990s.

	North Sea Farmers	Brittany Algae Cluster	Norwegian Seaweed Association (NSA)	Zanzibar Seaweed Cluster
				Despite the 30+ years of existence of the industry, there is still very little valued addition, while 99% of the seaweed is still exported unprocessed as raw material for multinational companies abroad. The ZaCI vision is to be the best producers and sellers of quality seaweed and seaweed products in Eastern Africa To ZaCI mission is to tap into the existing scientific knowledge and farming experience on seaweed production and utilize it to bring innovation into seaweed farming to help farmers produce high-quality seaweed and utilize the seaweed in the country by making value-added products for food and income diversification.
Objectives and Services	The objectives of the ***North Sea Farmers cluster*** are: • Facilitate knowledge exchange in the sector • Identify knowledge gaps • Close knowledge gaps by initiating & facilitating innovation / collaboration projects • Identify (market) opportunities & trends • Enable collaborations in seaweed value chains • Represent the sector towards policy, markets and other sectors • Give visibility to the seaweed sector and its players • Ensure long-term perspective for NSF as sector organization Services and activities provided to members by the ***North Sea Farmers*** cluster include the following:	The objectives of the ***Brittany Algae Cluster*** are: • Boosting the circular economy and innovative companies in the algae ecosystem, promoting financial support for companies in the Breton sector; • Networking and sharing a strategic ambition for the Breton algae sector, promoting the Breton algae sector and its societal commitment;	The key focus of the ***Norwegian Seaweed Association*** is as follows: **Collaboration** • Exchange of knowledge and experience from seaweed farming and production as a viable industry in Norway. • Promote common interests to public authorities. • Formulate demanding issues for further research.	The aim of the ***Zanzibar Seaweed Cluster Initiative*** is to combat challenges which are directly faced by seaweed farmers considering that since 1989 there has been no innovation (both in farming and value addition technologies) but only exporting of raw unprocessed seaweed. **Innovation** ZaSCI mostly works in two areas of innovation:

North Sea Farmers

Networking Events:

Networking events twice a year featuring inspiring guests, presentations, and workshops.

Solid Knowledge Base:

Exclusive access to a wide range of resources:

Online knowledge base with articles, presentations, and documents. Topics include seaweed cultivation, certification (NEN/CEN), subsidies, project management, and more.

Member Consultancy

Direct support with questions or issues.

Match-making within our network for structural operational support.

Monthly Newsletter

Stay updated with our monthly newsletter, featuring news from members and the sector.

Lobby and Stakeholder Management

We actively represent and advocate for the sector through:

Involvement in multiple stakeholder groups, steering committees, and advisory boards. Policy input to governments, research institutes, and related organizations.

Dedicated Partnerships

Every aspect of the seaweed value chain is represented in the community: an extremely wide array of interests, activities and challenges. As North Sea Farmers we can help you understand the value chain and who is doing what.

Brittany Algae Cluster

- Encouraging the emergence of collaborative projects with the prospect of creating activities throughout Brittany;
- Creating sustainable jobs and offering new activities to existing marine sectors;
- Contributing to the fight against climate change by storing carbon and avoiding CO 2 emissions by replacing fossil-based products;
- Taking into account sustainable development and the preservation of natural resources at the heart of this sector in all the undertaken and supported actions.
- Supporting food and energy sovereignty in Brittany, in France.

Norwegian Seaweed Association (NSA)

Branding and markets

- Identify and explore national and international markets for seaweed products.
- Create a common brand for Seaweed from Norway.
- Streamline production
- Professionalize cultivation and industry to become internationally competitive.
- Create product standards for the seaweed industry.

Marketing/Common branding:

- Seaweed from Norway
- Exhibitions in Europe
- Market insight, priority

Product development and quality

- Guidelines for product development
- Food safety
- Updating laws and regulations

Production technology

- Effective seedling production
- Farming infrastructure
- Harvesting and preprocessing
- Processing units; drying, freezing, fermenting, blanching

Zanzibar Seaweed Cluster

- developing innovative deep-water farming technologies with the aim of increasing the production of the higher valued seaweed cottonii.
- developing seaweed value addition technologies and empowering farmers and processors in the new technologies.

Awareness Raising and Market Development

In conducting its activities, ZaSCI observed that many people in Zanzibar and Tanzania in general do not know much about seaweed and its uses. For more than 10 years ZaSCI had aimed at advertising itself, giving the knowledge on local usage of seaweed and increase market for its seaweed products by holding a Seaweed Day.

National Seaweed Day

- ZaSCI held its 7th Seaweed Day on 23rd July. ZaSCI has also been supported by the Ministry of trade and industry, Ministry of blue economy, SMIDA, FAO, UNIDO, KOICA, ZMBF, and TANTRADE

	North Sea Farmers	Brittany Algae Cluster	Norwegian Seaweed Association (NSA)	Zanzibar Seaweed Cluster
			Sustainability • Monitoring ecosystem influence in seaweed farms • Valorization of ecosystem services • Regenerative aquaculture • Sustainability strategies **Knowledge and Competence** • Conferences and seminars • Focus Groups • Study trips • Exchange of experience • R&D **Common Development Projects** • Partnership in research projects on behalf of the members • Sharing of results from R&D projects • Status and reputation	**New Product Development** In 2006, ZaSCI started its activities with a group of 21 women in one village, (Kidoti), in northern Zanzibar. The first activity was to produce seaweed powder which was used to make seaweed soap and body cream. Trials were made for these initial products in 2006, and in 2008 the first seaweed products to be produced by a Zanzibari (and Tanzanian) seaweed farmer — the powder and soap — were marketed In 2019 ZaSCI had 25 groups that made seaweed products in Zanzibar. The products are made using the lower valued seaweed Eucheuma (commercially called Spinosum) so as to increase its value.
Membership	The ***North Sea Farmers*** network extends as follows: • More than 100 paying member organizations, including: • Over 40 internationally operating companies • Almost all Dutch wind farm operators • Universities and knowledge institutes • Over 1,000 stakeholder contacts in Europe • EU and Dutch governmental and regulatory stakeholders • Nature, fishery and aquaculture NGOs • Standardisations & certification committees	The ***Brittany Algae Cluster*** is an alliance which brings together companies, the driving forces of this sector, territories, higher education and research establishments, and financial establishments. The cluster management position is financed by Europe, the Brittany Region, the Technopôle Brest-Iroise, the CCIMBO, Crédit Agricole sea sector, Crédit Mutuel Arkéa and Crédit Maritime BPGO.	The ***Norwegian Seaweed Association*** is funded by Innovation Norway and membership fees, and has around 70 partners from the whole value chain from start-ups, industry partners, R&D, suppliers, investors, customers and public funders.	The Zanzibar Seaweed Cluster Initiative consists of a well-established and efficiently working triple helix leadership team. Currently ZaSCI has 3,700 members, out of them 500 are seaweed processors from 28 groups scattered in Unguja and Pemba and composition of members as follows:

	North Sea Farmers	Brittany Algae Cluster	Norwegian Seaweed Association (NSA)	Zanzibar Seaweed Cluster
				• *Academia*: Institute of Marine Sciences (University of Dar es Salaam), Zanzibar Agricultural Research Institute, State University of Zanzibar. • *Government*: Ministry of Agriculture; Ministry of Livestock and Fisheries (Department of Marine Resources), Ministry of Empowerment. • *Business*: Seaweed farmers, Seaweed buyers/exporters, Seaweed users (small scale value addition), Zanzibar Chamber of Commerce, Industry and Agriculture.
Projects	**First Commercial Implementation** **North Sea Farm 1** In collaboration with Van Oord, Algaia, and Amazon's Right Now Climate Fund, we are establishing a sustainable, nature-inclusive seaweed company integrated within an offshore wind farm. **Off Shore Test Sites** Located 12 km off the coast of Scheveningen, the OTS is an innovation hub set on 6 km² of North Sea territory. It serves as an incubator for start-ups and scale-ups aiming to challenge and validate their innovations in the real-world, demanding conditions of the offshore environment.			GlobalSeaweedSTAR-Safeguarding the Future of Seaweed Aquaculture. The Research works on seaweed diseases, biosecurity practices, seaweed taxonomy, and resilience of seaweed farmers OceanForesters to implement a trial concept on co-farming of Seaweed, basket traps (for fish), and Giant clams "toward a marine Ecosystem Lifeboat" Schmidt Marine Technology Partners -implementing 3 activities- Production of a Documentary on ZaSCI, Planting seaweed in rafts and tubular nets with basket traps

REFERENCES

Albrecht, M. (2023). A Norwegian seaweed utopia? Governmental narratives of coastal communities, upscaling, and the industrial conquering of ocean spaces. Maritime Studies, 22(3). https://doi.org/10.1007/S40152-023-00324-2

Araújo, R., Vázquez Calderón, F., Sánchez López, J., Azevedo, I. C., Bruhn, A., Fluch, S., Garcia Tasende, M., Ghaderiardakani, F., Ilmjärv, T., Laurans, M., Mac Monagail, M., Mangini, S., Peteiro, C., Rebours, C., Stefansson, T., & Ullmann, J. (2021). Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. Frontiers in Marine Science, 7. https://doi.org/10.3389/FMARS.2020.626389

Asri, A., Le Masson, V., Montalescot, V., Lim, P. E., Nor, A. M., Hussin, H., & Shaxson, L. (2021). The role of migrants in the Malaysian seaweed value-chain. Marine Policy, 134, 104812. https://doi.org/10.1016/J.MARPOL.2021.104812

Baghel, R. S. (2023). Developments in seaweed biorefinery research: A comprehensive review. *Chemical Engineering Journal, 454*, 140177.

Balina, K., Romagnoli, F., & Blumberga, D. (2017). Seaweed biorefinery concept for sustainable use of marine resources. *Energy Procedia, 128*, 504-511.

Banach, J. L., Koch, S. J., Hoffmans, Y., & van den Burg, S. W. (2022). Seaweed Value Chain Stakeholder Perspectives for Food and Environmental Safety Hazards. Foods, 11(10), 1514.

Barbier, M., Charrier, B., Araujo, R., Holdt, S., Jacquemin, B. & Rebours, C. (2019) PEGASUS - PHYCOMORPH European Guidelines for a Sustainable Aquaculture of Seaweeds, COST Action FA1406 (M. Barbier and B. Charrier, Eds), Roscoff, France. https://doi.org/10.21411/2c3w-yc73

Billing, S. L., Rostan, J., Tett, P., & Macleod, A. (2021). Is social license to operate relevant for seaweed cultivation in Europe? Aquaculture, 534. https://doi.org/10.1016/j.aquaculture.2020.736203

BIM. (2023). *A Strategic Review of Irish Macro Algae Cultivation*. Available at: https://bim.ie/wp-content/uploads/2023/05/BIM-IMAS-Strategic-Review.pdf

CBI. (2022). The European market potential for seaweed. 14th February. [Online]. Available at: https://www.cbi.eu/market-information/fish-seafood/seaweed/market-potential

Chopin T. (2006) Integrated multi-trophic aquaculture. *Northern Aquaculture*, 12(4): 4

Crown Estate Scotland. (2022). Seaweed Asset Profile. Asset summary.

Cybercolloids. (2020). Scoping a Seaweed Biorefinery Concept for Ireland: Report for Bord Iascaigh Mhara. Available at: https://bim.ie/wp-content/uploads/2021/02/BIM-Scoping-a-seaweed-biorefinery-concept-for-Ireland.pdf

DAFM (2022). *National Strategic Plan for Sustainable Aquaculture Development 2030*. 123 pp + appendices

Department of Business, Enterprise and Innovation (2019). *Enterprise 2025 Renewed – Building resilience in the face of global challenges*. Available at: https://enterprise.gov.ie/en/publications/enterprise-2025-renewed.html

Department of Enterprise, Trade and Employment. (2023) *White Paper on Enterprise.* Available at: https://enterprise.gov.ie/en/publications/white-paper-on-enterprise-2022-2030.html

Ding H, Ma J (2005) Simultaneous infection by red rot and chytrid diseases in Porphyra yezoensis Ueda. J Appl Phycol 17:51–56

Duarte, C. M., Bruhn, A., & Krause-Jensen, D. (2022). A seaweed aquaculture imperative to meet global sustainability targets. *Nature Sustainability, 5*(3), 185-193.

European Commission. (2022a) Accelerated Seaweed Production for Innovative and Robust seaweed aquaculture in Europe. Available online: https://cordis.europa.eu/project/id/101066815

European Commission. (2022b). Towards a Strong and Sustainable EU Algae Sector (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions No. COM(2022) 592 final). Brussels.

European Commission. (2023). From butter to baths, seaweed's potential is being tapped in Europe. Horizon: *The EU Research & Innovation Magazine*. 9th August. [Online]. Available at: https://projects.research-and-innovation.ec.europa.eu/en/horizon-magazine/butter-baths-seaweeds-potential-being-tapped-europe

European Union. (2024). Cluster Definitions. Available at: https://clustercollaboration.eu/cluster-definitions

FAO. (2022). *The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation*. Rome: Food and Agriculture Organization (FAO). https://www.fao.org/documents/card/en/c/cc0461en.

Gairn, L. (2024). Norway to boost multi-trophic aquaculture with new regulation. *We Are Aquaculture*. February 24th. [Online]. Available at: https://weareaquaculture.com/news/aquaculture/norway-to-boost-multi-trophic-aquaculture-with-new-regulation

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The Governance of global value chains. Rev Int Polit Econ, 12(1), 78–104.

Gereffi, G., & Lee, J. (2016). Economic and social upgrading in global value chains and industrial clusters: Why governance matters. *Journal of business ethics, 133*(1), 25-38.

Gombau, R. (2022). Financial feasibility of seaweed farming in Norway. https://munin.uit.no/handle/10037/26627

Hasselström, L., & Thomas, J. B. E. (2022). A critical review of the life cycle climate impact in seaweed value chains to support carbon accounting and blue carbon financing. Cleaner Environmental Systems, 6. https://doi.org/10.1016/j.cesys.2022.100093

Hossain, M. I., Ghose, T. K., & Begum, M. E. A. (2022). Analysis of Seaweed Value Chain to Improve Coastal Livelihood and Blue Economy of Bangladesh. Transforming Coastal Zone for Sustainable Food and Income Security, 1015–1025.

Interreg NWEurope IDEA project. (nd). IDEA position paper – Algae value chains. Available at: https://vb.nweurope.eu/media/17469/idea-position-paper-value-chains-v8.pdf

Jacinto, E.R. and R.S. Pomeroy. (2011). Developing markets for small-scale fisheries: utilizing the value chain approach. In: Pomeroy, R.S and N.L. Andrew. Small-scale Fisheries Management, pp. 160–177. CABI Publishing, Wallingford, UK.

Kim, W.C., Mauborgne. R. (2005). Blue Ocean Strategy: From Theory to Practice. *California Management Review*, Vol 47, No 3, pp.105-121.

Lange, L., Bak, U. G., Hansen, S. C. B., Gregersen, O., Harmsen, P., Karlsson, E. N., Meyer, A., Mikkelsen, M. D., Van Den Broek, L., & Hreggviðsson, G. Ó. (2020). Opportunities for seaweed biorefinery. Sustainable Seaweed Technologies: Cultivation, Biorefinery, and Applications, 3–31. https://doi.org/10.1016/B978-0-12-817943-7.00001-9

Loureiro R, Gachon CMM, Rebours C (2015) Seaweed cultivation: potential and challenges of crop domestication at an unprecedented pace. New Phytol 206:489–492.

Mac Monagail, M. and Morrison, L. (2020). The seaweed resources of Ireland: a twenty-first century perspective, J. Appl. Phycol. 32: 1287–1300, https://doi.org/ 10.1007/s10811-020-02067-7.

Makame, W. H. (2022). The Seaweed Sector in Zanzibar: A Multimethod Approach to Value Chain Analysis. 315–333. https://doi.org/10.1007/978-981-19-4211-2_14

Mather, C., & Fanning, L. (2019). Social licence and aquaculture: Towards a research agenda. Marine Policy, 99, 275–282. https://doi.org/10.1016/J.MARPOL.2018.10.049

Menzies, B., Brook, T., & Parker, A. (2021). CROWN ESTATE SCOTLAND Economic Feasibility Study on Seaweed (Cultivation and Supply Scenario).

Mirera, D. O., Kimathi, A., Ngarari, M. M., Magondu, E. W., Wainaina, M., & Ototo, A. (2020). Societal and environmental impacts of seaweed farming in relation to rural development: The case of Kibuyuni village, south coast, Kenya. Ocean & Coastal Management, 194, 105253. https://doi.org/10.1016/J.OCECOAMAN.2020.105253

Msuya, F. E. (2021). The Zanzibar Seaweed Cluster Initiative: Fostering Seaweed Farming and Value Addition Innovation to Cope with Impact of Climate Change in Tanzania. In World Scientific Encyclopedia of Climate Change: Case Studies of Climate Risk, Action, and Opportunity Volume 2 (pp. 185-192).

Nor, A. M., Gray, T. S., Caldwell, G. S., & Stead, S. M. (2020). A value chain analysis of Malaysia's seaweed industry. *Journal of Applied Phycology, 32*, 2161-2171.

North Sea Farmers. (n.d.). 10 points action plan - seaweed industry roadmap - North Sea Farmers. Retrieved November 8, 2023, from https://www.northseafarmers.org/sector/10-points-action-plan-seaweed-industry-roadmap

O'Shea, R., Collins, A., & Howe, C. (2022). Offshore multi-use setting: Introducing integrative assessment modelling to alleviate uncertainty of developing seaweed aquaculture inside wind farms. Environmental Challenges, 8. https://doi.org/10.1016/J.ENVC.2022.100559

Patarra, Rita & Paiva, Lisete & Neto, Ana Isabel & Lima, Elisabete & Baptista, José. (2011). Nutritional value of selected macroalgae. Journal of Applied Phycology. 23. 205-208. 10.1007/s10811-010-9556-0.

Polaris Market Research. (2022). Alginate Market Share, Size, Trends, Industry Analysis Report, 2022 - 2030. Available at: https://www.polarismarketresearch.com/industry-analysis/alginate-market#:~:text=Report%20Outlook,4.7%25%20during%20the%20forecast%20period

Precedence Research. (2023). Alginate Market. Available at: https://www.precedenceresearch.com/alginate-market

Ramli NM, Verreth JAJ, Yusoff FM, Nurulhuda K, Nagao N, Verdegem MC (2020) Integration of algae to improve nitrogenous waste Management in Recirculating Aquaculture Systems: a review. Front Bioeng Biotechnol 8:1004

Scottish Government. (2022). Understanding the potential scale for seaweed-based industries in Scotland - Final Report.

Selnes, T., Giesbers, E., & van den Burg, S. W. K. (2021). Innovation and Collaboration: Opportunities for the European Seaweed Sector in Global Value Chains. Journal of Marine Science and Engineering 2021, Vol. 9, Page 693, 9(7), 693. https://doi.org/10.3390/JMSE9070693

Stobierski, T. (2020) What is a value chain analysis? 3 Steps. 3rd December. [Online]. Available at: https://online.hbs.edu/blog/post/what-is-value-chain-analysis

Strittmatter, M. et al. (2022) 'My seaweed looks weird: a community web portal to accelerate pathogen discovery in seaweeds', Applied Phycology, 3(1), pp. 300–305. Available at: https://doi.org/10.1080/26388081.2022.2059783.

Taelman, S. E., Champenois, J., Edwards, M. D., De Meester, S., & Dewulf, J. (2015). Comparative environmental life cycle assessment of two seaweed cultivation systems in North West Europe with a focus on quantifying sea surface occupation. *Algal Research, 11*, 173-183.

The World Bank. (2023). Global Seaweed: New and Emerging Markets Report, 2023. Available at: https://documents1.worldbank.org/curated/en/099081423104520569/pdf/P175786076444d0d8099f70563b5aa30b7c.pdf

UNU-CRIS. (2021). Sustainable Value Chain for the Seaweed Industry in Malaysia and the ASEAN Region: A Roadmap for Policy Formulation | UNU-CRIS. UNU Institute on Comparative Regional Studies. https://cris.unu.edu/seaweed-industry-malaysia-and-asean

van den Burg, S. W. K., van Duijn, A. P., Bartelings, H., van Krimpen, M. M., & Poelman, M. (2016). The economic feasibility of seaweed production in the North Sea. Aquacult Ecol Manag, 20(3), 235–252. https://doi.org/10.1080/13657305.2016.1177859

van den Burg, S.W.K., Dagevos, H. and Helmes, R. (2018) 'Sustainable seaweed value-chains: Economics, consumer attitudes and environmental impacts'. Wageningen Economic Research. Available at: https://research.wur.nl/en/publications/sustainable-seaweed-value-chains-economics-consumer-attitudes-and .

van den Burg, S. W. K., Dagevos, H., & Helmes, R. J. K. (2021a). Towards sustainable European seaweed value chains: a triple P perspective. ICES Journal of Marine Science, 78(1), 443–450. https://doi.org/10.1093/ICESJMS/FSZ183

van den Burg, S., Selnes, T., Alves, L., Giesbers, E., & Daniel, A. (2021b). Prospects for upgrading by the European kelp sector. Journal of Applied Phycology, 33(1), 557–566. https://doi.org/10.1007/S10811-020-02320-Z/FIGURES/7

van den Burg, S. W. K., Selnes, T., Dias, A., Alves, L., Nuhoff-Isakhanyan, G., Helmes, R., & Daniel, A. (2019). Prospects for upgrading European seaweeds; a value chain perspective (pp. 137–138

van Osch, S., Hynes, S., O'Higgins, T., Hanley, N., Campbell, D., & Freeman, S. (2017). Estimating the Irish public's willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture. Marine Policy, 84, 220–227. https://doi.org/10.1016/j.marpol.2017.07.005

Vance, C., Pollard, P., Maguire, J., Sweeney, J., & Murphy, F. (2023). Sustainable scale-up of Irish seaweed production: Quantifying potential environmental, economic, and social impacts of wild harvesting and cultivation pathways. Algal Research, 75, 103294.

Vazquez Calderon, F., Sanchez Lopez, J.Guillen, J., Avraamides, M. eds. (2022). An overview of the algae industry in Europe. Producers, production systems, species, biomass uses, other steps in the value chain and socio-economic data, Publications Office of the European Union, Luxembourg.

Wahyularassati, A., Susiloningtyas, D., & Handayani, T. (2019). Value-chain distribution of seaweed production in Amal Coast, Tarakan Island. IOP Conference Series: Earth and Environmental Science, 311(1), 012082. https://doi.org/10.1088/1755-1315/311/1/012082

Wenäll, T., & Leufstedt, A. (2023). Navigating the Seaweed Biorefinery Value Chain Implications for a Seaweed Farmer. Available at: https://odr.chalmers.se/items/3fb5af83-f8b7-4e42-a119-93d1edc488f9

Wickham, S. B., Darimont, C. T., Reynolds, J. D., & Starzomski, B. M. (2019). Species-specific wet-dry mass calibrations for dominant Northeastern Pacific Ocean macroalgae and seagrass. *Aquatic Botany, 152*, 27-31.

Zhu, X., Soro, A., Tiwari, B. & García-Vaquero, M. (2022). Seaweeds in Ireland: Main Components, Applications, and Industrial Prospects. 10.1007/978-3-030-91955-9_10.

BIM
Ireland's Seafood Development Agency

E info@bim.ie
W www.bim.ie
T 01 2144100
𝕏 @bordiascmhara