European Commission

Blue Bioeconomy Forum – Draft Roadmap for the blue bioeconomy

Version for open consultation

July 2019

Written by Technopolis Group and Wageningen Research (June – 2019)

Dear reader,

This document encompasses the findings of the Blue Bioeconomy Forum over the course of the last year. We engaged with representatives and stakeholders in the blue bioeconomy community in our 7 December 2018 and 25 June 2019 events, our workshops on 12-13 March 2019, in questionnaires, interviews, and discussions on other events. We have tried to capture all major issues that hinder blue bioeconomy development in Europe and provide suggestions for ways forward for immediate uptake, until 2025 and beyond.

The blue bioeconomy is full of opportunity and we hope to have captured the possibilities in our illustrative descriptions in the text boxes.

Please provide us with your comments or recommendations before 31 August 2019 on:

http://openconsultation.bluebioeconomyforum.eu

Yours sincerely,

on behalf of the Blue Bioeconomy Forum team,

Andreas Ligtvoet.

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1. Executive summary

The blue bioeconomy encompasses all economic activities for which aquatic biomass is being produced or used. This multi-faceted economic sector shows great potential for sustainable growth in the European Union. While large numbers associated with economic outlooks may be contested, profit and non-profit stakeholders agree that the blue bioeconomy offers unique possibilities to tackle several sustainable development goals, while promising superior products to consumers and generating decent business opportunities.

Before the blue bioeconomy can fulfil its contribution to people, planet and prosperity, there are still many hurdles to be overcome. This roadmap represents the collective effort of business, academia, governments, and civil society – united in the Blue Bioeconomy Forum and its activities – to identify challenges and suggest ways forward for tackling these challenges in the short, medium, and longer term. For this roadmap, the Forum has consciously chosen to emphasise *novel and upcoming products, applications and services* and thus to underrepresent existing blue bioeconomy businesses. This attempt to focus was done to contain the effort for signalling the challenges in application areas from food, feed, pharmaceuticals, cosmetics to chemistry, and in no way negates the business and growth potential of more established subsectors.

The fact that many activities within the focus of this roadmap are innovative directly links to one of the most acute problems that should be tackled: due to the nascent phase of many companies and projects, there is a lack of clarity in a range of items: rules and regulations (along with required licences) that apply to the activities, lack of solid information on the size of the market and the number of businesses involved and hence business risk, lack of reliable statistics and scientific measurements that support decisions. Many of the businesses that were interviewed in the context of this roadmap are true pioneers that constantly face new and often unforeseen issues. They operate in a niche that is not (sufficiently) supported by the dominant institutional settings or that falls under different legislatory and organisational regimes. This is part of being an entrepreneur in uncharted economic territories; the question is to what extent and how such activities could be supported and stimulated. Harmonisation of regulation – both horizontally across different domains like agriculture and fishery as well as vertically across different governance layers – is an obvious and urgent requirement.

There is a range of further challenges to the blue bioeconomy, which are all addressed in this document. Starting from four thematic priorities (Policy, environment and regulation; Finance and Business development; Consumers and value chains; Science, Technology and Innovation) the discussions held in the roadmap process have led to further specification and aggregation. The following table provides an overview of the main challenges that have been identified as key priorities.

Table 1 Challenges of the blue bioeconomy sector

Short name	**Challenge**
Policy, environment and regulation	
Licences / Permits	Obtaining licenses and permits to set up activities is difficult for companies
Novel food	Novel food status and procedures are unclear for companies
Ecosystem services	Environmental benefits are not recognised and/or remunerated
Finance and business development	
Understanding finance	Blue bioeconomy projects and businesses lack understanding of investment landscape and how to present opportunities to potential investors

Short name	**Challenge**
Funding mechanisms	Lack of funds and mechanisms to support blue bioeconomy projects and start-ups
Skills and qualifications	Human resources needs (skills and qualification) in the blue bioeconomy sector
Consumers and value chains	
Consumer acceptance	Lack of consumer acceptance of blue products
Side products	Lack of valorisation of rest raw materials from marine origin materials
Production costs	High costs of blue production
Seasonality	Difficulty in stable production of aquatic or marine biomass due to seasonality
Logistics	Logistical challenges for aquatic of marine biomass processing
Science, Technology and Innovation	
Researcher-industry dialogue	Dialogue and sustainable cooperation between researchers and industry is needed
Marine exploration	Exploration of marine environment has technical challenges and high costs
Research infrastructures	Lack, underuse and geographical discrepancy of research infrastructures
Access to data	Lack of access to data, research results and data banks

It should be noted that many of these challenges are interconnected and require a holistic approach towards tackling them. In the roadmap text these connections are indicated.

Reading guide

This roadmap document was produced by the Blue Bioeconomy Forum on request of the European Directorate-General for Maritime Affairs and Fisheries as well as the Executive Agency for Small and Medium Enterprises. The intended audience, however, is the full range of stakeholders in the blue bioeconomy. Chapter two provides a short description of the ways forward targeted to different stakeholders while chapter three provides a more lengthy description of issues per thematic area (the different "roads" in this roadmap). The annexes provide the context of the document and the policy areas involved, the research process and the sources consulted. Further documentation related to the Blue Bioeconomy Forum can be found on http://bluebioeconomyforum.eu

2. WAYS FORWARD

This section provides suggested ways forward in response to the challenges identified during the roadmap process. The ways forward are fitted per challenge, but also take into account measures that have a cross-cutting effect. When a specific action also addresses another challenge, this is indicated.

Each way forward gives an indicative timeframe for its implementation. We differentiate:

- Short term actions (2019-2020): These are both actions that have a priority and that realistically can start being implemented "tomorrow".
- Medium term actions (2020-2025): These actions require more time and preparation in order to be launched by the implementing bodies.
- Long-term actions (2025+): These actions are necessary but complex to be achieved, they require that prior actions take place and are fully implemented.

Each way forward also shows which specific actions are required/expected per stakeholder. For the purposes of the roadmap, we differentiate four main typologies of stakeholders:

- European Commission
- National and/or regional bodies
- Industrial players
- Research community

Although not specifically addressed in the ways forward, citizens and civil society organisations should in general be informed and consulted where developments in the blue bioeconomy touch their daily activities.

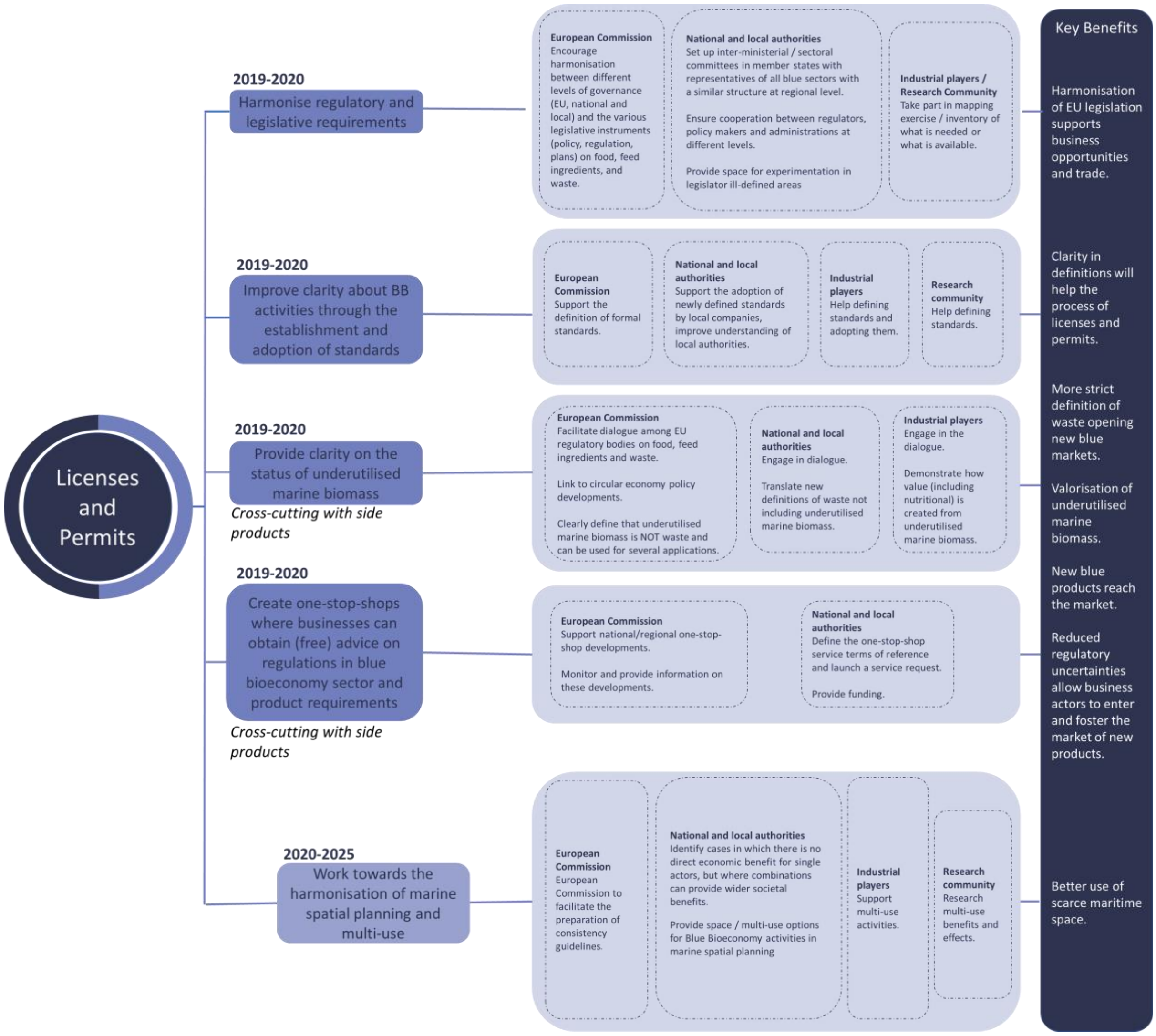
Finally, the last column of the ways forward graphs provides an indication of the key benefits that each action seeks to achieve.

2.1 Obtaining licenses and permits to set up activities is difficult for companies

A range of challenges for activities in the blue bioeconomy lies in the legal realm. There is unclarity with regard to definitions of the activities undertaken and under which policy field they fall: fishery or agriculture are the most logical candidates but do not sufficiently cover the activities. It makes sense to clarify and harmonise the rules that apply to blue bioeconomy activities – not only between policy fields, but also between different layers of governance from the EU-level to the local level. Clarification can at certain points be achieved through formal standards as promoted by standardisation bodies.

For businesses operating in the blue bioeconomy, one-stop-shops can be one way of reducing the burden of operating in this new and upcoming sector: it would mean that regional or national governments can support the companies in their search for the right licences and permits.

In the medium term, multi-use of scarce marine space should be facilitated.

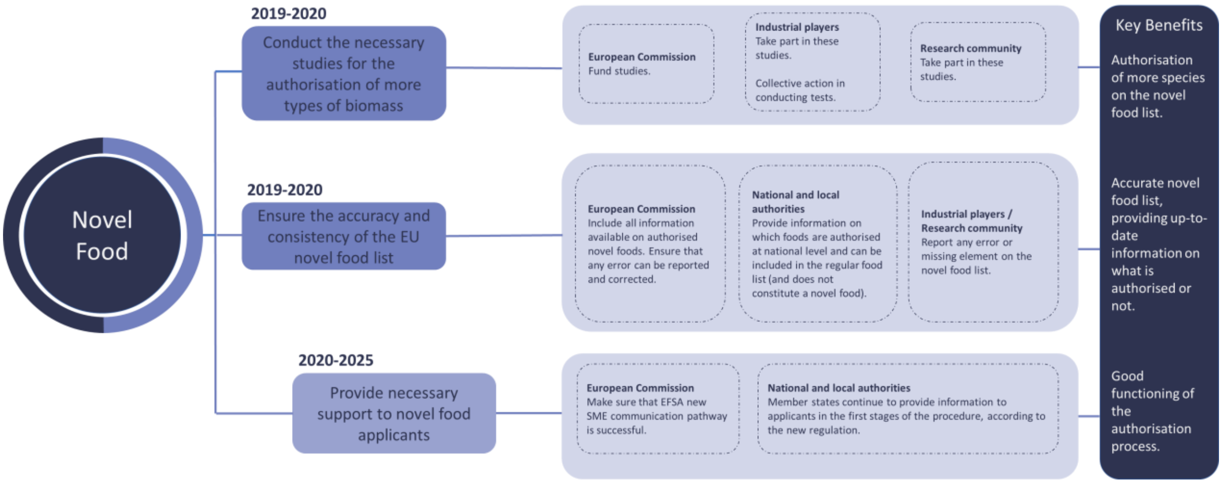


2.2 Novel food status and procedures are unclear for companies

Getting more blue biomass authorised on the EU Novel Food list would help the Blue Bioeconomy to scale up, offering more opportunities to commercialise high-value products, and support the sector. Effective implementation of the regulation is important to protect EU citizen's health, but also to protect the sector from unfair competition.

The Blue Bioeconomy Forum suggests to:

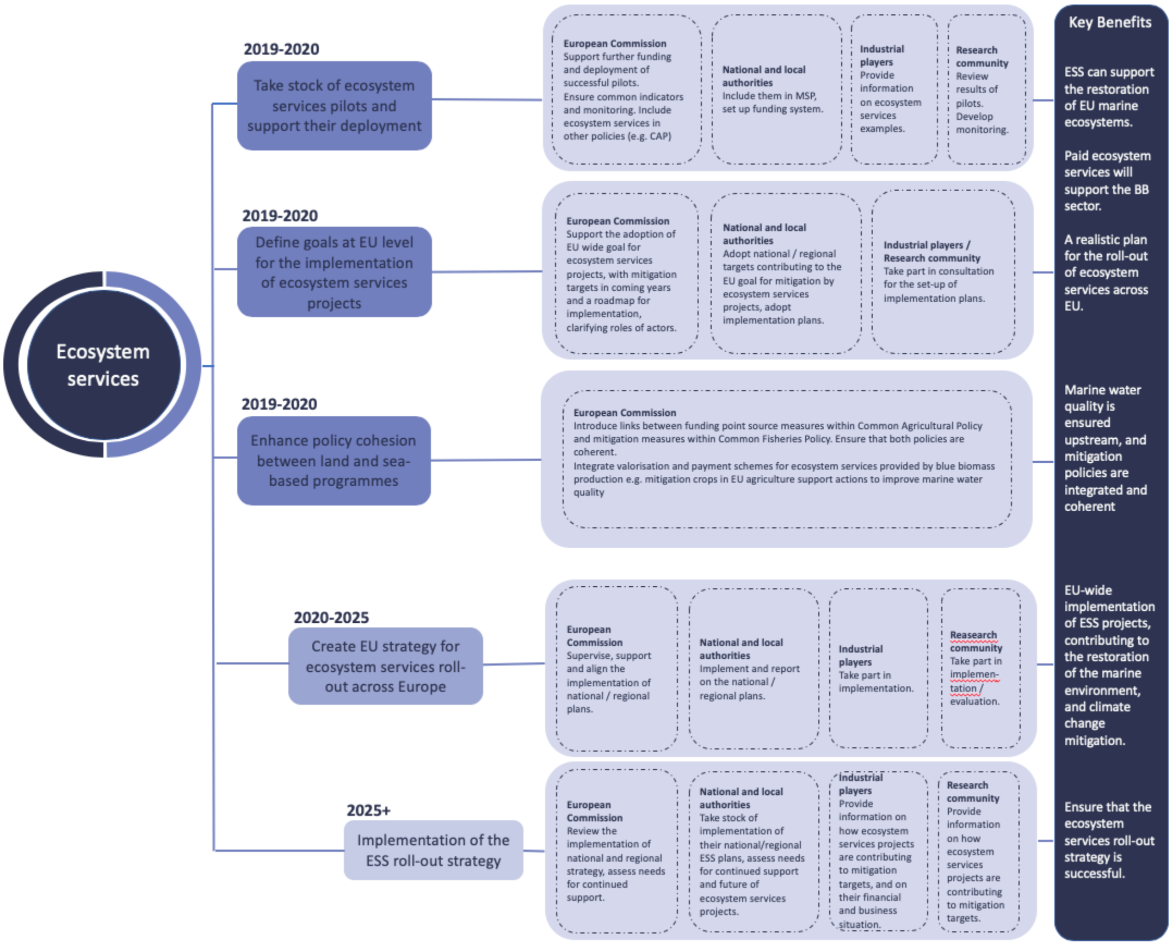
- Make the Novel Food authorisation more affordable, by publicly funding projects to prepare the analytical procedures that ensure the safety information for each product. These procedures are the most expensive part of a novel food dossier. They would then fall into public domain, and companies would be able to use them to prepare their own dossiers.
- Ensure the accuracy and consistency of the Novel Food list, in order to improve transparency. Notably industry and researchers should be able to inform public authorities when they notice an error or a missing information.
- Further support novel food applicants, especially SMEs, to navigate the procedure. Support would for example take the form of efficient communication pathways, and consistent information at EU and National level.



2.3 Ecosystem services are not recognised and/or remunerated

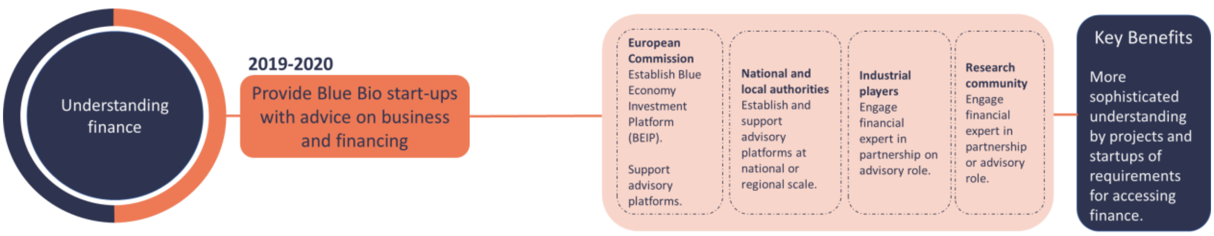
A number of blue bioeconomy activities can provide ecosystem services, that could be valorised as instruments to achieve EU environmental targets. The Blue Bioeconomy Forum suggests to:

- take stock of past and current projects in the domain, especially in innovation in valorising ecosystem services; different ways of implementing ecosystem services on national and regional level recognising that conditions vary significantly from sea basin to sea basin; and project and companies who support the upscale of ecosystem services. There is also a need to define the interplay between different types of ecosystem services.
- secure high-level support for payments for ecosystem services and create cohesion between the Common Agricultural Policy (CAP) and the Common Fisheries Policy (CFP) .
- define and implement an EU strategy for an institutional framework for ecosystem services across European sea basins. This strategy should ensure common monitoring of results, involvement of all actors, including local communities, coherence between sea- and land-based policies (especially at the EU level), long-term funding mechanisms and implementation targets.



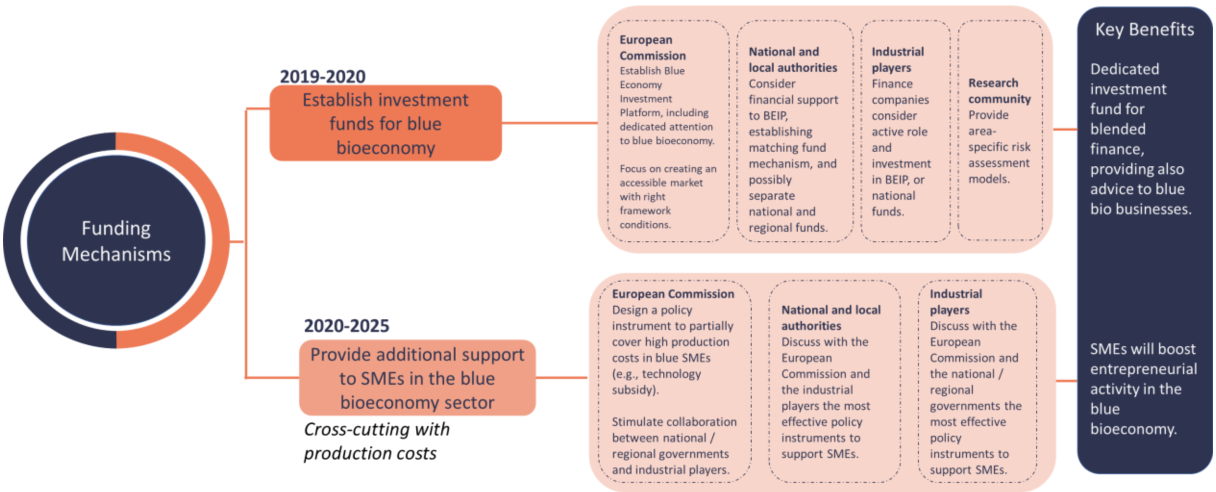
2.4 Blue bioeconomy projects and businesses lack understanding of investment landscape and how to present opportunities to potential investors

Start-ups and small businesses in the Blue Bioeconomy require financing to move through further phases of technology development and commercialisation. Investment will continue to come from a range of sources, including, among others, angel investors, venture capital, equity funds, and credit facilities. Developing appropriate and convincing financing plans is challenging for many start-ups, which often lack the necessary expertise or experience in-house. It is important therefore to provide blue bioeconomy start-ups with advice on financing. The European Commission is establishing a Blue Economy Investment Platform, which can provide such an advisory function. For relevant regions, it would also be helpful for national and local authorities to support advisory platforms or innovation hubs more targeted to the local Blue Bioeconomy. Businesses and research projects should also engage financial expertise in their advisory or management structures.



2.5 Lack of funds and mechanisms to support blue bioeconomy projects and start-ups

To address the lack of financing for blue bioeconomy start-ups and SMEs, dedicated investment funds should be established. This has been proposed within the framework of the new Blue Economy Investment Platform. National and local authorities should consider contributing to such a platform, and also to establishing a matching fund mechanism. Separate national and regional funds are also a promising option. Blended finance models will continue to develop in this sector and any of these initiatives or mechanisms should provide the opportunity for investment management companies to participate as investing partners. The research community can assist with better area-specific risk assessment models, which can improve the sophistication and reliability of risk-return analyses for blue bioeconomy investment proposals. Over the longer term, the blue bioeconomy sector could benefit from policy instruments, such as technology subsidies or partnership initiatives, to partially offset high production costs. This is particularly important for sub-sectors offering social and environmental benefits, including ecosystem services. Other stakeholders should engage with discussions on the design of the most appropriate supporting policy instruments.



2.6 Human resources needs (skills and qualification) in the blue bioeconomy sector

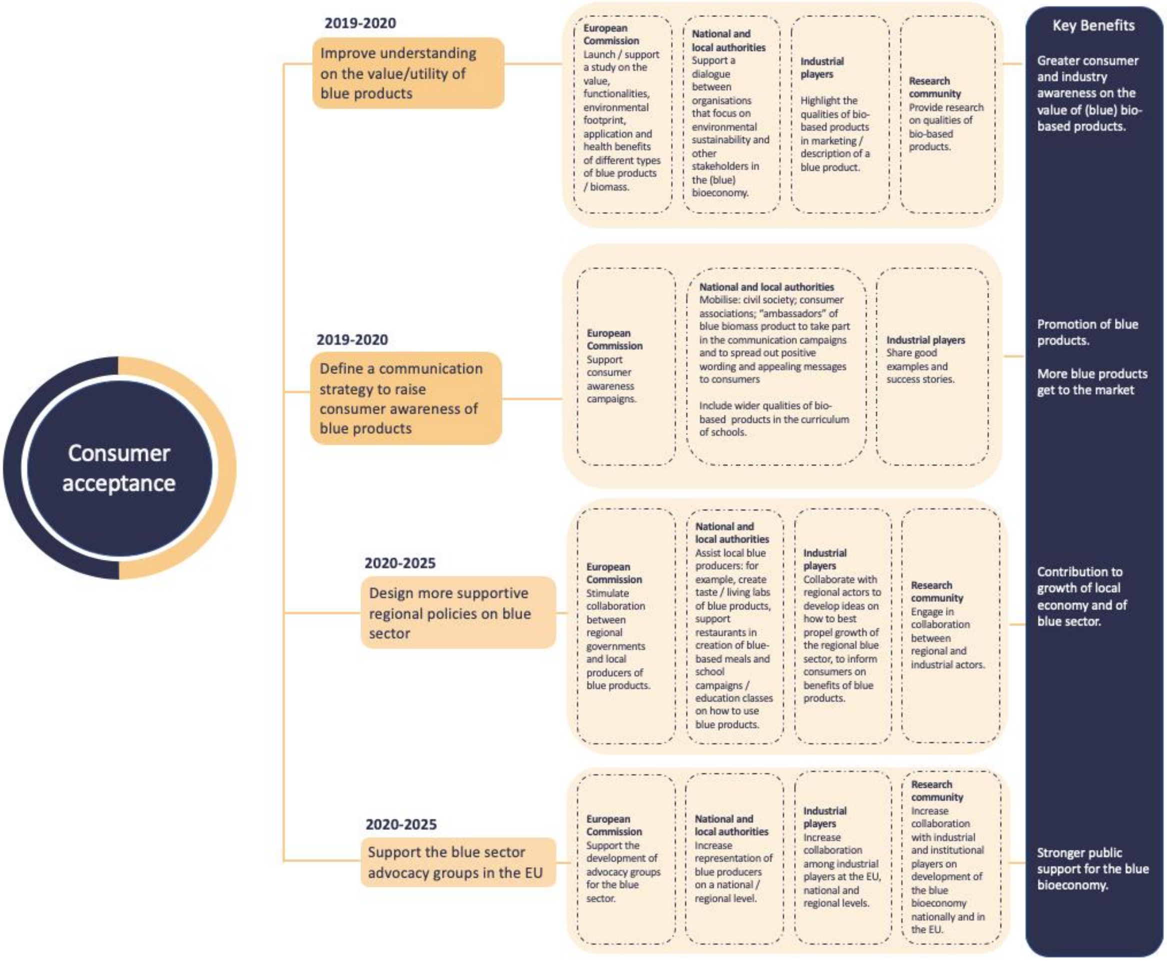
The skills required for success become more complex with each phase of product development. Whereas in initial phases the needs are for specialized technical skills, in latter phases, these are expanded to include specific types of business skills. Members of the investment community active in the blue bioeconomy have remarked that entrepreneurs and project leaders often lack necessary business skills for growing a small startup or business. These people usually have a natural science or technical background. Their academic training often does not include even basic business skills training (marketing, sales, management, finance and accounting, etc.). The lack of multidisciplinary skills can constitute a bottleneck to innovation.

2.7 Lack of consumer acceptance of blue products

The qualities, health benefits, functionalities and utilities of blue biomass/products are still hotly debated. As a result, the type and amount of public support, as well as consumer acceptance of novel products is limited. To raise consumer acceptance of blue products, the value of these products needs to be more widely understood, and reciprocally, producers should recognise concerns among potential consumers (such as price, sustainability, and health benefits.).

The Blue Bioeconomy Forum suggests to:

- Undertake a study on the functionalities and application of different types of blue biomass/products, to stimulate research community to publish/disseminate findings on qualities of bio-based products.
- Define a communication strategy that mobilises the right people (including civil society; consumer associations; "ambassadors" of blue biomass producs, such as chefs), emphasises appeal for consumers (such as sustainability of products; origin and traceability) with positive wording
- Design supportive regional policies for the blue sector, including both "soft" measures (such as assisting local producers with the organisation of local fairs) and interventionist measures (such as fiscal policies to support production at cheaper prices) to stimulate the development of innovative and sustainable products from blue biomass origin.
- Promote collaboration among business, institutions, and environmental organisations to contribute to growth and development of the blue sector regionally and across the EU.

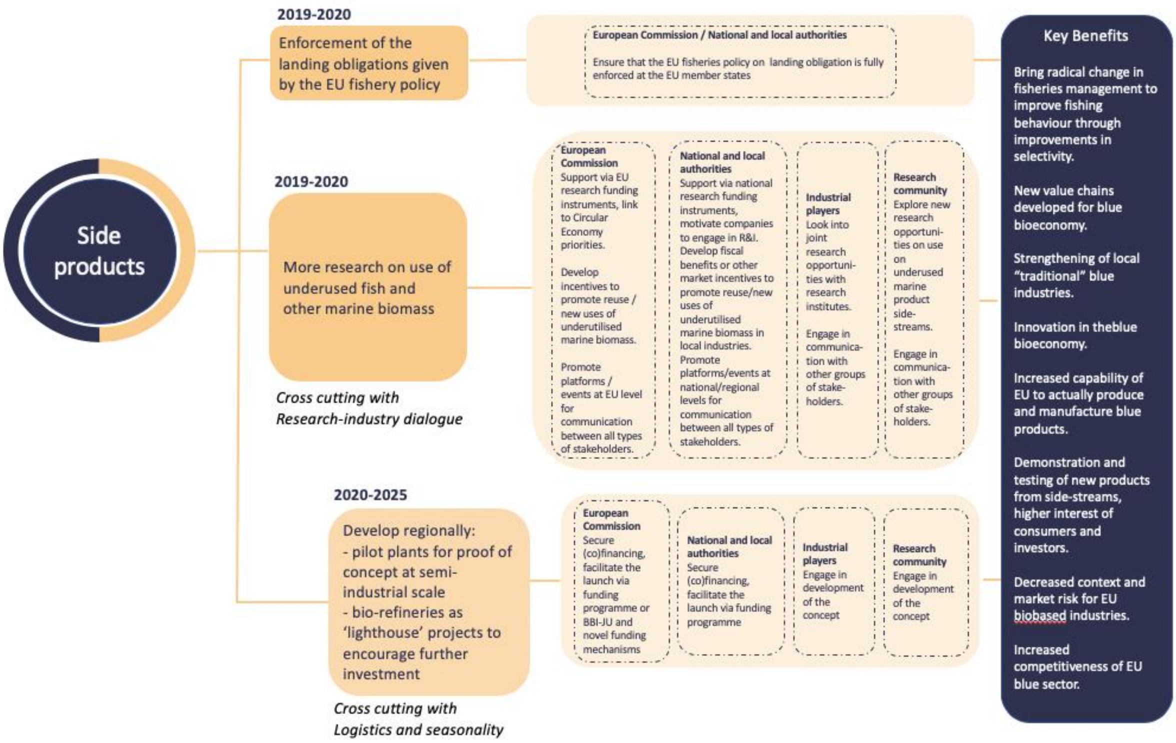


2.8 Lack of valorisation of rest raw material from fisheries

jDiscards of seafood resources, namely fishery "non-target" species count for 25% of total volumes of marine fishery catch, while the discards in the fish processing industry reach up to 75% of the total volume of products. This problem has been raised continuously over the last decade, but technical solutions have not been commercialised (FAO, 2011), (EUMOFA, 2018), (EC DG RTD, 2016). Main barriers are:

- lack of awareness and interest in business community and investors , including lack of successful examples of tested products and business models based on valorisation of rest raw material
- unclarity in regulatory areas, for example, whether rest raw material from fishing should be considered as waste, limiting their use as inputs for new products

Ways forward include reinforcing the demonstration efforts for solutions to rest raw material valorisation that will cover not only food related sectors, but also other value chains where side products can be utilised. This requires better exchange between researchers, business and investors Reducing regulatory uncertainties could also help attract investors.



2.9 High costs of blue production

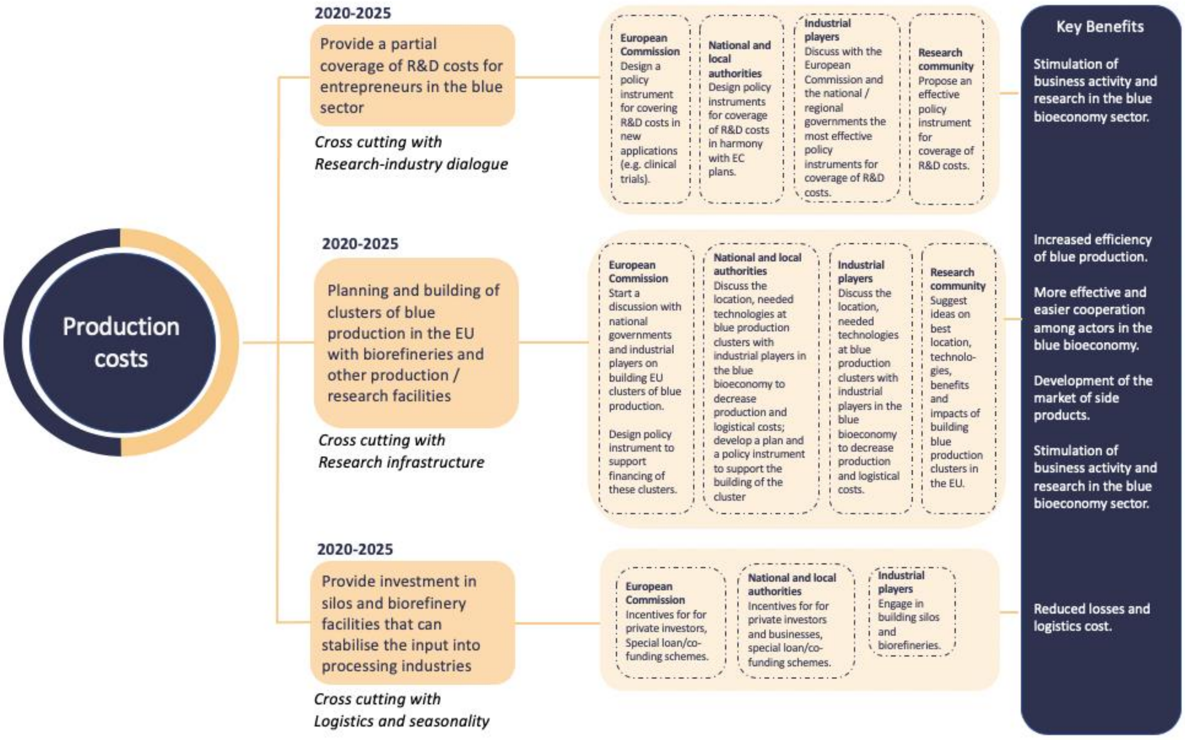
Entrepreneurs in the blue bioeconomy sector face relatively high production costs, due to a lack of available and accessible production/processing facilities, as well as risks and expenses during the R&D phase.

The Blue Bioeconomy Forum suggests to:

- Build clusters of blue production with biorefineries and other production facilities across the EU supported by investment in production facilities. Appropriate infrastructure for timely processing, logistics and transportation of biomass is an essential factor for both energy and cost efficiency in production and research.

- Design and implement a policy instrument to partially decrease R&D costs of clinical trials, to assist in critical research areas of the 'blue' sector (e.g. development of compounds for biomass drying or salt extraction) and to stimulate research/product development.
- Design a funding mechanism for SMEs and create incentives for private investors and companies to invest in facilities like biorefineries and silos. As identified above, business advisory services could support scaling up production and diversification of product portfolio, and accessing available financial support from the regional, national or EC programmes.

Above-listed suggestions are expected to stimulate business activity and research in the blue bioeconomy sector, to increase efficiency of blue production, reduce losses and logistical costs.



2.10 Logistical challenges for biomass processing

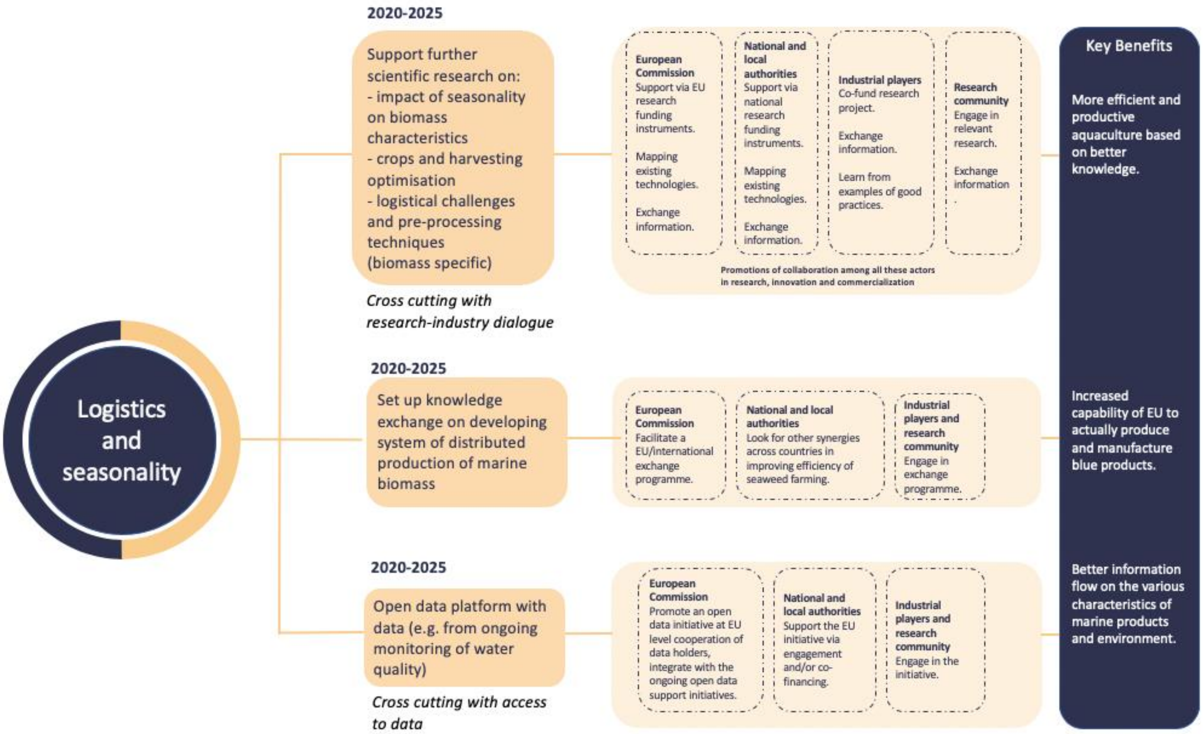
35% of consulted BBF stakeholders face logistical challenges, of which 80% are technical in nature, rather than being related to legal or policy issues. Technical challenges include complex and expensive operations throughout the entire supply chain, including harvesting, storing, processing, transport and delivery. A better understanding is required of the impact of seasonality on the quality of marine resources, especially in the context of ongoing climate change. Research on these challenges should be linked with commercialisation and the involvement of public and private actors.

Lack of access to data on pollution, quality and temperature of water prevents entrepreneurs to optimise their production process. Ensuring open access to such data, as well as integrating various monitoring data sources in one platform, requires joint action by public, research and industry actors.

Costs arising from the remoteness or sparse locations of farmin or wild harvesting locations from processing facilities can be addressed by clustering these.

The compliance with regulations on preventing waste of by-catch incurs logistical challenges and costs for companies. However, in countries where the market of by-catch is developed, the fisheries are able to reap a profit.

Dissemination and exchange of existing good practices on distributed harvesting, processing of biomass, optimisation of the logistics of by-catch fishing resources would be helpful.



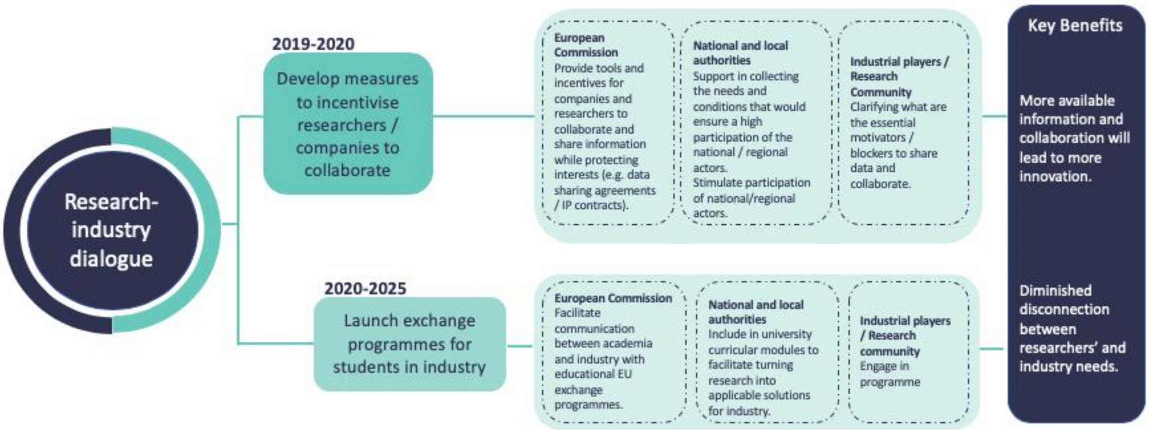
2.11 Dialogue and sustainable cooperation between researchers and industry is needed

Better links and collaborationis needed to develop and deliver successful products to consumers.

The Blue Bioeconomy Forum suggests to:

- *Develop measures to incentivise researchers and companies to collaborate*. The interests and motivators from one actor to another can be very different. If concrete actions, such as co-design of research with industry, are taken to facilitate cooperation with specific agreements, knowledge transfer is facilitated between the academic and applied research entities and the private sector.
- *Launch exchange programmes for students and academics in industry and vice versa*. Possible examples include involvement of PhD students in industrial projects and/or seminars. Such activities could enhance alignment of expectations of both sides in all collaborative activities. These activities could also lead to matchmaking of talents in research and industry, as well as increasing awareness among researchers about market needs.

Increased and improved cooperation between researchers and industry can have cross-cutting effects on the other specific challenges that have been identified.



2.12 Exploration of marine environment has technical challenges and high costs

The provision of a pipeline of new marine organisms to screen for novel compounds is an essential support for future innovation (Hurst, 2016). However, the technical challenges of accessing areas outside the shallow coastal zone and the costs of deep-water exploration mean that much remains to be discovered in the oceans' depths.

Activities and financing thus generally focuses either on fundamental research or the application potential of the functional components with high end market applications. Many approaches require a new methodological and systematic approach.

The Blue Bioeconomy Forum (based on ERA-Net activities) suggests to:

- Explor targeted environments and hotspots
- Develop next generation sampling methods
- Develop novel methods for the taxonomic, chemical, and biochemical evaluation of marine species as sources of bioactive compounds.

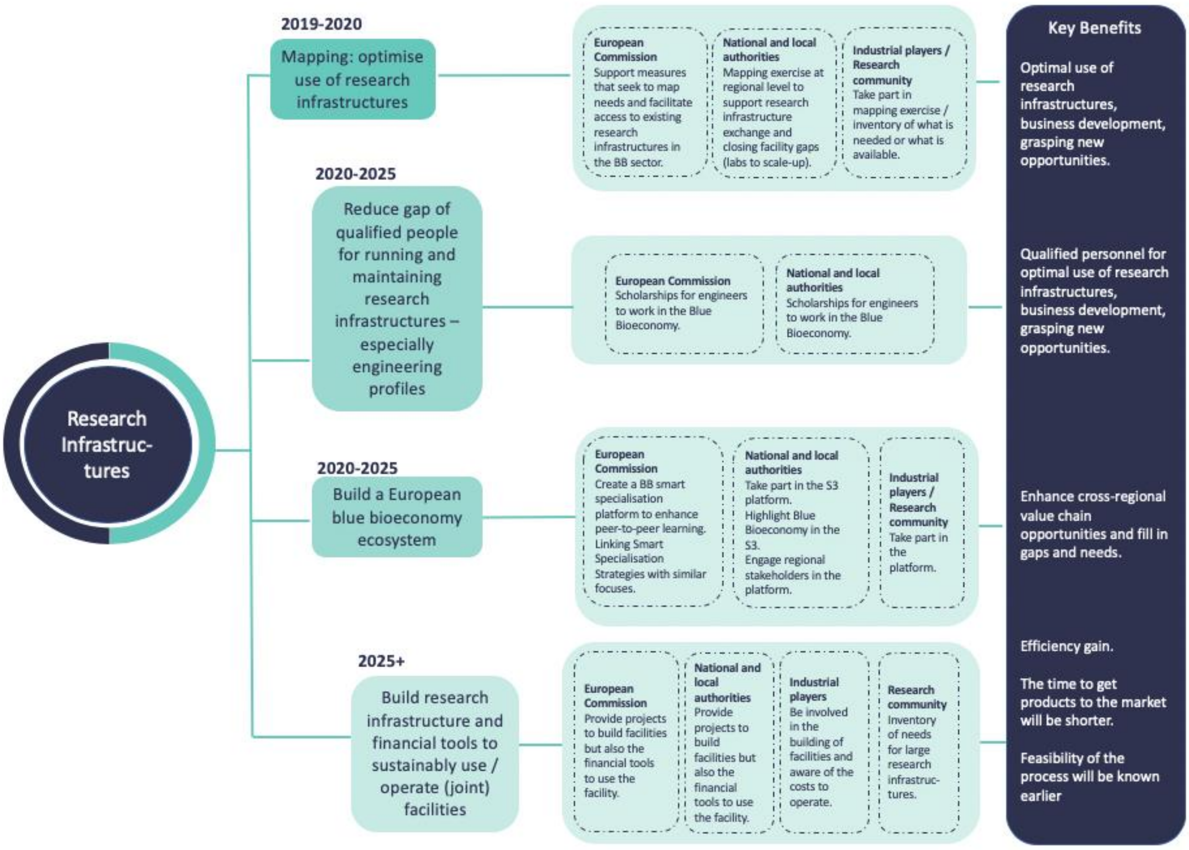
More collaboration would also help in reducing exploration costs, for example, through optimisation of multi-purpose screening on hotspots or sampling programs.

2.13 Lack, underuse and geographical discrepancy of research infrastructures

The availability of **relevant and accessible research infrastructures**, comprising physical as well as human resources, is essential to continue and enhance the development and utilisation of outputs from marine biotechnology. The most urgent technological challenges are in the demonstration plant phase (TRL 6-7), and the upscaling to flagship/first-of-a-kind (TRL 8), when economies of scale have not yet been achieved. Although lack of information about available infrastructure was mentioned in the BBF working groups, there are databases at DEMO or pilot scale that provide an overview of the available infrastructures. However, none are specific for blue bioeconomy.

The Blue Bioeconomy Forum suggests to:

- Build on existing projects to map and optimise the use of specified, available research infrastructures (in particular at TRL 6-8) including personal skills needed to operate these facilities.
- Bring together different scientific disciplines to promote innovation, turning scientific findings into flourishing businesses. Such activities relate to the "New Skills Agenda for Europe" as well as national, regional and sector initiatives that should boost the labour market across the Member States. These initiatives are aimed at a) retraining and up-skilling the current labour force and b) enabling the system to better prepare the future labour force.
- Build, from 2025 additional research infrastructures and generate financial tools that assure sustainable accessibility and operation of the facilities.

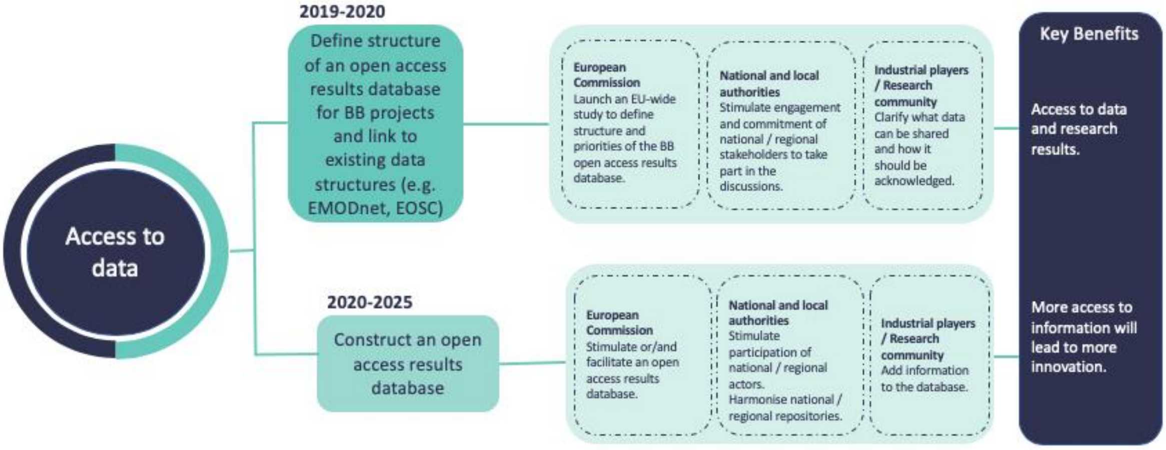


2.14 Lack of access to data, research results and data banks

Issues regarding access to data, research results (including data from unsuccessful experiments) and data banks are considered as challenges that, when available, may stimulate the development of the Blue Bioeconomy. It is needed to strengthen the collaboration between academics and industry and to develop ways to incentivise researchers / companies to share data. A big challenge is to unify / streamline the available data sources and portals that we have worldwide. Therefore, it is proposed to link Blue Bioeconomy projects with European initiatives to share and standardize data according to e.g. EOSC (European Open Science Cloud) and FAIR data management and tools, a common data language to ensure data stewardship across borders/disciplines based on FAIR principles. Furthermore, the broad range of changes required for the implementation of the FAIR data principles should be taken into account.

The blue bioeconomy forum suggests:

- Define structures and establish means for Blue Bioeconomy data and results that can be shared, according to existing data structures. The EMODnet could be a good starting point; the awareness and visibility of this data source should be improved. National databases should be integrated or federated.
- Stimulate and facilitate "delivery" and "use" of information in open access results databases. For commercial data new tools must be developed (e.g. data pods and/or licenses for data sharing).



3. THEMATIC PRIORITIES – CHALLENGES OF THE BLUE BIOECONOMY SECTOR

This section of the roadmap further describes the main challenges identified by the Blue Bioeconomy Forum.

Although some of the challenges are attributed to a specific thematic area, the challenge itself (or the solution to that challenge) might be cross-cutting with other thematic priorities.

For instance, access to data was at first mainly addressed from the angle of research data, biobanks and project results (therefore under Science, Technology and Innovation). However, access to data is also an issue or part of the solution across other thematic areas (e.g. for ecosystem services; for monitoring seasonality; to assess logistical challenges and processing costs).

The lack of skills and qualifications is another cross-thematic challenge. The blue bioeconomy sector demands profiles that combine engineers, biomarine scientists, business competences. This issue emerges in finance and business development, as well as science, technology and innovation.

Another over-arching challenge mentioned during the discussions at the Forum, is generalised lack of understanding of what the "blue bioeconomy sector" is. This can represent a challenge in many ways:

- When public authorities lack understanding of the sector, it is difficult to regulate innovative applications in the sector. Problems vary between jurisdictions and public authorities don't know the risks and rules, and don't know where to classify companies. For the companies, it is complex to obtain authorisation, it requires multiple authorisations since the business model can be linked to multiple activities. The interaction between the public and private sector is difficult and time-consuming in order to achieve mutual understanding. Intense lobbying from private to public authorities is necessary. In addition, entrepreneurs must also understand the legislations in place that might affect their sector.
- This challenge also affects matching entrepreneurs and investors to scale-up business opportunities. As explained under section of finance and business development, the lack of understanding also affects access to funding capacity.
- Being an emerging sector - at least for those activities that are not traditional aquaculture and food production - there is no such thing as an established and mature European blue bioeconomy community. The Blue Bioeconomy Forum has been the first attempt to put together all stakeholders of the European blue bioeconomy community and to create a space for exchange and an opportunity to represent the sector widely. The discussions conducted with the regional stakeholders also show that from one region to another there are high divergencies in terms of the maturity of established blue bioeconomy communities at regional level. There is also a role to play for the regions in supporting the blue bioeconomy sector to thrive, and this starts by having established blue bioeconomy communities at regional level.

The following sub-sections provide a detailed description of the challenges that have been identified among each BBF thematic priorities.

3.1 Policy, environment and regulation

3.1.1 Obtaining licenses and permits to set up activities is difficult for companies

It has become clear from our sources, working group discussions and interviews, that many elements of the Blue Bioeconomy sector are still relatively immature – at least in terms of the definitions that describe the different activities that fall under this broad umbrella term. This relative newness immediately translates into a lack of descriptions of how businesses in the field ought to operate – in other words policies and regulations. To a certain extent regulatory opaqueness is both an opportunity and a hindrance. In a situation where new businesses are developing a period of relative freedom and low legislative pressures allow for the businesses to experiment and also demonstrate where their strengths and weaknesses lie. It is conceivable that only after a certain grace period (several growth seasons / years) it would make sense to enforce stricter requirements. This, however, would require close interaction with public authorities to understand and monitor activities.

At the same time, lack of definitions and clear guidelines also create uncertainty or, in a wider European (or even national) context, inequality (see Text box 1). Whereas from a process point of view it can be understood that entrepreneurs may pro-actively influence decision making on licences in certain areas, while in other areas the links between policy makers and companies are more distant, this contradicts the idea that in Europe market opportunities should be comparable in different member states. Harmonisation of regulations and licencing regimes seems a logical step, although the existing regimes may be the result of clear (political) choices and different interests.

Text box 1 Complexity of licensing

In many countries, the cost of doing business is fulfilling requirements for specific licences or permits. Licences are not always fit for novel applications: aquaculture (open/closed/multitrophic), harvesting, operational scales (or industrial versus farming), processing and refrigeration may all require different licences. Definitions regarding specific activities at sea (constructing or building) may require different (or no) licences.

Needed improvements that are mentioned by our respondents are generally less bureaucracy, less time required to fill out forms, less travelling. As a good example, the Florida (USA) aquaculture licensing system is mentioned, in which licences can be acquired online, by filling in online tests, within one day.

Text box 2 Multi-use at sea

Several of our respondents indicated that there are national (and temporal) differences regarding the access to areas reserved for offshore wind farms. Whereas from a wider perspective multi-use of marine space makes sense, for each individual actor it raises several issues. The H2020 MUSES project covered multi-use and also concluded that regulatory implications differ across countries. In some countries (e.g. UK), multi-use of sea space is already taking place and discussions are on-going in relation to innovative ways for integration; in other countries (e.g. Germany) regulatory aspects are still a major barrier. In Belgium, early wind concessions excluded all activities around wind farms, but exceptions to regulations have been made to facilitate experimental research projects. In the Netherlands, it was already allowed to transverse windmill farms, but from the end of 2019 first commercial wind-weed combinations will take place.

From the point of view of operators there are unknown risks of operations within the windfarm and the resulting need for prohibitively high insurance costs. There is uncertainty about health, safety and emergency concepts while they are operating within *the windfarm.*

Source: MUSES (Multi-Use in European Seas) project, Deliverable 4.2.1: Multi-Use Analysis, 30 April 2018

Whereas it is the explicit intention of the BBF to look towards all aquatic biomass novel use, the algae sector is a case in point: recent research on the definition of algae in EC legislation (Monard, 2018) has found 365 acts in which the term is used, but often in different contexts. As one of our respondents noticed, the same challenges apply in algae as for other economic sectors. For the algae sector, however, there is sometimes redundancy in the classification of the economic activity due to the broad range of applications/services provided. It can be fitted inside aquaculture, industry, agriculture, environment, maritime planning.

Text box 3 Mussel farming to reduce eutrophication

The EU framework on water protection, specifically the Water Framework Directive (WFD) and the Marine Strategy Framework Directive, (MSFD) have led to many actions amongst member states to improve the quality of water.

A measure that could be applied to reduce the excess load of nutrient content is mussel farming (Petersen et al., 2016). The mussels extract the nutrients present in the sea and therefore contribute to the mitigation of eutrophication. Besides, mussels have a huge potential for food production (Suplicy, 2019) and have proven to be successful as feed and a source of energy as well . Furthermore, the remainder of mussels can be used as a valuable land fertilizer and is especially interesting for organic farmers who cannot use commercial fertilizers (Gallardi, 2014) . Despite its multi-purpose or functionality, mussel farming deals with difficulties regarding (realizing) systems for licensing and permits: each member state has to determine for itself what measure should be put in place. This leads to regions and countries interpreting the Framework(s) differently and some include mussel farming while others do not.

In Denmark, these cultures are accepted as a potential mitigation measure by Danish Nature (c.f. Petersen et al, 2016) in contrast to multiple other European countries, 'mitigation cultures' has moved from concept to reality in Denmark. Nutrient-catch cultures by mussel production in suspended cultures or as bottom culture are included in a catalog for marine eutrophication mitigation according to the WFD. Nutrient-catch is now tested in the Municipality of Mariager Fjord.

In Sweden, shell fish farming has been taken up as a possible mitigation measure in its national strategy (c.f. submariner Network). At the West-Coast of Sweden, there is a rigorous licensing system for mussel-farming for human consumption. Strikingly, the East-coast is still developing in this respect; the licensing-system of the West-coast is not directly applicable to the East. In Europe, mitigation using bivalve cultures has mainly been a topic in the Baltic region. Mussel production is seen as a contribution towards counteracting eutrophication, and up to 13 trial sites have been reported in operation (Lindahl et al. 2012).

In the Netherlands, because of the implementation of the EU bird and habitat directives through the Dutch nature conservation law, mussel farmers had to apply each period for obtaining permits. The process of obtaining permits, however, could become counteracted by other stakeholders. Stakeholders had the chance to ask for a state court evaluation of the permits issued by the government. After a permit was rejected by the state court in 2008, an agreement was pursued and reached between the mussel farmers, the government and the NGOs.

Text box 4 CEN Technical Committee 454

On the basis of the Commission's request (M/547), a technical committee (TC/454) has been established by the European Committee for Standardisation CEN to work on standards related to terms and definitions on functions, products, and properties of algae and algae products:

- *specifications for algae-based products*
- *quality specifications for biofuel production*
- *specifications for algae processing*
- *quality characterisation of algal products for non-energy applications*
- *specifications for gaseous capture/soluble nutrient compounds for algal products*
- *specifications for solid and liquid residue streams*

Whereas originally the standardisation efforts were mainly related to renewable energy requirements, the work of the committee has expanded to include food/feed and chemicals/materials/cosmetics/pharma. Work on terminologies is finalising, but other standards are still under development.

Source: Bert van Asselt, JRC Workshop on Algae Production, 27/2/2019; Commission Implementing Decision M/547 / COM(2016)1582; CEN working plan 2019

3.1.2 Novel food status and procedures are unclear for companies

The food and food supplements market represents an important opportunity for several blue bioeconomy sectors, but is yet untapped. In order to access this market, producers must ensure that the substances that they use are authorised, but most of them are extracted from biomasses that fall under the Novel Food Regulation (NFR). Established in 1997 and recently revised, this regulation defines novel food as "food that has not been consumed to any significant degree in the EU before 15 May 1997 (…). This can be newly developed, innovative food or food produced using new technologies and production processes, as well as food traditionally eaten outside of the EU" (European Commission, 2018)

The NFR is of particular importance to the micro- and macro- algae sectors, as well as jellyfish, Arctic shrimp, and certain types of oysters. Entering the food market can be a bridge to scalability for producers: it would allow companies to enter the market with a high value product that is easy to produce and scalable, which frees up investment for pursuing high-value products based on the same organism.

However, the regulation has acquired a reputation of being extremely challenging for most blue bio businesses. This is reflected in the responses to our survey: of the 14 businesses that indicated that the NFR was relevant to their activities, only one had actually gone through the procedure. Of those who had not, half of them indicated that the application procedure was a factor in their decision not to apply. While some difficulties have been tackled with the revision of the regulation, others remain.

Firstly, marine biomass requires scrutiny over the level of substances that they tend to accumulate and are known to be detrimental to human health. This has led the EC to produce a recommendation on products based on seaweeds[1] (EU) 2018/464). The EC recommends that Member States, in collaboration with food and feed business operators, monitor during the years 2018, 2019 and 2020 the presence of arsenic, cadmium, iodine,

[1] https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX:32018H0464

lead and mercury in seaweed, halophytes and products based on seaweed. Marine biomass is therefore under particular scrutiny to pass the authorisation process of the Novel Food regulation. However, as demonstrated in the example below, the benchmarks employed to assess ingredients' innocuity do not always fully reflect the specificities of blue biomass.

Text box 5 PEGASUS project

*To ensure that all new blue bio-substance represents no danger for human health, producers must provide studies demonstrating their harmlessness, based on a number of established benchmarks. However, it appears that some of these are not well adapted to blue bio-substances, especially in the case of algae. One often quoted example is heavy metal levels for safe consumption in cosmetics and food. The recently published report from the PEGASUS project (PEGASUS –Phycomorph European Guidelines for a Sustainable Aquaculture of Seaweeds) sums up the issue as follow: "Regulations in some countries do not distinguish between organic and inorganic heavy-metal compounds such as arsenic and cadmium, which can be found in some seaweeds. This creates unnecessary health debates over the appropriateness of eating seaweed or using it as feed for animals. The consumption of seaweeds in China, for example, is many times higher than that of the EU, but there are no detectable negative health effects. The reason is that most of the heavy metals in seaweed are organic and therefore harmless for humans –but this understanding is not taken into account in EU regulations today, making their amendment necessary"***.***

The necessity to provide extensive and detailed Dossiers to ensure a novel food's innocuity comes at a cost which is often beyond the means of most blue bio companies, which tend to be SMEs with limited resources to conduct the studies (estimates of application cost range from 200-500 k€ for 1 ingredient).

While SMEs often struggle to secure funding to prepare an NFR dossier, the length of the procedure, with no certainty of a positive answer, adds another layer of difficulty. Several of the stakeholders seeking a novel food authorisation insisted on this point, which was partly resolved with the reform of the regulation to introduce a time period for consultation, assessment, and authorisation (with the possibility to halt periods when further information is asked from the applicant).

In addition to its cost and length, the procedure was also perceived as being unclear and creating unfair uncertainties. For example, Member States were initially in charge of the approval procedure and applied different requirements. This led to a strategic approach by companies to where to apply for approval, and also created confusion as to the requirements. In some Member States, there was also a lack of clarity and guidelines appropriate for blue biomass.

As a result, only a handful of blue biomass products have been successfully added to the list of authorised novel foods. This has contributed to a great number of food products being marketed without authorisation, although this is largely due to ignorance among sellers. As an illustration, when the European Commission conducted an investigation in September 2017 with Member States' food control authorities on food products marketed online, they found out that 2/3 of the products reviewed where not authorised, including 428 non-authorised novel foods out of a 1100 websites search. (European Commission, 2018)

At this stage, there is no detailed evidence on the presence of illegal blue bioproducts being placed on the European food market. However, examples exist, such as *Nannochloropsis gaditana* microalgae species (van Loveren & Unamunzaga, 2018). This situation can have a very detrimental effect on both public health, and the reputation of the blue bioeconomy.

In January 2018, the revised NFR (EU) 2015/2283 entered into force. The new procedure introduced a number of changes:

- A centralised online system to submit applications dossiers, managed by EFSA
- New time period providing more transparency on the authorisation process
- New food categories, covering Blue biomass, ensuring a better tailoring of information demanded
- Guidelines to assist companies
- A new communication pathway between EFSA and companies to accompany applicants, especially for SMEs, is to be set up
- Introduction of a dedicated pathway for traditional foods

These changes are expected to lead to an increased number of applications, and ensure that more support and clarity is provided to applicants, although they cannot fully solve all challenges. This is notably the case of high cost and long procedures. But there is still room for improvement, notably in the tailoring of the Novel Food system to the Blue Bioeconomy sector. For example, one of the issues highlighted by stakeholders is that the Union list of novel foods and the Novel Food catalogue often include information that is inaccurate or incomplete, from identifying the right substance, to adequately describing the authorised use. This can lead to uncertainty for producers on whether their product is authorised or not, and on whether they need to apply for an extension of use. Information displayed on the Novel Food catalogue, as well as what constitutes a Novel Food or not in the first place, come from Member States. While EFSA now centralises the authorisation process, member states keep an important role in providing information on what is already allowed, and under what conditions.

An overview of existing studies made in the context of the Novel Food application would be helpful, as well as more cooperation at the international level.

The European regulation is one of the most stringent in the world, in order to ensure the safety of products placed on the European market. However, this create a strong difference with authorisation processes in Asia or United States markets, where it is easier to put new food on the market. Participants in the consultation suggested that the EU should foster collaboration at the international level, either with other countries, or within the Food and Agriculture Organisation of the United Nations, or the World Trade Organisation, to both inform European bodies on foods that are not yet authorised on the European market, and to promote harmonisation of rules between countries.

3.1.3 Ecosystem services in the blue bioeconomy are not recognised and/or remunerated

The release of excess nutrients (e.g. nitrogen, phosphorus, carbon) and heavy metals into the sea can have a detrimental effect on the environment and human health. For example, nutrients can lead to an increased occurrence of microalgal blooms and excessive growth of some macroalgae, resulting in eutrophication and oxygen depletion in the marine environment. As such, they affect maritime activities, including blue bioeconomy activities.

However, excess nutrients could be used for the growth of economically interesting seaweeds and shell-fish. These extractive species (mussels and oysters, sea urchins and sea cucumber, micro- and macro-algae) can be raised to filter the water column of nutrients, but also heavy metals or CO2, with no need for extra feed (Buck, Nevejan, Wille, Chambers, & Chopin, 2017). While biomass removing nutrients can often be reused in further products such as food or feed, biomass used to capture heavy metals might have more limited application due to health and environmental risks linked to the release of the captured substances.

These are examples of ecosystem services that the blue bioeconomy can contribute to, by restoring the marine environment and supporting the development of a sustainable aquaculture. While nutrient removal is often quoted as an example, other types include removing and processing excess biomass from algae blooms or invasive species, providing nursery space for local species (coastal fish and crustacean nurseries), or actively preserving and restoring habitats such as salt marshes. "*Marine ecosystem services are the services provided by the processes, functions and structure of the marine environment that directly or indirectly contribute to societal welfare, health and economic activities*." (Austen, et al., 2019). As such, a blue bioeconomy production activity does not itself provide the service, but supports the capacity of the ecosystem to provide this service.

However, in our survey, many respondents explained how their activities, based on eco-innovations, could improve aquaculture, making it more sustainable and circular, beyond the notion of ecosystem services. For example, by making aquaculture more efficient and less polluting, the blue bioeconomy can relieve the pressure on depleted fish stocks. (As an aside: blue bioeconomy products can also be used for waste treatment, such as jellyfish-based membranes for water filtration in waste treatment plants).

During discussions in the Blue Bioeconomy Forum, it was suggested that the total value of aquaculture could potentially increase by about 10-15% with the inclusion of ecosystem services, which could be used as a mechanism to boost the sector in the short to medium term.

Uncertainties regarding the capacity of the blue bioeconomy to support ecosystem services

The possibility to support the provision of ecosystem services through blue bioeconomy activities has been discussed in the literature since the 1980s and numerous pilot projects have been set up (Nielsen, Cranford, Maar, & Petersen, 2016). However, there is still uncertainty regarding the reality of the environmental contribution, which is based on a lack of harmonised definition and measurement frameworks. This, in turn, affects the capacity to reward this contribution, and make it financially viable.

A first issue deals with the definition of the service provided and the scale considered. For example, multitrophic aquaculture is often considered as sustainable way to develop aquaculture without damaging the local environment. But while many projects are set up at farm level (e.g. setting up mussels or macroalgae harvesting near fish farms to clean up the excessive release of nutrients), participants to the Forum workshops insisted on the higher relevance of focusing on sea basin scale instead, and to consider not just avoiding damage, but restoring the overall environment. This would require a scale up of existing examples and better monitoring of effects.

In order to account for ecosystem services, how much of the toxic substance has been removed from the water needs to be measured. But there is also a need for life-cycle assessments and ecosystem modelling to prove the actual benefit. Also, a number of pilot projects have proved to be less efficient than expected in terms of nutrient uptake (see Text box 6).

Challenges in setting up viable business models

While pilot projects have often set up activities focusing entirely on the physical characteristics of ecosystem services, there are clear difficulties in setting up a functioning business model. Ecosystem services are often not accounted for, and not remunerated. Several options have been implemented:

- Public funding: most pilot projects were set up with public research funding. Some proved less cost-effective than planned, and many did not have a business plan for continuation beyond the funding period.

- Commercial reuse of the biomass produced: in some cases, the product of the activity can be sold to keep financing the activity. This is notably the case of nutrient extracting species such as mussels and algae, which can be sold for feed and sometimes food, providing that toxins levels are below the sanitary norms. More demonstration, and more accurate ex-ante estimates are often needed to make the case for an ecosystem system-oriented business.
- Co-use: multitrophic aquaculture is a common example (e.g. shellfish near cage culture of fish to reduce eutrophication resulting from fish production) (Buck, Nevejan, Wille, Chambers, & Chopin, 2017), although it still raises concerns over its capacity to really make a difference.

While ecosystem services are expected to play an important role in pollution mitigation, very few projects have managed to become economically viable, and this type of blue bioeconomy activity has still not reached the scale envisaged by stakeholders. The absence of dedicated remuneration for the ecosystem service itself has proven a major barrier. Stakeholders mentioned examples where the polluter-pay principle was applied (e.g. Denmark), and invoke the possibility to reproduce funding schemes implemented in other sectors. For example, modelled on carbon emission credit, governments could set up nutrient emission credits, where consumers would pay a tax on high-trophic species to compensate low-trophic species that can extract the excess nutrient. Further inspiration could be taken from land decontamination and phytoremediation policies. Other examples include the absence of fishing quota for invasive species in Latvia. But in general, stakeholders mentioned the lack of political will to set up payment schemes to develop bioremediation. For ecosystem services to be viable, there is a strong need for local (financial) investment.

Beyond ecosystem services

When asked to describe the ecosystem service that they support, some respondents to our survey provided descriptions that fall best under the term “eco-innovation”, i.e. activities that enable the development of a sustainable aquaculture. These activities covered the provision of data technology to assess water quality for a better management of aquaculture farms, and aquaponics or recirculating aquaculture systems, which help diminish pressure on wild fish stocks, and offer possibilities to implement circular processes for the reuse of waste.

Text box 6 Mussels farming for nutrient extraction in the Baltic Sea

In 2018, the Baltic Blue Growth project reviewed ten pilot farms of Blue mussels in the Baltic sea, which aimed at removing nutrients, between 2007 and 2016. The report includes a comparative analysis of best ways to optimise the production of mussel biomass explicitly for nutrient catch. One of the main bottlenecks identified in this report is the impact of low salinity on mussel growth: actual nutrient removal was often far below what had been expected due to mussels being slower to grow, and reaching a smaller size, therefore consuming fewer nutrients. This was especially problematic in areas with strong eutrophication, as algae bloom tends to impede mussel growth as well (in addition to damaging installations). A small size also meant less meat to eventually exploit to support the project after the end of public funding.

The issue of actual nutrient catch compared to the estimated potential is likely to be a major barrier to the funding of further projects. There is a lack of data on nutrient uptake, but it is estimated that in low salinity areas like the Baltic Sea, real uptake has been up to ten time less than what had been hoped for. In addition, trying to solve this problem with larger farms might raise other concerns, as they can also result in nutrient accumulation themselves. There is a need for more ecosystem modelling to really assess where such farms would have an added value. (Hedberg, Kautsky, Kumblad, & Wikström, 2018)

Text box 7 Removing invasive algae for further exploitation

Invasive species that are able to establish themselves in the European environment can be a serious threat to native species and habitats. The European Union tackles the issue under the Invasive Alien Species Regulation (EU Regulation 1143/2014), which prioritises prevention of the introduction of non-native species and encourages their eradication where possible.

But there is also a third aspect to the strategy: to minimise the harm they cause in cases where the species are already established. A project led by Portugal's Polytechnic of Leiria has studied what management of invasive species could mean in the context of a number of invasive seaweeds found around the Iberian coastline.

The AMALIA (Algae-to-Market Lab Ideas) project mainly focused on six seaweed and algae species. AMALIA has mapped where these species can be found and has identified what the priorities are in terms of their management. For example, bladder weed is found in some locations around the Galician coast but is considered low impact and offering low economic benefits, and therefore is not a priority for management.

The other species, could be managemed for sustainable economic benefits. The collection of these target species may become a solution and sustainable management practice contributing to marine ecosystem resilience and even site restoration.

In practice, this means bringing companies, researchers and conservation experts together to study how value can be derived from use of these natural resources in a range of contexts. In some cases, the potential uses are well-known because the species have been extensively exploited in the regions where they are native.

Other ways in which the EU could make use of the invasive algaes and seaweeds are medicines, cosmetics, animal and fish feed, other forms of food and even as a sustainable alternative to plastic film used as food wrapping. For example, devil's tongue weed could be commercially interesting because of the anticoagulant properties of its extracts. Harpoon weed extracts are already being used in cosmetics and have antioxidant, antibacterial, antiviral, antifungal and anti-parasite properties. Wireweed is able to absorb heavy metal pollutants, and could be used for environmentally-friendly antifouling paint used on ship hulls. Green sea-fingers also have antifouling and antifungal properties, and can absorb ammonia.

New products from the seaweeds could become available over the next two to three years, according to AMALIA. The project has worked with laboratories and students to assess some of the possibilities.

Source: www.amaliaproject.eu

Text box 8 Seaweed farming as a way to reach climate goals

The Dutch Climate Agreement is a cooperation between industries, academics, civil society organisations, and government with the explicit goal to reduce the Dutch CO2-emissions to fulfil the requirements of the 2015 Paris Agreement. The draft text that was agreed upon by the Agriculture Table sub-group on 21 December 2018 mentions as one of the targets the use of water for capturing CO2: developing blue space for seaweed farms and associated nature development (the initial target of 14.000 square kilometres was removed from the final text of the document).

Source: https://www.klimaatakkoord.nl "Klimaatakkoord hoofdstuk landbouw en landgebruik" 28 June 2019 (visited on 9 July 2019)

3.2 Finance and business development

Many stakeholders of the Blue Bioeconomy Forum mention difficulties with finding finance. They often had contact with a broad range of financing possibilities: private equity, angel investors, investment funds, venture capital and commercial banks. Some companies also mentioned contact with development banks and public funding. Challenges in finding financing are an obstacle for blue bioeconomy development, as already noticed in the context of Bio-Based Industries (BBI) and the Blue Economy (BE): in a survey launched in 2017 the majority of BBI and BE projects (33 out of 43) mention that they faced access-to-finance issues (InnovFin, 2017).

Fccording to the Marine Biotechnology Strategic Research and Innovation Roadmap (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016), the most urgent technological challenge is in the demonstration plant phase (TRL 6-7), and the upscaling to flagship/ first-of-a-kind (TRL 8), when economies of scale have not yet been achieved. This is reflected by the funding gaps seen in Bio-Based Industries projects, where the main funding gaps exist in upscaling from pilot to demonstration projects and in moving from demonstration to first-of-a-kind (FOAK) and industrial-scale projects (InnovFin, 2017). The often cited 'Valley of Death' (phase where there is a lack of financing) is also seen in the commercialisation phase (product development and commercialisation) (Acacia, Metis, Panteia, ICF and CASE, 2018) as well as in the R&D phase. However, some stakeholders mention that public funding is focused mainly on the R&D phase and there are plenty of financing opportunities there; other stakeholders mention having troubles with finding financing for research in the blue bioeconomy.

Our working groups highlighted that funding is particularly a problem for mid-scale projects (between EUR 1 million and EUR 10 million). This is comparable to the funding gap found in the Blue Economy, which lies between EUR 3 million and EUR 15 million (Acacia, Metis, Panteia, ICF and CASE, 2018).

Part of the reason for the financing challenge is that the financing landscape for the Blue Bioeconomy is considered immature. This is the case for most of the blue economy, as 65% of highly relevant investors for the blue economy were established in the past 5 years (Acacia, Metis, Panteia, ICF and CASE, 2018). Furthermore, a substantial number of financing platforms are not dedicated to the blue economy, but cover a broad range of sectors (EIF, 2018). As the Blue Bioeconomy is a fairly small sub-sector of the blue economy, it is even more difficult to find the financing platforms covering this specific area.

High risks are often mentioned. These can be market and demand risks (due to a lack of developed markets and insufficient and fluctuating demand for products from the bioeconomy) or regulatory risks (resulting from a lack of effective, stable and supportive EU regulatory framework) (InnovFin, 2017). Furthermore, there are natural risks for the blue bioeconomy, e.g. diseases affecting animals (fish, shrimps, oysters), storms causing physical damage to aquaculture farms, a drop in oxygen level and temperature changes.

From the perspective of emerging fund managers in the blue economy, the problem is not generally a risk-return problem, but a shortage of capital in their funds (Acacia, Metis, Panteia, ICF and CASE, 2018). However, in the bioeconomy, highly characterised by new technologies and innovations, information asymmetry and technology risks are limiting the tendency to invest. Most Financial Market Participants prefer more mature and technologically advanced projects (InnovFin, 2017).

In the next sections we will more elaborately display the challenges that are perceived as the most important financial challenges (by the Blue Bioeconomy Forum):

- Blue bio projects and businesses lack understanding of investment landscape and how to present opportunities to potential investors
- There is a lack of funds and mechanisms to support blue bio projects and start-ups.

Text box 9 Financing structures in the pharmaceutical sector

The pharmaceutical sector provides an interesting example for the Blue Bioeconomy with respect to evolution of financing innovative start-ups. As with many new technologies and innovations in the Blue Bioeconomy, the development of new drugs is also characterized by long investment periods and large risks of failure. The ecosystem of start-ups conducting innovation in this area has developed into what has been termed a "market for ideas", financed primarily by venture capital, in which companies can obtain successive rounds of financing from different investors, based on milestones related to the results of experimentation. This process is enabled partly by the patent system, allowing fairly clear protection and licensing of intellectual property and resulting drugs, including limited competition once products finally come to market . The development of this ecosystem over the past few decades has been supported by a corresponding phase of higly liquid and rising equity markets.

3.2.1 Blue bio projects and businesses lack understanding of investment landscape

A lack of understanding on the part of the investment community is mentioned as a big challenge in the Blue Bioeconomy, which aligns with what is also seen in both Blue Economy and bio-based industries. This challenge is often mentioned by companies and startups, and was also identified in the Blue Economy Investment Platform study (Acacia, Metis, Panteia, ICF and CASE, 2018). In the Blue Economy startups and businesses mention, for example, a lack of understanding on the part of Venture Capital Funds of the technology risk, market potential and potential upside. But the rapid growth of investors in the blue economy also shows the growing attention and perceived attractiveness for the blue economy, which could also be the case for the blue bioeconomy.

Discussions with various investors indicates that blue bio startups are generally even less familiar with the investment landscape. This includes the variety of different forms of finance (debt, equity, etc.) as well as the range of investors. In many cases, their managers or founders lack understanding of the relevant investment options and what is necessary to access them. Indeed, investors and intermediaries have highlighted this point during discussions and interviews conducted in the elaboration of this roadmap. This is not surprising because most projects and startups are led by researchers and innovators, who are driven by the belief in their technology or product, and its social or market potential. Such managers are not experienced in business finance.

According to investors, Blue Bioeconomy projects do also present inherent difficulties in presenting an attractive business proposition. The reasons for this include risk inherent with new technologies or new products (for which little is known about market acceptance), longer lead times until revenues are generated, and uncertainty concerning possible regulatory issues. Furthermore, expensive license costs, IP hurdles and safety rules for offshore work are mentioned to be costly (see section 0).

For projects that do manage to present a solid business model, funding seems to be available. As one interviewee (who owns a company) states: "*A growing number of investors are considering funding projects, companies within blue bio-sector. If a project seems successful, some banks are even fighting to fund such project. Hence, capital is available and accessible, but an entrepreneur should present a good business model, good product and a good management team to convince investors.*" Also, another interviewee (an investor) mentions that although there are certainly several risks involved in blue bioeconomy projects, they can partly be mitigated by insurances.

Is there something special about these issues in the case of the blue bioeconomy, compared to other new technological sectors? That is not clear. In many new technological and research-driven sectors, an innovator may have an excellent idea, but does not think of providing the information that investors require in order to assess risk and rewards. The blue bioeconomy often involves new products, but that is not so dissimilar to other areas, such as nanotechnology. One particular characteristic of the blue bioeconomy is uncertainty concerning permits and licensing, particularly with respect to access to specific maritime and estuarine areas, which is required for many of the products and technologies under development.

Most investors may not have a detailed understanding of the risks of blue bio-businesses. Transparency, clarity and effective communication are central for gaining their trust. Businesses need assistance in appreciating what kind of information investors required. This is linked to the next challenge identified on the need for mechanisms to link investors and businesses.

Some projects and start-ups directly address this challenge by engaging financial expertise in their management structure. This has even been observed in the case of Horizon 2020 projects which have engaged venture capital experts into their advisory boards. Even with a limited role, these advisors help project or business managers with understanding the options available for raising finance and how to best access them. In working group discussions, it was repeatedly stated that more attention is required on defining and promoting the investment readiness of projects and companies. Part of this is about learning the basics and learning the language of start-up financing. There is also a clear link with the challenge of developing entrepreneurial and business skills among blue bio businesses (see section 0). Financial expertise is one such skillset that needs to be integrated for successful business development.

3.2.2 There is a lack of funds and mechanisms to support blue bio projects and start-ups

A second, but related, challenge for financing the blue bioeconomy is the lack of investment funds and related mechanisms that are available for this sector. This challenge has been identified by a number of recent studies, including the Blue Investment Platform Study (Acacia, Metis, Panteia, ICF and CASE, 2018) and the study on access to finance in bio-based industries and the blue economy by the EIB (InnovFin, 2017).

There are clear signs of interest among investors. This was voiced in interviews and working group discussions, as well as being documented in the above blue economy studies. One start-up manager explained, for example, being approached by potential investors at scientific conferences.

This interest in investing is lacking dedicated investment vehicles or funds in order to access opportunities. There is also a lack of platforms to bring investors together with projects and businesses. Both of these gaps have been documented in the Blue Economy Investment Platform study. The EU's Annual Economic Report on the Blue Economy 2018 highlights that investment capital is available for blue biotechnology but that this is scattered across various sources (EC, 2018). The Blue Economy Investment Platform study offers several alternative structures for funds that would operate with support from the European Commission (either directly or indirectly), for the blue economy, including the possibility of a dedicated fund focused on the blue bioeconomy sub-theme (Acacia, Metis, Panteia, ICF and CASE, 2018).

Regarding platforms, the Blue Economy Investment Platform Study already identified the need for associated structures which would address gaps in technical understanding and expertise and provide a matchmaking structure. A technical assistance facility responds to the lack of financial expertise among companies seeking financing by supporting them in preparing investment cases. Such a facility also addresses the need for improved understanding among fund managers of technologies, market potential and possible risks, enabling improved assessment of risk-reward opportunities.

The need for such technical support for blue bio companies was highlighted in working group discussions and surveys. Promising investment proposals for investors need to address the 10+2 timeframe common in private equity and venture capital. This timeframe consists of an investment cost period of 5 years followed by 5 years of monetizing the new technology before moving into profit generation. If a company has a longer term horizon, due for example to longer time needed to develop technology, then financing structures are needed that provide investors with possible exit opportunities. The challenge posed by longer-term investment periods was highlighted among companies responding to the surveys. The lack of technical assistance facilities and matchmaking structures restricts many companies from addressing these needs of the capital markets and accessing more finance. Another consequence is that potential investors are obligated to support these activities themselves. While some individuals involved with particular projects have indicated that they are personally willing, they indicate that more investment could be channelled to the sector if these services were being publically supported.

Text box 10 Blue Economy investment Platform

In 2018, DG MARE commissioned a study to support the development of a Blue Economy Investment Platform (Acacia, Metis, Panteia, ICF and CASE, 2018)*. This resulted in a range of options for investment fund(s), supported by the EC and/or the EIB, to address financing needs in the Blue Economy, including direct, indirect and co-direct investment structures. Among the direct structures, there are possibilities to target these by specific sub-sector, such as the Blue Bioeconomy, stage of technological development, or by geographical region. For an investment fund targeting the blue bio sector, extensive technical expertise would need to be developed. The study also makes the case for associated structures that would provide technical support to investors and recipients. At the time of developing this current Roadmap for the Blue Bioeconomy, the Commission had not yet made specific proposals on the specific form for such a platform.*

3.2.3 Human resource needs (skills and qualifications) in the blue bioeconomy sector

The European labour marke tis facing a shortage of specialized and technical skills in Science, Technology, Engineering and Maths (STEM) and also challenges due to the changing dynamics brought about by technological change. As a relatively new sector driven by breakthroughs in scientific research in notably marine biology and related innovation, the blue bioeconomy is confronting such skills challenges. Much activity in the blue bioeconomy is now concentrated at the stage of transfering research to commercialization and gradually to viable businesses that may be upscaled. Having the right skills is critical to successfully crossing this 'valley of death' (2006).

The skills required for success become more complex with each phase of product development. Whereas in initial phases specialized technical skills are needed, latter phases also demand specific types of business skills. In a recent (2018) study on the impact of game-changing technologies on work in manufacturing, the essential multidisciplinary skills required for innovation were identified for five different technologies, including industrial biotechnology:[2]

- Management positions requiring more advanced technical skills;

[2] https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/fomeef18001en.pdf

- Technical experts requiring more non-technical skills;
- Specialised positions combining two or more types of technical expertise.

The scarcity of these skills forms a bottleneck for innovation and the development of the blue bioeconomy. One response has been the Blue Biotechnology Masters Course, which has identified together with businesses the skills development to include in their programme.[3] The relative importance of these multidisciplinary skills varies across different phases of innovation.

In the initial phases, when scientific findings lead to technology transfer, multiple technical skills are essential, for example through the combination of marine biology and engineering. In the blue bioeconomy, finding the right combination of expertise is a compounded challenge due to the diversity of the sector. The blue bioeconomy is, after all, not based around one or two technical innovations, but rather on a wide range of combinations of specializations within natural sciences and engineering. Within the current market, there appears to be sufficient inflow of students within the fields relevant to the sector. The challenge encountered so far is that the popularity of the fields (notably algae and biotech) relevant for the blue bioeconomy cannot be met by academic offers. Members of the working group indicate that these mismatches are substantial (examples of around 60 applications for 2 positions, for example) and hamper the potential for this sector. With sufficient potential from within academia, a subsequent key challenge is ensuring the right combination of specializations find each other to enable technology transfer.

Text box 11 Example skills for biomass transformation

While research is well developed at the biology level, there is a lack of engineering skills for biomass transformation. Companies are lacking technicians and engineers with knowledge of marine biomass, and they are currently left with working with agrofood specialists, who in particular lack an understanding of working in a saline environment.

The need for these specific combined specialisations does not merely rest at academic level; feedback from the sector also indicates that the combination of skills and expertise required for the maritime sector is not sufficiently available at the level of vocational education.

Technical experts with a successfully developed product require more non-technical entrepreneurial skills to turn the product into a viable business.[4] These products tend to originate from academic transfers, start-ups, or spin-offs of existing business, rather than emerging from existing and well-established business. It is often the technical experts themselves who have to turn the product into a success, and therefore require entrepreneurial skills to do so. Their academic training often does not include basic business skills training (marketing, sales, management, finance and accounting, etc.) or soft skills required to manage a team (communication, team work, etc.). Technical experts requiring business & soft skills to make their product as a success, are often also referred to as the 'T-shaped professionals" (derived from ICT sector - 'depth of technical knowledge' is the vertical stroke of the T and the 'breadth of expertise' using soft skills is

[3] https://www.bbmbc.eu/

[4] https://www.researchgate.net/publication/305654195_New_Skills_for_Entrepreneurial_Researchers

the horizontal stroke of the T). [5] Members in the working group have identified this to be a major challenge to the current stage of the sector.

Text box 12 Baltic Blue Biotechnology Alliance – incubator approach

The Baltic Blue Biotechnology Alliance of the Submariner Network provides a possible solution to this issue with a biopark function and incubator approach. This supports research groups and start-ups to develop technologies to the next level. This is a combination of technical and financial support.

What role does the Alliance play?

The Alliance has a rolling call for submission of ideas, with deadlines for review and evaluation twice a year (spring & autumn). The most promising applications are invited to pitch their idea to an international expert panel and receive feedback about the feasibility and potential of their idea.

The Alliance invites feasible ideas to join its mentoring programme and assigns mentor institutions.

Mentors and case owners work together to determine and formulate the specific needs of the case:

- *What is currently missing to bring this idea closer to the market?*
- *What are the case owner's specific requests towards the Alliance: A biomaterial or compound? Access to laboratories? Support and expertise in business planning? Something else?*

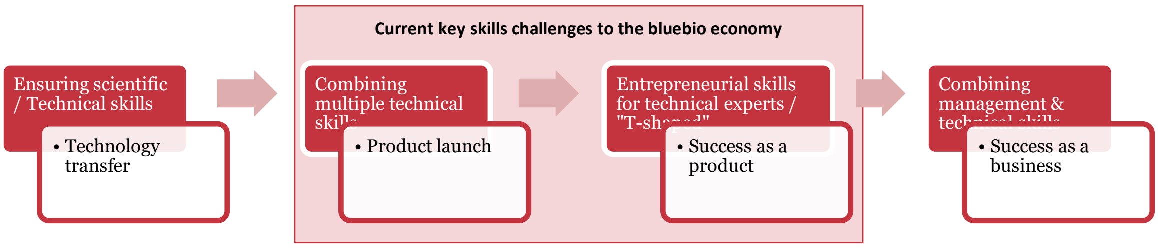
This is when mentor and case owner review the Alliance members' individual service offers to find the perfect fit. The Alliance can also involve external experts and institutions if the case owner's request cannot be met internally.

The Alliance is gaining experience and formulating a service offer that will function in a self-sustaining network beyond 2019.

Source: https://www.submariner-network.eu/images/projects/alliance/downloads/sub-alliance-brochure-WEB.pdf

Once investors have been attracted and the success of a product has been established, the financial means can attract (and afford) general managers to ensure the success of the business. In this process, multidisciplinary is again essential, whereby managers need to understand sufficient levels of the technical process to lead the business successfully. The figure below demonstrates these phases of development and the current key challenges for the blue bioeconomy in that process.

Figure 1 Skills challenges for innovation: state of play in the blue bio economy



Source: Technopolis 2019

[5] https://www.digitalsme.eu/digital/uploads/March-2019_Skills-for-SMEs_Interim_Report_final-version.pdf

Through the *New Skills Agenda for Europe* (in place as of 2016), the EU acknowledges the need for initiatives to overcome the shortage of appropriately qualified staff in Europe. In addition, national, regional and sector initiatives aim to boost the labour market across the Member States. These initiatives are aimed at a) retraining and up-skilling the current labour force and b) enabling the system to better prepare the future labour force. These efforts are often aimed at STEM professionals and tend to be developed with these skills challenges in the innovation process in mind. These initiatives provide opportunities for the bluebio economy to be involved in and ensure that they are developed with the needs of the sector in mind. These activities should focus on bringing together different scientific disciplines to enable innovation and turning scientific findings into flourishing businesses.

3.3 Consumers and value chains

The development of the blue bioeconomy sector highly depends on entrepreneurial activities in this sector, in relation to both existing value chains and consumer acceptance of novel products. Five key challenges that inhibit dynamic development of entrepreneurship in the blue bioeconomy were identified.

3.3.1 Lack of consumer acceptance of 'blue' products

According to the BIOWAYS project (2017) and research conducted by Wageningen University (2015), European consumers are generally unfamiliar with the concept of 'bio-based' products. Either they confuse this with the term 'organic' or there is a misunderstanding about the environmental and health impacts of bio-based products. As a result, there is only limited consumer recognition and acceptance of bio-based products in Europe. Consumers' perceptions of products that originate from aquatic and marine environments are strongly associated with fish products, while microalgae, seaweeds, shellfish and aquatic plants are largely unknown. This is due to a lack of consumer history with bio-based marine products. This is evident even among the 'blue' bio-based products: globally, consumer acceptance of 'blue' food products is higher than for feed, cosmetic, pharmaceutical and other products, due to a longer consumer history in the food sector, and consequently, a larger market (for example, 85% of global seaweed industry comprises food products) (FAO, 2018). Knowledge about application, use, qualities, benefits and potential of marine bio-based products is still limited. The ongoing debates about utility and functionality of bio-based products from aquatic and marine environments are contributing to mixed consumer perceptions. As a result, the demand for aquatic bio-based materials and products is lower in Europe than, for example, in Asia.

Entrepreneurs within the blue bioeconomy sector are struggling to position and sell their product on the market, and are therefore looking for effective marketing techniques. Based on experience in other industries, large companies are typically acting as brand leaders. They develop stories on new products, build associations with specific phenomena/words/experiences to imprint a new product in the memory of consumers. The branding approach of large companies presupposes a consumer target group that is likely to buy a product. The small companies can either develop products for the same target group as limited editions of large brands or choose an alternative clientele for which the existing key messages will be adjusted. In the latter case, the marketing of novel products requires investment, which in case of many European SMEs is a significant obstacle.

Text box 13 Consumption of mussels in Europe

In Europe, the level of mussel consumption by inhabitants varies greatly by country. Spain, France and Italy make up 78 percent of the total consumption, representing only 35 percent of the population. In countries like Greece, mussels are not part of the traditional diet. Consumer perception of the fresh/chilled produce is low in Greece, the population has serious concerns about the quality and food-safety issues (toxicity of mussels).

Despite the overall high consumption in European countries (around 600 000 tonnes annually), mussels are not well known, not only in areas distant from the coast. Getting people to show an interest in the product, and subsequently buying it, would require a combination of several factors: information dissemination to explain the product to consumers, facilitating the presence of the product in restaurants or retail shops, and last but not least, offering products in an easy-to-access format.

Collective branding by a group of producers is currently the favoured marketing tool for businesses selling to consumers in the case of fresh or little processed fisheries and *aquaculture products in Europe, with several hundred labels existing. All collective brands dedicated to aquatic products, promote a higher quality based on a combination of attributes; such as rigorous production practices, particular fishing technique, particular area of production, or even country of production.*

Source: FAO. (2014). Globefish research programme: the European market for mussels. Available at: http://www.fao.org/3/a-bb218e.pdf

Text box 14 How companies try to change the perception of consumers about seaweed

In most areas of the United States, seaweed serves solely as a wrapping for rice and fish, and is often tempered by being doused in soy sauce and wasabi. Several manufacturers are trying to up seaweed's status as a covetable food ingredient by incorporating the greens into unexpected products like pasta and marinara sauce.

According to CEO of Algaia, Fabrice Bohin: "The main driver for the increasing interest towards seaweeds is linked to consumer pressure for natural products with a healthy nutritional profile but also the mainstream trend towards sustainability. Seaweed is one of the most sustainable raw materials as it does consume CO2 when growing and does not require any irrigation water, cultivation land, pesticides or fertilizers to grow. In addition, there are a lot of possibilities to naturally cultivate seaweed to expand the resource if needed without impacting the planet".

In 2017, Univar announced a distribution agreement across Europe for the AlgaVia brand of Whole Algae Ingredients from TerraVia. TerraVia's product lines include Lipid-Rich Whole Algae and Protein-Rich Whole Algae. Lipid-Rich Whole Algae is available in golden and cream varieties, which can replace eggs and dairy fats in a wide range of applications including bakery, beverages and desserts.

Source: Blumenfeld, J. (2017). Brands find new flavour opportunities with seaweed. Available at: https://www.newhope.com/food-and-beverage/brands-find-new-flavor-opportunities-seaweed ; Selby, G. (2017). Special Report: Seaweed and Microalgae Driving New Product Development. Available at: https://www.foodingredientsfirst.com/news/special-report-seaweed-and-microalgae-driving-new-product-development.html

Due to debates about the health benefits, functionalities, application and utility of blue biomass/products, there is a lack of agreement on how 'blue' products should be promoted oradvertised and whether there is a need to provide public assistance for raising consumer awareness and acceptance of these products. Among proponents of public intervention there is an argument that the immature Blue Bioeconomy sector needs public support in promoting aquatic/marine-based products. Regional governments are considered to offer most effective and justifiable support to local 'blue' producers. Experts that recommend marketing assistance at the EU level argue that a well-defined labelling system for bio-based products could enhance consumers acceptance (KBBPPS, 2018; OpenBio, 2018; SAPEA, 2017). Discussions on the labelling reveal two divergent views. First, there are too many labels that are either disregarded by consumers or create confusion. The creation of a new label requires the development of standards and mechanisms of quality control. The second view (pro-label) is that a new label or incorporation of 'blue' products into existing labels, such as "organic", "eco", "natural", "sustainable", "green+blue", "bio-based", would be an effective tool in informing consumers about characteristics of a product and thereby raise consumer acceptance. Another frequent suggestion is origin denomination labelling - "Made in …". This approach is expected to raise acceptance of local/regional consumers and producers.

In contrast to proponents of public intervention, many actors argue that market forces should take care of promotion, marketing and branding of 'blue' products. Each entrepreneur has the freedom to develop and present a unique product in a market. The additional support from the public cannot be easily justified, it may disincentivise companies to invest in marketing of their product, misallocate resources in the market and it can be of little economic value. More importantly, the lack of agreement on utility and benefits of 'blue' products poses a challenge for correct promotion of these products in public initiatives.

3.3.2 Lack of valorisation of rest raw materials from marine origin materials

Poor management of seafood resources results in considerable waste at the global level. Estimates of waste produced in fisheries and aquaculture include volumes as high as 130Mt and value-lost of up to 43 billion EUR (EUMOFA, 2018).

The most pronounced problem is that of *fishery wastes,* which has become a global concern and which is affected by several biological, technical and operational factors as well as socio-economic drivers. The *definition of "fish wastes" includes many fish species or by-catch products* having no or low commercial value, undersized or damaged commercial species as well as species of commercial value but not caught in sufficient amounts to warrant sale (Caruso, 2015).

Every year discards from the world's fisheries exceed 20 million tons equivalent to 25% of the total production of marine fishery catch and include "non-target" species, fish processing wastes and by-products. However, the use of fish as feed cannot be governed only by fishery market forces and, on the other hand, the need for responsible fisheries and aquaculture development has been underlined in order to preserve aquatic biodiversity (FAO, 2011)

Fishery discards from European fleets are significant. The EU has launched a joint policy to reduce unwanted by-catches and eliminate discards in European fisheries. However implementation of the EU Regulation for the reduction of fish wastes is still required.[6]

Furthermore, poor utilisation and waste at almost every stage in the fish food supply chain actually means that consumption is much lower. More than 50% of fish tissues including fins, heads, skin and viscera are considered "wastes" (EUMOFA, 2018). Some studies suggest that in some cases just 21% of EU finfish catches end up on consumers' plates (EC DG RTD, 2016).

Only a small fraction of marine biomass is presently used outside the food and feed sectors. Large amounts of sidestream (skin, bones etc) are thrown away, while they can be high value inputs for many products.

In mollusc aquaculture there is also unappreciated potential for waste valorization . Shells from the aquaculture industry are widely regarded as a nuisance waste product. With increased awareness of the need for a circular economy many arguments are put forward for considering shells as a valuable biomaterial that can be reused for both environmental and economic benefit (Morris, Backeljau, & Chapelle, 2019).

Text box 15 Shells from aquaculture: a valuable biomaterial, not a nuisance waste product

Shell waste can be a big problem for shellfish producers, sellers and consumers, both practically and financially. Depending on the species, shells can account for up to 75% of the total organismal weight.

There are a number of implemented and unexploited ways of sustainable use of seashells as an input in new products and processes.

Among the exploited valorisations strategies are:

- *Livestock and hen feed supplement in order to improve the health of livestock,*

[6] https://ec.europa.eu/fisheries/cfp/fishing_rules/discards_en

particularly bone health, but also in laying birds as a supplement to improve the quality and strength of eggshells

- *Use of shells as a soil liming agent. This practice involves treating soil or water with lime (or a similar substance) in order to reduce acidity and improve fertility and oxygen levels.*
- *Using shells as a simple material for construction or incorporated into aggregate and mortar mixes. Shell waste has many characteristics that might make it suitable for certain construction aggregates.*
- *Use of mollusc shells as biofiltration medium for treating wastewaters, removing heavy metals, as a pH buffering medium in ponds and aquarias,*

Examples of potential and unrealised sustainable (non energy intensice) applications of mollusc shells include the following:

- *De-icing of roads, that is use of waste CaCO3 from the aquaculture industry as the calcium donor in the formation of calcium acetates, that is an environmental-friendly road grit not containing chlorine, an alternative to the rock salt.*
- *Use of mollusc shells as the drainage layer in green roofing structures. The drainage layer is important in carrying away excess water from the roof. Whole shells may be ideal for such structures, as when heaped they provide a complex 3D structure to aid drainage. In addition, CaCO3 shells incorporated into green roofing structures may help with the neutralisation of acid rain, and the reduction in heavy metal contamination in the resultant drainage water.*
- *Uncalcined, variously graded calcareous shells can be used as: heavy metal, nitrate, sulphate and phosphate sorbents, as well as a pH buffering substrate and an oxidation substrate*
- *Use as a substitute to conventional mortar sands, incorporation into cement mixes*
- *Shells returned to the marine environment: a growing body of evidence suggests that shells are a valuable material within the marine environment and may provide a variety of ecosystem services. Further, there are an increasing number of organisations, charities and research groups that are already returning shells to the marine environment for conservation reasons.*

Source: (Morris, Backeljau, & Chapelle, 2019).

One of the causes of the problem, according to the BBF stakeholders is the dominant perception of marine by-products as a waste. Many consumers and entrepreneurs do not recognise the potential of blue by-products and co-products, assuming that they are of low quality and with questionable effects on health. It was recommended that more research should be conducted to show the usability, value and health benefits of side stream products, thereby assisting in changing the perception.

Furthermore, the development of the market of by-products is rarely considered a viable business idea by current traditional business owners that produce those streams, due to a lack of realisation of their business potential. Many business opportunities are neglected, and entrepreneurs are not aware of effective business models that facilitate collaboration within the 'blue' value chain. The BBF stakeholders concluded that public assistance is needed for training of entrepreneurs and financing marketing efforts for changing the perception of the value of side stream products.

The geographic scattering of blue bio industries also poses logistical difficulties. The storage facilities and delivery of by-products should be adequate to ensure that by-products do not get spoiled before reaching a producer or a consumer. Public incentives are needed to facilitate investment in logistics facilities.

The BBF stakeholders recognise a mismatch between several regulations related to production and trade of bio-based products, as well as regulatory restrictions on the use of rest raw material and by-products. Researchers, in particular, admitted that they are discouraged fromo transforming an idea into a product, due to these barriers. Hence, various stakeholders would welcome the creation of a one-stop-shop where they can obtain (free) advice on regulations in blue bioeconomy sector. In addition, enhanced dialogue is needed among regulatory bodies to ensure complementarity and harmony between regulations. The food regulation authorities are expected to be active in discussion of 'blue' regulations.

To complement this discussion, the EC DG RTD 2016 workshop extensively addressed the fishery by-products as part of the conference FOOD 2030 in 2016 (see box below).

Text box 16 Recommendations of the DG RTD workshop

Direct financial support actions

- *Develop a roadmap (including a feasibility study) on best (food) use of underused fish biomass, including infrastructure needs.*
- *Use research funds to develop regional pilot plants for proof of concept for fish and for algae food products at semi-industrial scale.*
- *Develop large demonstration or smaller regional bio-refineries for underutilised fish biomass and for microalgae as 'lighthouse' projects to encourage further investment – e.g. using PPP*

Communication actions

- *Foster and facilitate dialogue between fisheries, scientists, food technologists, health officials and end-users.*
- *Involve industry and scientists in societal debate to raise awareness and promote trust.*
- *Ensure industry and societal involvement in research strategies to provide solutions. use of existing networks (e.g. FARNET Fisheries Local Action Groups).*

Governance actions

- *While maintaining food safety requirements, monitor the impact on availability of marine biomass for human consumption.*
- *Ensure long-term stable regulatory framework that provides a stable operating environment and predictability to facilitate investment in technology and know-how.*
- *Ensure that MS promote aquaculture communication actions that have a clear place in structural funds (EMFF Article 68) and may also include the production, processing and marketing activities along the supply chain.*

Source: Recommendations from the stakeholder workshop "Aquatic food products and new marine value chains", (EC DG RTD, 2016)

3.3.3 High costs of 'blue' production

One of the greatest challenges for development of a 'blue' business or commercial project is the relatively high cost of production. Marine and aquatic-based biomass has specific characteristics, which can result in more complex production processes compared to other industries and lead to additional challenges, such as storage and transportation of biomass. The extraction of salt, carbon and water, the maintenance of light intensity, temperature, pH levels, quantity and quality of nutrients, sterilisation and filtration of the biomass or water treatments are among few processes that need to be considered in production of 'blue' biomass (FAO, 2017). Based on survey results and discussions with experts in the blue bioeconomy, the major factor that leads to higher costs is a complex production process that requires adoption or upgrade of novel technologies and intense energy input.

Production processes of 'blue' products are very diverse and complex. The costs incurred during cultivation of biomass, harvesting, post-harvesting/pre-processing and processing stages vary depending on the type of final product and associated costs of production methods, techniques and technologies used (Acien, Fernandez-Sevilla, Magan, & Molina-Grima, 2012). Until now, no study has been conducted to compare costs across production processes of 'blue' products. Hence, it is difficult to identify the costs of different types of 'blue' products, to compare costs across regions/countries, to undertake a cost-benefit analysis and to define areas in which public support is needed.

Processing of biomass typically includes several stages with high production costs: energy-intensive process of drying the biomass, fractioning for extraction of needed components, and the use of photobioreactors. Novel technologies that are used in the production process are, on the one hand, increasing productivity and decreasing production costs, but, on the other hand, they take up a significant share of investment, especially for small scale production. The speed of development of biorefinery technologies, to a large extent, determines the use of bioresources (Norden, 2015). The current lack of biorefineries and costs of other production/research facilities at sea is one of the critical challenges for timely processing of biomass and for decrease of transportation costs. Favourable production locations that have appropriate infrastructure for logistics and transportation of biomass are an essential factor for energy efficiency, cost-effective production and research (Slegers, 2014). The building of biorefineries cannot take place on many sea coasts, as these facilities occupy large spaces and could trigger social discontent. Hence, experts suggest building a few clusters of 'blue' production in the EU, thereby concentrating production and reducing costs for many entrepreneurs. Among other potential solutions is more cooperation among producers in sharing of facilities and technologies.

Text box 17 Costs of spirulina production

Spirulina grows well in sunny, warm alkaline waters and can be continuously cultivated outdoors in a pure culture. Photobioreactors, tube, plate and tank systems have been developed to grow algae in closed systems in colder climates, to prevent contamination, or grow higher value algae that require more cultivation control. Photobioreactors and closed systems have been considered too costly, not competitive and are not generally used for commercial spirulina production. To lower costs, future farms need to integrate nutrient resources, refine production systems and produce a variety of end products, from valuable extracts to inexpensive protein.

Many French spirulina micro-farmers try to use low-cost technology. Although micro-farms may not enjoy the same production cost savings as large-scale production, they can make up the difference by selling directly to local clients. A commercial farm producing finished products gets about 35% of the retail price, 65% going to distributors, wholesalers and retailers. A micro-farmer, selling directly to the local community can capture up to 100% of the value chain.

Source: Henrikson, R. (2011). Development of a Spirulina Industry – Production. Available at: http://www.algaeindustrymagazine.com/special-report-spirulina-part-5-development-of-a-spirulina-industry-production/

The scale of production is critical for determining the size of fixed and variable costs. Large scale of production leads to smaller costs per unit. This suggests a limited potential for small and medium-size enterprise (SME) with 'blue' profile unless assistance is available to cope with high costs or investment for scaling up the production. Alternatively, development of the sector will be driven by large companies that can gradually grow the market, decrease apprehensions of investors and increase business viability of 'blue' SMEs. In the latter scenario, the presence of SMEs in blue bioeconomy will be delayed. Participants in the Blue Bioeconomy Forum suggested non-monetary instruments that could assist 'blue' SMEs, including business advisory support for scaling up production and diversification of portfolio, and assistance in accessing available financial support from the regional, national or EC programmes.

Although compliance with regulations for high value markets incurs greater costs, the profits from the sale of products from, for example, cosmetic or pharmaceutical sectors could balance out the expenses in the long run. Hence, some experts in the blue bioeconomy do not advise providing additional public support for companies that develop such products. Nevertheless, one of the mechanisms to provide a balanced support for organisations that develop products with different levels of added value is to partially cover R&D costs. The unpredictable duration, success and expenses of clinical trials for pharmaceutical products are major risk factors and disincentives to explore business opportunities. A policy instrument that could decrease costs of clinical trials, assist in critical research areas of the 'blue' sector (e.g. development of compounds for biomass drying or salt extraction) and stimulate research/product development could be effective at these starting stages of the 'blue' sector.

Discussions on coping with high costs of production revealed that producers have to optimise the productivity of the biomass and the cost-effectiveness of the entire cycle of processing. This implies that producers have to monetise all components that were extracted and fractioned from the biomass. To do this, it is necessary to stimulate development of the market of by-products for increase of business-to-business sales. Several participants in the Blue Bioeconomy Forum highlighted the need to create the blue biomass market in the EU, as it would help to compare prices of biomass in a specific region and season, assisting to better predict costs and profits of companies, and it would stimulate the market orf by-products. Potentially, this could also attract more investors to the 'blue' sector.

3.3.4 Difficulty in stable production of aquatic or marine biomass due to seasonality

Seasonality is an important issue in aquaculture and in fishing, as it often cannot be controlled, except in some cases of shellfish aquaculture where farmers using closed systems can manipulate the temperature and food supply. At the same time some examples of optimisation of technical resources across various activities in various seasons have been demonstrated (see Text box below).

Text box 18 Synergies in a using offseason fishing boats for seaweed harvesting

> *An example of optimisation of the resources in various seasons comes from the Estonian Fishery and Seaweed Aquaculture company. Estonian seaweed farmers have established cooperation with the local fishery company. They involve fishing boats in harvesting seaweed which appears to be a good supplementary work for fishermen during the fishing off-season. The naturally occurring red seaweed near Estonian islands has been recently deployed in developments on extracting red colorants. As it is a wild resource it has quota for harvesting the biomass and two companies have historically licenses to do it. One of them is a company called Tinurek OÜ, whose main activity is fishery. Currently they use their fishing boats for harvesting the seaweed as well. The company had to install technical adjustment of the equipment used. Such diversification of the fishing boats have been fully economically justified.*

Source: interview with Mariann Nõlvak, Tartu Biotechnology Park

As fishing activities have less of a focus in the present Roadmap, the major discussion about seasonality challenges are related to the seaweed aquacultures due to a higher potential for new products and value chains.

Stable value chains based on marine and aquatic biomass require a high and predictable input and biomass productivity combined with a high content of the demanded components, like for instance carbohydrates that can be fermented to biofuel, proteins for fish feed or bioactive compounds that can be used in functional food.

However, the seasonal variation in chemical composition is characteristic for seaweeds and it poses challenges for the manufacturing of product from it. At least one third of the blue bioeconomy stakeholders involved in our survey *indicated seasonality as an important challenge* in developing their business and research products (BBF survey, 2019).

The comparative analysis of traditional (lignocellulosic) biomass and seaweed biomass shows that variation in composition of seaweed is much extremer in comparison to the compositions in traditional biomass (ECN, 2013). In general, seawater has the highest nutrients concentrations during the dark season and gets depleted of nutrients during the microalgae blooms in spring. Thus, the seaweeds have developed strategies to fit the seasonal changes in light and nutrients availability (SINTEF, 2014).

While it is difficult to control the quality of the biomass especially in open systems, due to seasonal, as well as other environmental variations, more adaptive approaches in seaweed and algae farming can be promoted. Despite ongoing research projects studying seaweed and algae composition dynamics under various conditions, there are still large knowledge gaps in this area. For instance, a better understanding of seaweed ecophysiology for development of cultivation strategies could ensure predictable yield, composition and quality of biomass.

Another challenge on a more generic level is that the nature of marine and aquaculture assumes specific harvesting seasons which prevents constant input flows for further production. Consultation with experts indicated that seasonality related challenges in seaweed farming can be addressed in ways similar to challenges in traditional agriculture. Seasonality is addressed by special solutions that allow stabilising, storing, preserving or pre-processing the harvested biomass that allow to maintain the best quality and content and year-through inputs for the further production.

Discussions revealed a strong need to strengthen the scientific knowledge base as the solutions addressing the seasonality challenge will be a result of better understanding of ecophysiology of seaweeds and natural processes, and availability of good quality data. In summary the following action lines have been proposed (by order of importance, according to our respondents):

1. To narrow the existing knowledge gap, to promote and support further scientific research of impact of seasonality on biomass characteristics in various conditions, open sea, open pond and closed aquaculture systems, as well as in multitrophic aquaculture systems, and other conditions;
2. Promotion of research and innovation in monitoring the crops and harvest at the optimum/ the moment on the highest compound;
3. Establish a decision support system e.g. for growing macro algae based on data models. It should be online open platform that can offer e.g. matchmaking and various data. E.g. European Open Data Initiative intends to bring together all R&I produced data;
4. More R&I on qualities of crops and promote cultivation of specific breeds of seaweed or macro-algae that are less impacted by seasonality;
5. Mobilise and incentivise private and public investment in silos and biorefinery facilities that can stabilise the input into processing industries.

3.3.5 Logistical challenges for biomass processing

The chain of logistical processes is quite long, as it involves material handling, production, packaging, storage, inventory and transportation. Although logistical challenges can vary for different types of blue product (e.g., seaweed, shellfish), there are some common challenges that are faced by many producers within the blue bioeconomy sector. 35% of Blue Bioeconomy Forum survey respondents face logistical challenges. The technical challenges include complex and expensive operations throughout the entire production cycle, starting from harvesting, processing and ending with transportation and delivery. Most technical challenges are attributed to the specific characteristics of aquatic and marine biomass.

The limited life of some blue biomass and the containment of salt and water are major factors which require fast processing and, consequently, transportation of the biomass. For example, the high content of water in the biomass increases the weight of the raw material that needs to be handled, thereby affecting the amount of time, human resources, technologies and energy for packaging, storage and transportation (Balan, 2014).

The overall state of the marine ecosystem and climatic conditions in a region have an impact on the amount and quality of biomass. Currently, the lack of access to open data on pollution, quality and temperature of water in seas does not allow 'blue' entrepreneurs to monitor changes in biomass. The seasonality of biomass and its changing characteristics are affecting the scalability of production and the logistical processes. As a result, the logistical costs might vary depending on a harvesting season. Appropriate technologies can optimise the quality of biomass and the logistical operations. However, based on experience of many 'blue' entrepreneurs, such technologies are either not easily available or accessible, due to location and high cost.

The farming, wild harvesting locations and facilities for (pre)processing can be remote or sparsely located. This leads to higher spending on inputs and resources, lower energy efficiency and greater risks of compromise on the quality of biomass (Slegers, 2014). Hence, logistical challenges are not merely related to convenience, but to financial sustainability of companies and to quality of 'blue' products. The co-sharing of bioreactors, biorefineries, silos and other facilities decreases costs on the use of technologies and allows to form clusters of 'blue' companies in those locations.

Based on survey results and discussions with experts, the list of policy-related logistical challenges is dominated by the regulations on waste and the processes for obtaining specific permits. The valorisation of fishing by-catch resources is an important issue for the development of market of such resources and for environmental sustainability. For example, the fishing by-catch can be voluminous and take significant space on the fishing boats. The utilisation and transportation of by-catch creates additional cost for fishers. Such regulation can be considered burdensome, however, in countries where the market of by-products is developed the fisheries are able to reap a profit. In case of Iceland, by-catch finds its market and it is sold for value of 0,5 -1 EUR per kg, depending on the species.

Text box 19 The need for a bio-refinery approach for shell waste processing

Shrimps and lobsters are among the most popular crustaceans for food consumption. However, the shell waste produced by the seafood industry is a growing problem. The Food and Agriculture Organization estimates that in Euopre alone more than 750,000 tons of crustacean shell waste is produced every year.

Besides potentially profiting from selling value-added products, the saving of disposal costs which range from about 60 EUR/t for landfilling to 160 EUR/t for incineration could create an additional boost for the concept, and illegal ocean dumping could be avoided.

The main cost factors identified in the economic process analysis are the stirred tank reactors for the pre-treatment, the Lactobacillus seed, the enzymatic depolymerization, and especially the monomer synthesis. Summarized, the process in not cost-efficient enough.

The pre-treatment of the raw material to yield the chitin is a key step in the process starting from a material with negative to low input price resulting to a significant price of pure chitin/chitosan. This cost structure and the various competing application of chitin/chitosan derivatives require an integrative bio-refinery approach including cost-effective biotechnological pre-treatment as substitute for the harsh conditions and high chemical load in the chemical processing route.

Source: Rampelotto, P.H. and Trincone, A. (2017). Grand Challenges in marine biotechnology; Gruber, K. (2013). Nylons made from shrimps. Available at: http://www.youris.com/bioeconomy/fisheries/nylons_made_from_shrimps.kl

Text box 20 MODHEAt® - efficient technology for drying of seaweed

SFTec is a Finnish startup that aims to generate added value by enabling the efficient reuse of industrial residual resources. It brought to the market MODHEAT®, an industrial drying technology that is efficient, affordable, scalable and mobile and can handle many materials including seaweed. As a partner of the Baltic Blue Biotechnology Alliance network SFTec could test the opportunities offered by the drying technology in the blue bio-economy sector. Very good results have been obtained from drying seaweed where SFTec managed to convert seaweed into biogas and use this energy to dry other seaweed/ macro-algae on the location closeby the harvesting. This technology can helps to avoid the deterioration of the raw material and reduce its weight before it is transported to processing facilities.

Source: Submariner Network, Baltic Blue Biotechnology Alliance

Text box 21 Geothermal energy for drying seaweed

Geothermal energy has been used in Iceland for many purposes including drying seaweed. The seaweed manufacturer Thorverk uses geothermal heat directly in its production. The company harvests seaweed found in the waters of northwest Iceland using specially designed harvester crafts. Once landed, the seaweed is chopped and dried on a band dryer that uses large quantities of clean, dry air heated to 85°C by geothermal water in heat exchangers. The plant has been in operation since 1976, and produces between 2,000 and 4,000 tons of rockweed and kelp meal. The product has been certified as organic. The plant's annual use of geothermal energy is about 150 TJ

Source: Orkustofnun - National Energy Authority of Iceland

3.4 Science, technology and innovation

The development of the blue bioeconomy is based on scientific, technological, research and innovation developments. There are four key challenges that need to be addressed in order to unlock the potential of the sector.

Although the research community and the industrial players already cooperate in several ways, there is an acute need to improve how these collaborations are established and sustained, addressed in each of the sub-sections below.

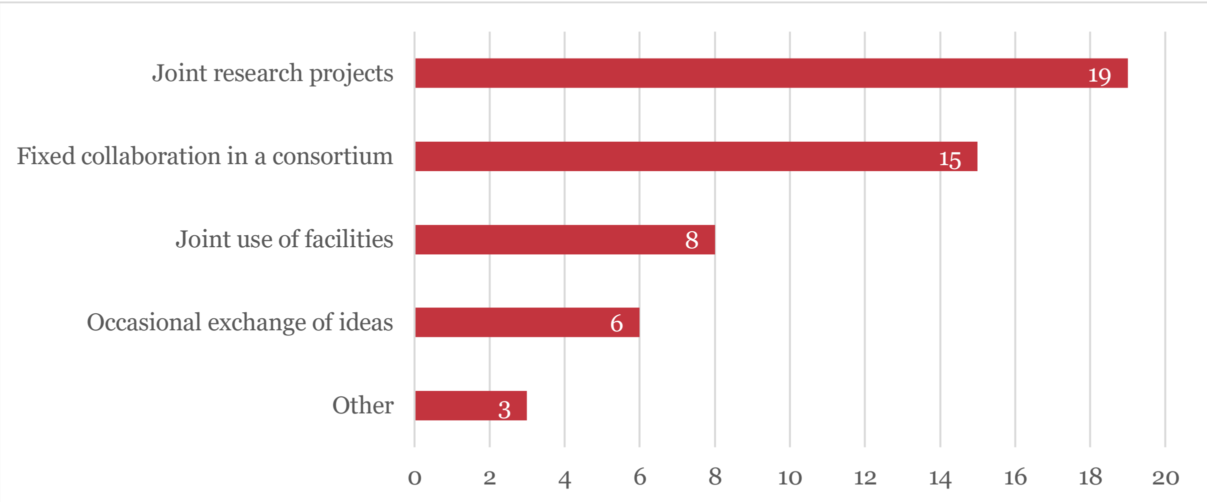
3.4.1 Dialogue and sustainable cooperation between researchers and industry is needed

Significant progress has been made over the past decade in building a community to support research and innovation in marine biotechnology in Europe. Nonetheless, there remains a need to establish better links between researchers, industry and the array of end-users. Mechanisms are required that are conducive to support industry/academic collaborative approaches to develop markets and businesses (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016).

Public funding for collaboration between researchers and industries has helped. However, increased research funding requests from industry does not necessarily mean common goals and understanding between researchers and businesses. At the same time, the increasing difficulty for researchers to secure funding for their projects might stimulate them to approach companies and industries more frequently for funding.

The BBF survey shows that most researchers already collaborate with the industry sector, while about half of the surveyed companies collaborate with research organisations. The most common types of collaboration consists of joint research projects and fixed collaboration in a consortium. There are also occasional exchanges of ideas between these two types of stakeholders and joint uses of facilities. Other forms of collaboration are reflected in activities such as: commercialisation; technical and business support; spin-offs and rendering services coming from the researchers, and; providing services coming from the companies.

Figure 2: Survey question: Please describe the form of collaboration (n=21)



Some researchers suggest that bureaucracy be minimised and procedures to access major funding sources be eased. Respondents also recommended facilitating mutual understanding through two-way dialogues. Some proposed improvements include putting up a funding platform destined to better align researchers' and industrials' needs.

Among surveyed respondents, start-ups and SME's indicated that access for them to research grant programmes and financial support would also support collaboration. Public grants should also include an element designed to encourage sustainable collaboration. These remarks tend to emphasize the need for research to be more directed towards the development of business, that is to say, be more responsive to industry needs.

It is important to identify the respective motivations and constraints among academia and industry. What holds back researchers from finding practical applications for their discoveries, and what would encourage them to do so? For industries, a detailed analysis of the different stages of the value chain and technology development is required in order to identify where increased collaboration would benefit generating new market solutions and products.

The Blue Bioeconomy forum emphasises the importance of shifting the mindset of researchers. This can be promoted upstream by developing different research habits, integrating in academic training the skills and tools to empower researchers to turn their discoveries into applicable solutions for the industry. This would also help address questions of uncertainty concerning the cost of development of products, the resource availability as well as the skills and competences required for efficient industrial end-use applicable solutions.

3.4.2 Exploration of marine environment, technical challenges and high costs

Considerable efforts have been devoted to the exploration of marine environment, organisms, and potential products. However, due to the high biodiversity and the tremendous effects of seasonality and geography on composition and morphology, researchers expect that many species remain to be discovered. Recent projects and trials have been conducted, amongst others within the framework of MBT-ERA NET.[7] The general conclusion that was drawn is that exploring the chemical and biological diversity of our oceans as a source of novel materials and food is the essence of this strategic research area. . The provision of a pipeline of new organisms to screen for novel compounds is an essential support for future innovation. (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016)

The cost of exploration activities is high, resulting in innovations which are mainly in the pre-competitive or in a commercial domain. Therefore, financing generally focuses either on fundamental research or the application potential of the functional components with high-end market applications. The MBT-ERA NET Marine Biotechnology Strategic Research and Innovation Roadmap[8] prioritises exploring targeted environments and hotspots; developing next generation sampling methods; and developing novel methods for the taxonomic, chemical, and biochemical evaluation of marine species as sources of bioactive compounds. This would contribute to lower costs of exploration and screening (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016).

More collaboration is also needed. Optimisation of multi-purpose screening on hotspots or sampling programs could lower costs and foster more synchronised utilisation of research activities.

The ERA-NET Marine Biotechnology Strategic Research and Innovation Roadmap suggests: 1) Continued targeting of microorganisms in deep-sea sediments, microbial

[7] http://www.marinebiotech.eu/marine-biotechnology-era-net

[8] http://www.marinebiotech.eu/launch-marine-biotechnology-research-and-innovation-roadmap

symbionts from sponges and other organisms; macro- and micro-algae; bivalves, crustaceans, fish and fish processing discards, and marine fungi as sources of biologically active natural products; 2) The discovery of new marine species including microorganisms, as a source of novel materials; 3) Exploiting the potential of genetic resources in the discovery process; and 4) Exploring the chemical and biological diversity of marine organisms (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016).

Other challenges include ensuring that future increases in production remain within sustainability limits. The development of production in coastal zones is not yet at its maximum. There is considerable areas worldwide where production could increase (Gentry, et al., 2017). The EC has suggested that production could increase up to 2-fold of current levels (European Commission, 2017). This will likely be achieved by improvements, including efficiency in current aquaculture practices, while new production areas and, marine production further offshore is yet to be considered.

New insights and ideas on the application of e.g. offshore, agriculture, greenhouse cultivation and forestry technologies to improve aquaculture are required. The development of devices such as ROV (remotely operated vehicles) allow for exploration purpose (collection of samples; data mining techniques) to target areas of high marine biodiversity. Both the exploration as well as the exploitation phase will benefit from techniques such as; remote sensing, geoinformatics, remote monitoring tools, high-end food and production tools (land based technology at marine production sites, on e.g. disease management, product quality and production management).

Data-driven technologies are key: monitoring, automation, and analysis are aspects of digitalization that have the potential to transform the aquaculture industry, which is not immune to the digital disruption affecting other industries. Clean water is always needed, and improved recirculation technologies will further advance the industry, but which segments of aquaculture will gain most advantage from this progress remains to be seen.

The focal point for Ocean Monitoring and Surveillance developing a framework for "A comprehensive ocean observing system (polar, bio, eco, BGC, eDNA, deep ocean, +)" with the focus on understanding the marine ecosystem. The ambitions may well be combined with the exploration potential for biochemical discovery programs.

The well-managed and controlled culture of marine biomass needs to be further developed as sustainable sources of biomass in parallel with the development of sustainable harvesting of marine species from the wild. Creating useable products from marine biomass requires feedstock to undergo some form of transformation. Typically this is a refining or extraction process, which yields intermediate or final products. Biomass processing generally involves several intermediary steps from harvesting to end use. Circular agriculture may well be used as an example and to develop marine value chains and processes (Scholten, 2019), both on a horizontal (land to sea interaction) and vertical (ecosystem interaction).

- Reducing the complexity of the supply chain by integrating biomass production and refining, reducing energy demand and waste in processing marine biomass.
- Removing bottlenecks in marine biomass transformation and conversion by identifying novel processes and marine enzymes that can modify biomass, tailor its chemical and biological properties and reduce the energy demand of transformation.
- Engaging in research to support the expansion of cultured biomass production including measures to minimise and mitigate environmental impacts; addressing waste management; enhance biosecurity and the introduction of new production

systems (breeding/hatchery/ genetics/nutrition and health etc.) and expand the use of molecular methods.

- Harnessing knowledge and expertise from other sectors of the bioeconomy to support the rapid development of pilot scale equipment and scaleup of marine biomass refining.

3.4.3 Lack, underuse and geographical discrepancy of research infrastructures

, Dedicated research tools and facilities to fully exploit marine biological resources are needed, bridging aquaculture, mariculture, marine biotechnology research and areas of fundamental and applied sciences (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016). This need is most urgent to support the demonstration plant phase (TRL 6-7) and also the upscaling to flagship/first-of-a-kind (TRL 8), when economies of scale have not yet been achieved (Hurst, Børresen, Almesjö, De Raedemaecker, & Bergseth, 2016) (Enzing, C., Ploeg, M., Barbosa, M. Sijtsma, L., 2014). There are four groups of challenges:

(1) **Lack of infrastructure for testing the scalability of technologies**.. Start-ups and industry need access to versatile and flexible pilot plants and demo-facilities which can run pilot, pre-market scale-up projects at an acceptable cost to the new industry. A real constraint is the lack of support for operational expenses to keep pilot plants running. There are examples of companies that decided not to use these facilities for running trials due to high costs. In addition, if these facilities risk being under-used if they are not involved in several projects.

Text box 22 Organizing infrastructure

In Iceland a feasibility study is presently being conducted by the Nordic council of Ministries on the type of instrumentation, the size and business case for such scale-up facilities (focus on biorefinery). This study considers factors such as the composition of the biomass (water, protein, fat, polysaccharides, smaller components, etc.), whether the facility is constructed into different unit operations, for concentration extraction, can it be used on different kinds of raw materials?

The objective of the study is to answer the following questions:

- Is there a need?
- What is needed?
- How can it be operated?
- What should be the scale? (small laboratory or industry scale)
- What is the relevant volume of biomass?

The study is at its first stages, it should involve stakeholders such as: research organisations, governmental bodies, industry / industry organisations.

(2) **Underuse of research infrastructures in higher TRL levels**. Costs for using research infrastructures are also a constraint for projects that are attempting to scale up from lab to pilot, and further from pilot to full scale. As a result, facilities are underused. 30% of surveyed participants indicated that research infrastructure is insufficiently used (for all TRL levels).

(3) **Geographical discrepancy in the availability of research infrastructures**. The participants of the working group pointed out that there is unequal distribution of facilities, with some regions generally having sufficient research infrastructure and, while others lack access. This results in missed opportunities, for example some inland regions with potential for aquatic non-marine developments

Lack of information about available infrastructure was also mentioned in the working group. Several overviews related to available infrastructures at DEMO or pilot scale, although not specific for blue bioeconomy, are available. Examples include:

- SmartPilots, an INTERREG Europe project co-funded by the European Fund for Regional Development (ERDF). "Pilots4U" set up an easily accessible database of open access pilot and demonstration infrastructure for the European bio-economy[9].
- The European Marine Observation and Data Network (EMODnet) contains the EMODnet Human activities portal which gives access to European infrastructures facilities in EU waters[10].
- European Marine Biological Resource Centre (EMBRIC)
- The Marine Research Infrastructure Database, developed by EurOcean.

Initiatives such as EMBRC-ERIC, EMBRIC, EMODnet, BRISK2, Baltic Blue Biotechnology Alliance do provide information or access to facilities for users from all sectors, for either precompetitive studies or commercial applications. These facilities are located mainly in Western Europe, with the exception of the Alliance project in the Baltic region (see text box below).

Text box 23 Mapping and utilisation of available infrastructure – Baltic Sea Region

Not each and every Baltic Sea Region country can provide the infrastructure and expertise needed for piloting and scaling-up. The Baltic Blue Biotechnology Alliance aims to bridge this gap. Companies in the Baltic region that conduct research can express to the consortium members their needs in terms of facilities, as was done for example for a microalgae facility in Denmark. The Baltic Blue Biotechnology Alliance also provides advisory and analytical services, bioresources, equipment, legal advice and business development and marketing. Information exchange is key to pooling such national capacities.

Source: https://www.submariner-network.eu/projects/balticbluebioalliance

Text box 24 European Centre for Information on Marine Science and Technology (EurOcean)

The European Centre for Information on Marine Science and Technology (EurOcean) was established in 2002. The members of this independent scientific non-governmental organization comprises leading European marine research, funding and outreach organisations. Its aim is to facilitate information exchange and generate value-added products in the field of marine sciences and technologies between a wide range of governmental and non-governmental actors.

The members of EurOcean developed a dedicated platform that provides a comprehensive list of all existing facilities in Europe that are dedicated to marine sciences, covering a broad range of activities.

The information available about the infrastructures includes technical characteristics

[9] See: https://www.biopilots4u.eu

[10] See: http://www.emodnet-humanactivities.eu

(e.g. Research Vessels, Underwater vehicles and large equipment and Aquaculture research facilities), services offered by the operator (e.g. simulation of ocean conditions, emulators to reproduce the mechanical output of an ocean energy,..), availability (e.g. Access Conditions) and contact points (e.g. Operators, owners).

This database is intended for all stakeholders - scientists, engineers, policy makers, private companies, universities - for their respective needs, either as user or as operator, or as designer, or as funder. An iterative map with search criteria allows search of information on discipline, operating areas and related projects.

Source: eurocean.org

(4) **Lack of relevant human resources**. The long-term sustainability of research infrastructures is closely linked to the availability of qualified personnel, particularly engineers. Such qualified personnel are typically given project-based short-term contracts. Interviews with companies revealied that engineers have more career opportunities in traditional areas, as compared tothe Blue Bioeconomy.

3.4.4 Lack of access to data, research results and data banks

Research results, even when publicly funded, are currently rarely freely available, which hampers sharing of knowledge, especially concerning data. There is no easily accessible database that centralises the information produced, making retrieval costly and time consuming. Marine Biotechnology ERA-NET has created an open access portal to exchange information and data, though only limited research results are available[11]. There is a need for unifying and streamlining available data sources and portals. Pprojects benefitting from EC funding are required to make data freely accessible. In this regard, the EC is also launching the EOSC (European Open Science Cloud). However academics and industry have different motives for sharing or not sharing data and information. Academics often make results open, while for industry, the tendency is to protect and not disclose results which might yield competitive advantage. Some companies prefer not to file patents, but to protect their innovation with trade secrets. Compulsory obligations are more effective if it is clear what is provided in return. Strengthening collaboration between academics and industry could help to increase incentives for sharing data and research results.

Text box 25 European Open Science Cloud (EOSC)

*The EOSC will allow for universal access to data and a new level playing field for EU researchers. A pan-European federation of data infrastructures will be built around a federating core, providing access to a wide range of publicly funded services supplied at national, regional and institutional levels, and to complementary commercial services. EOSC has 6 lines of action: (1) **Architecture** of the federated infrastructures as the solution to the current fragmentation in research data infrastructures which are insufficiently interoperable. (2) FAIR **data** management and tools. A common data language to ensure data stewardship across borders/disciplines based on FAIR principles. (3) Available **services** from a user perspective. A rich environment offering a wide range of services covering the needs of the users. (4) Mechanisms/**interfaces** for accessing EOSC. A simple way for dealing with **open data** obligations or accessing research data across different disciplines. (5) **Rules** of participation for different EOSC actors. An opportunity to comply with existing legal and technical frameworks and*

[11] http://www.marinebiotech.eu/resources

increase legal certainty & trust. (6) ***Governance*** *of the EOSC, aiming at ensuring EU leadership in data-driven science but requiring new governance frameworks.*

Source: EOSC Strategy Implementation Roadmap (2018)

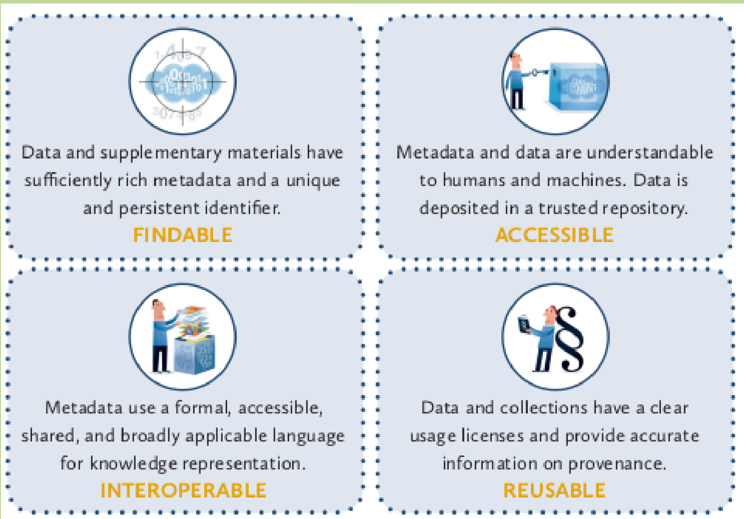
Almost all survey respondents indicated their willingness to share their data and results in an open science cloud. However, some respondents would expect financial compensation for the time needed to summarize their data, and some want assurances that they will not be legally responsible for the data, as well as wanting to be acknowledged and informed about use of their data. At the same time, it is important to note that data for patents cannot be published if the patent has not yet been granted. Furthermore, the publication of negative results is an important item to consider.

One example of how to share data is The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the Convention on Biological Diversity has been set up.[12] This provides a transparent legal framework for the effective implementation of one of the three objectives of the Convention of Biological diversity and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. These principles could guide efforts to establish an open science cloud for the Blue Bioeconomy.

Text box 26 Turning FAIR into reality.

The FAIR Data Principles are a set of guiding principles in order to make data findable, accessible, interoperable and reusable (Wilkinson, et al., 2016)*. These principles provide guidance for scientific data management and stewardship and are relevant to all stakeholders in the current digital ecosystem. They directly address data producers and data publishers to promote maximum use of research data.*

The European Commission expert group on FAIR data describes the broad range of changes required for the implementation of the FAIR data principles. It offers analysis of what is needed to implement FAIR and it provides a set of concrete recommendations and actions for stakeholders in Europe and beyond.



Source: European Commission "Turning FAIR into Reality" (2018)

[12] https://www.cbd.int/abs/about

Appendix A Background

Introduction and scope

The Directorate General for Maritime Affairs and Fisheries (MARE) and Executive Agency for Small and Medium Sized Enterprises (EASME) have initiated the Blue Bioeconomy Forum (BBF) to bring together a partnership of industry, public authorities, academia, and finance in order to strengthen Europe's competitive position in the emerging blue bioeconomy. The aim of the BBF is to develop a shared understanding of the current status of blue bioeconomy in Europe and to collectively identify strategic developments, market opportunities, appropriate financial assistance, regulatory actions and research priorities to advance the area. The forum seeks to exploit synergies between blue bioeconomy sectors which can benefit from the innovative and optimal uses of aquatic biomass, by sourcing biomass for a particular purpose (e.g. for high-value applications such as cosmetics), but also by valorising by-products and resulting ecosystem services.

For that purpose, the BBF project team, in a joint effort with its Steering Group members, thematic Working Groups and the active involvement of the wider blue bioeconomy community (the Forum) has designed and developed a Blue Bioeconomy Roadmap. The roadmap will provide a contribution to the industry’s future competitiveness, by supporting the main organisations active in the area (e.g. public authorities, private companies, funding agencies, R&D organisations) to establish a better understanding about the critical factors to succeed and develop a common vision to unlock the potential of the blue bioeconomy in Europe. The roadmap enables stakeholders to:

- Better understand the market’s future regulatory, research, financial assistance and product needs;
- Identify critical gaps between what exists and what is needed;
- Define the short-, medium- and long-term actions that are required to unlock the potential of the sector.

The document is organised in two main sections: Ways forward – actions that should be undertaken by different stakeholders, which are described in section 2. These ways forward correspond to the thematic priorities – challenges of the blue bioeconomy sector, which provide more background to the ways forward in section 3.

It is important, however, to describe our definition of the blue bioeconomy and the fact that for this roadmap not all subsectors of the blue bioeconomy were taken into consideration.

The European Commission defines Bioeconomy as *"the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy."* (European Commission, 2012). The addition of “blue” entails a focus on aquatic or marine environments. Thus, this document follows the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) definition as published in its report “Blue Bioeconomy – Situation report and perspective”:

> *... any economic activity associated with the use of renewable aquatic biological resources to make products. Examples of such products include novel foods and food additives, animal feeds, nutraceuticals, pharmaceuticals, cosmetics, materials (e.g. clothes and construction materials). Businesses that grow the raw materials for these products, that extract, refine, process and transform the biological compounds, as*

well as those developing the required technologies and equipment all form part of the blue bioeconomy. (EUMOFA, 2018)

However, the Blue Bioeconomy in the context of the BBF explicitly does not cover the "traditional" uses of biomass, such as fisheries and traditional aquaculture that are mainly aimed at food. These maritime economic sectors are more developed, established and are already subject to several standalone analyses and reports. The focus of this roadmap should in no way suggest that these other subsectors are worthy of less attention.

Process undertaken to reach this roadmap

The findings presented in the roadmap rely on:

- A community of over 375 members that are working on or interested in the Blue Bioeconomy, representing: industry, public agencies, financial organisations, researchers and civil society, of the European Union. These stakeholders receive information about the BBF activities and are invited to actively contribute to the development of the roadmap (via interviews, participation to events, surveys)
- The strong commitment of the BBF Steering Group members, taking an active role in the development of the roadmap
- Working Group members, that were actively involved in the BBF Working Group sessions around specific topic and have been consulted bilaterally for tailored interviews
- A state-of-Play report, bringing the first insights on the main developments of the blue bioeconomy in Europe and presenting a first selection of blue bioeconomy challenges based on desk research.
- Two surveys addressed to the BBF community:
    1. A first "short" survey launched in October/November 2018 to determine the priorisation of challenges for the discussions at the Working Group workshops (107 full responses received)
    2. An in-depth survey intended for members of the business and research community who are active in the Blue Bioeconomy, to help shape the content of the roadmap based on the results achieved from the Working Group discussions (86 full responses received)
- A BBF launch event organised on 7 December 2018 with over 90 participants. The goal of the event was to discuss the current status of the emerging Blue Bioeconomy in Europe and to identify strategic developments, market opportunities, financing possibilities and research priorities. The event was also the opportunity to host the first Working Group sessions. The outcomes of the event have been used for the roadmap on the development of the Blue Bioeconomy in the EU.
- Working Group workshops organised on 11 and 12 March 2019. The objective of the workshops was to identify the key challenges for advancing the Blue Bioeconomy in the next 2-7 years. The discussions were around the key challenges, the key questions that are related to these challenges, and some of the possible ways forward to be addressed in the roadmap document.
- A pipeline of 12 projects, whose owners have been invited to the BBF activities and have been consulted in bilateral interviews (31 interviews conducted)

- A second event organised on 25 June 2019 with over 140 participants. The goal of the second event was to discuss the draft roadmap for the blue bioeconomy. The discussions during the event have been used to sharpen the descriptions and ways forward presented in this document.

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